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**NITROGEN SOURCE INVENTORY AND LOADING
TOOL FOR THE RAINBOW SPRINGS BMAP
CONTRIBUTING AREA**

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This assessment was conducted by the Ground Water Management Section of the Florida Department of Environmental Protection's Water Quality Evaluation and Total Maximum Daily Loads Program to assist in the development and implementation of the Rainbow Springs Basin Management Action Plan to address the TMDL for nitrate. The results of this assessment, completed in September 2014, are based on the information provided in the document.

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

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SUMMARY OF FINDINGS

The Rainbow Springs Group is a first-magnitude complex of springs and a major discharge point for water from the Upper Floridan Aquifer (UFA), the highly transmissive limestone aquifer that is the source of water flowing from the springs. It is the fourth largest spring group (by magnitude) in Florida and has an average flow of 456 million gallons per day (Holland and Hicks, 2013). The Rainbow Springs Group and associated Rainbow Springs Run were identified as impaired because of ecological imbalances attributed to elevated nitrate in the water discharging from the springs. In 2013, a Total Maximum Daily Load (TMDL) was developed to establish a water quality restoration threshold for nitrate-nitrogen in the springs and spring run of 0.35 milligrams per liter. Elevated nitrate concentrations in the springs is a result of current and historical land use practices that have contributed nitrogen to the UFA system.

The Florida Department of Environmental Protection developed a Nitrogen Source Inventory and Loading Tool (NSILT) to identify the most significant sources of nitrogen in the ground water contribution area for the Rainbow Springs Group and estimate their loads to ground water in the area covered by the Basin Management Action Plan (referred to as the Rainbow Springs BMAP area). The NSILT is a geographic information system– and spreadsheet-based tool that provides spatial estimates of the relative contribution of nitrogen from various sources, and takes into consideration the transport pathways and processes affecting the various forms of nitrogen as they move from the land surface through soil and geologic strata that overlie and comprise the UFA. This report describes the methods, information, and data sources used in developing the NSILT to estimate nitrogen loads to ground water in the Rainbow Springs BMAP area. This information has been provided as a planning tool for the development and implementation of the Rainbow Springs BMAP to address the nitrate impairment.

The NSILT is being used in the Rainbow Springs BMAP to identify areas where nitrogen source reduction efforts could be focused to achieve the most beneficial effects on water quality. The NSILT was used to estimate nitrate loads from the following source categories:

- Atmospheric deposition.
- Wastewater land applications.
- Septic systems.

- Livestock waste.
- Agricultural and nonagricultural fertilizers.

This report describes the potential inputs and loads from these sources. Estimates of nitrogen loading to ground water take into account the various environmental processes that can attenuate nitrate in the subsurface and the rate of recharge to the UFA. The environmental attenuation factors are averages for each source based on information from previously published studies in Florida and elsewhere on various processes that remove nitrogen as it moves through the subsurface. After the nitrogen inputs are adjusted by applying an average attenuation factor for each source, the rates of recharge to the UFA are considered. Ground water in areas where the recharge rates are high is more vulnerable to contamination than it is in areas where recharge rates are low. To account for recharge rates to the UFA, nonattenuated nitrogen inputs in high recharge areas (greater than 10 inches per year) are multiplied by a weighting factor of 0.9, while nitrogen inputs are multiplied by a weighting factor of 0.5 for medium recharge area (4 to 10 in/yr).

The NSILT results indicate an estimated annual load of 602,402 kilograms of nitrogen (1,328,075 pounds) to the UFA in the Rainbow Springs BMAP area, representing an estimated 11% of the amount of nitrogen inputs to the land surface. Most of the nitrogen input to the land surface in a year does not reach ground water because of the various nitrogen attenuation processes and variations in rate of recharge to the aquifer. The greatest estimated loads of nitrogen in the Rainbow Springs BMAP area were from cattle farms (29% of the total estimated load), followed by septic tanks (19%), horse farms (18%), and crop fertilizers (18%). Percentages from the other assessed source categories were as follows: atmospheric deposition (7%), urban fertilizer (6%), land application of treated wastewater (2%), and miscellaneous livestock (1%).

Most of the nitrogen loading to ground water in the Rainbow Springs BMAP area (79%) occurs in high recharge areas. In these areas, the relative percentage contribution from each of the major nitrogen sources is as follows: cattle farms (27%), septic tanks (20%), horse farms (19%), crop fertilizer (17%), urban fertilizer (7%), atmospheric deposition (7%), land application of treated wastewater (2%), and miscellaneous livestock (1%).

The NSILT results provide a baseline understanding of existing nitrogen loads to ground water from multiple sources in the areas of spring basins most susceptible to ground water contamination. This tool

can also be used to evaluate the nitrogen load reduction benefits of various management actions and nitrogen reduction scenarios at various locations within the Rainbow Springs BMAP area.

FINAL
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1. INTRODUCTION

Florida springs are unique ecosystems which provide sites of recreational and cultural value. Springs integrate ground water vertically, spatially, and temporally from the expanse of the aquifer system and afford a way to assess regional ground water quality (Bush and Johnston 1988; Katz 2004; Davis 1996). To recharge the aquifer, infiltrating water travels through the soil profile and underlying geological substrate, a process that influences nutrient concentrations in the water by the time it reaches ground water. The quantity and quality of water recharge the aquifer is directly influenced by precipitation rates and land use activities within a springshed.

Over the past several decades, nitrate-nitrogen levels in spring waters and groundwater have increased substantially above background levels. There are several forms of nitrogen that occur in surface waters and groundwater as a result of biological and chemical processes as nitrogen is cycled throughout the environment. Although nitrate and ammonium are the predominant inorganic forms of nitrogen in the subsurface, nitrate tends to be the most mobile and readily leaches to groundwater once it moves past the root zone. In oxygen-limiting conditions, nitrate can be converted by bacteria to various gaseous forms of nitrogen (nitric oxide, nitrous oxide, and dinitrogen) that can be lost to the atmosphere.

Elevated nitrate concentrations in Florida's springs contribute to ecological imbalances in their receiving surface waters. This problem will continue if nitrogen source inputs are not reduced. Restoration plans to reduce these inputs must include activities to address the major sources and to obtain detailed nitrogen loading information from nonpoint and point sources within springsheds. This information would cover nitrogen sources such as fertilizer applied to cropland and turf grass, septic tanks, land application of treated domestic wastewater, atmospheric deposition, and animal wastes.

The Florida Department of Environmental Protection has developed the Nitrogen Source Inventory and Loading Tool (NSILT) to estimate nitrogen loading to ground water and to help identify the most significant contributing nitrogen sources. As described here, this Geographic Information Systems (GIS)-based tool uses the best available and most current information on nitrogen sources and summarizes nitrogen inputs and estimated loads of nitrogen to ground water. Nitrogen loads to ground water throughout the Rainbow Springs Basin Management Action Plan (BMAP) area are estimated by accounting for natural attenuation processes and ground water recharge rates applied to the nitrogen inputs to the land surface. The results of this tool can be used in the planning and implementation of the Rainbow Springs BMAP to help focus on specific areas and nitrogen source categories to achieve the greatest reduction in nitrogen loading and subsequently an improvement in water quality with respect to nutrients.

The technical approach in applying this tool involves the following steps: identifying the area to be assessed, characterizing the ground water recharge within that area, identifying land use and categories of land use that are potential nitrogen sources, calculating estimated nitrogen inputs to the land surface from those potential sources, calculating the attenuation of nitrogen from those sources, and ultimately, estimating nitrogen loads to the aquifer.

1.1 Rainbow Springs Group

The Rainbow Springs Group is the fourth largest spring group (by magnitude) in Florida and has been a popular recreational destination since the 1920s. The Rainbow Springs Group has an average flow of 456 million gallons per day (MGD) (Holland and Hicks, 2013). Recently, the Rainbow Springs Group and Rainbow Springs Group Run (the upper Rainbow River) were identified as impaired because of ecological imbalances attributed to elevated nitrate in the water discharging from the springs (Holland and Hicks 2013). In 2013 a Total Maximum Daily Load (TMDL) was developed to establish a water quality restoration threshold for nitrate of 0.35 milligrams per liter (mg/L) in Rainbow Springs Group and Rainbow Springs Group Run (Holland and Hicks 2013). Elevated nitrate in the springs is a result of current and historical land use practices that have contributed nitrogen to the Upper Floridan aquifer (UFA), the highly transmissive limestone aquifer that is the source of water flowing from the Rainbow Springs Group.

The NSILT is being used to provide stakeholders with information on the sources of nitrogen in the Rainbow Springs BMAP area and their relative contributions of nitrogen to the Upper Floridan aquifer. Although the TMDL is written for nitrate, ammonium and nitrate are the predominant inorganic forms of total nitrogen in the subsurface. Ammonium is typically converted to nitrate by microbial processes in the subsurface when oxygen is present and nitrate tends to be the most mobile form of nitrogen in the subsurface that readily leaches to groundwater. The NSILT provides information on nitrogen loading to ground water that is used as a planning tool for the development and implementation of the Rainbow Springs BMAP to address the nitrate impairment.

The Rainbow Springs BMAP area is generally based on the ground water contributing area (or springshed) that was delineated by the Southwest Florida Water Management District (SWFWMD) (Jones *et al.* 1996). The BMAP area covers an area of 434,703 acres (175,919 hectares [ha]), including considerable agricultural (40%) and urban/residential (27%) land uses. The Rainbow Springs Group is the source of the Rainbow River. The BMAP boundary includes portions of Marion and Levy Counties (**Figure 1**).

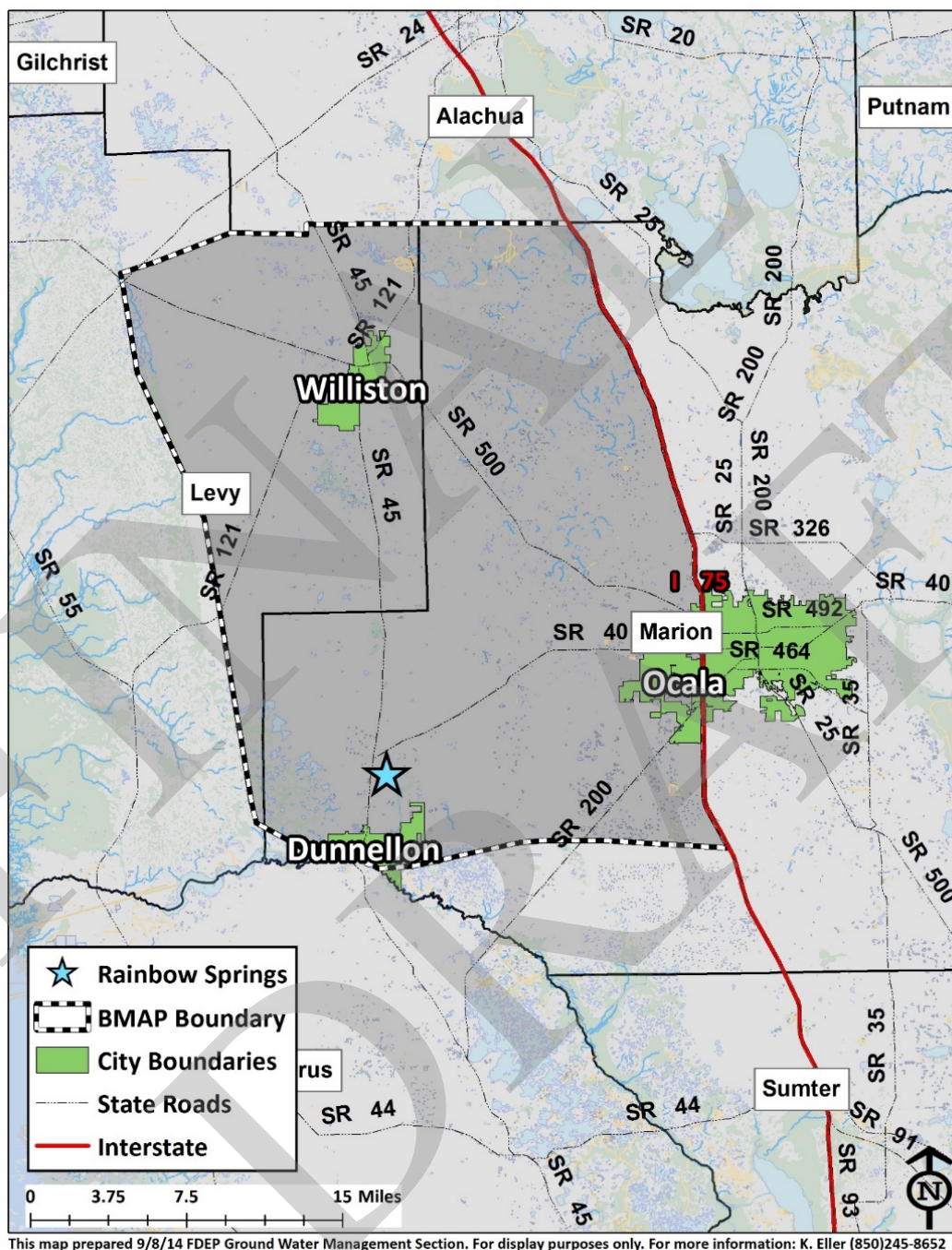


Figure 1: Rainbow Springs BMAP boundary and surrounding area

The eastern boundary extends to Interstate (I) 75 and coincides with the western boundary of the Silver Spring BMAP area. Although there is some overlap in the ground water contributing areas for Rainbow

Springs and Silver Springs, the BMAP areas for Rainbow and Silver Springs were established so that there is no overlap to prevent any duplication of efforts. Specifically, any portion of the Rainbow Springs springshed east of I-75 was included in the NSILT analysis for the Silver Springs BMAP area (Eller and Katz 2014). Additionally, the northern boundary was defined by the Alachua County border to avoid overlap with the Sante Fe BMAP boundary.

1.2 Aquifer Recharge

The Floridan aquifer system is composed of limestones and dolostones of Eocene to Miocene age occurring in Florida and parts of Georgia, South Carolina, and Alabama. The upper part of the aquifer system contains the Upper Floridan aquifer (UFA) and is the predominant source for groundwater discharging from Florida's springs. As a result of dissolution of the carbonate rocks that comprise the UFA, numerous karst features have developed over geologic time in this area, which in the absence of confining sedimentary layers, may result in water from the land surface moving directly into the aquifer through sinkholes. The UFA is the principal source of water for Rainbow Springs (Jones *et al.* 1996), and Faulkner (1970) estimated that water discharging from the springs comes predominantly from the upper 100 feet of the UFA. Consequently, the movement of ground water within the UFA responds quickly to changes in rainfall and recharge, and ground water can move rapidly within the UFA where conduits occur. In parts of the Rainbow Springs BMAP area, a surficial aquifer and an intermediate confining unit overlie the UFA and affect the rate and amount of recharge of rainfall to the UFA (Knowles 1996). The hydrogeological characteristics of the surficial aquifer, intermediate confining unit, and the average annual rainfall are the factors controlling the recharge rates to the UFA. In 2002, the United States Geological Survey (USGS) completed a numerical model of the intermediate and Floridan aquifer systems based on well data from 1993-94. 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 two main recharge categories in the Rainbow Springs BMAP area: medium recharge (4 to 9.9 inches per year [in/yr]) and high recharge (10 in/yr or greater) (**Figure 2**). The amount of annual recharge affects the transport of nitrogen to the aquifer. Therefore, we estimate that more nitrogen would be transported annually to the aquifer in high rate recharge areas than in lower recharge rate areas given that both areas receive similar nitrogen inputs to the land surface.

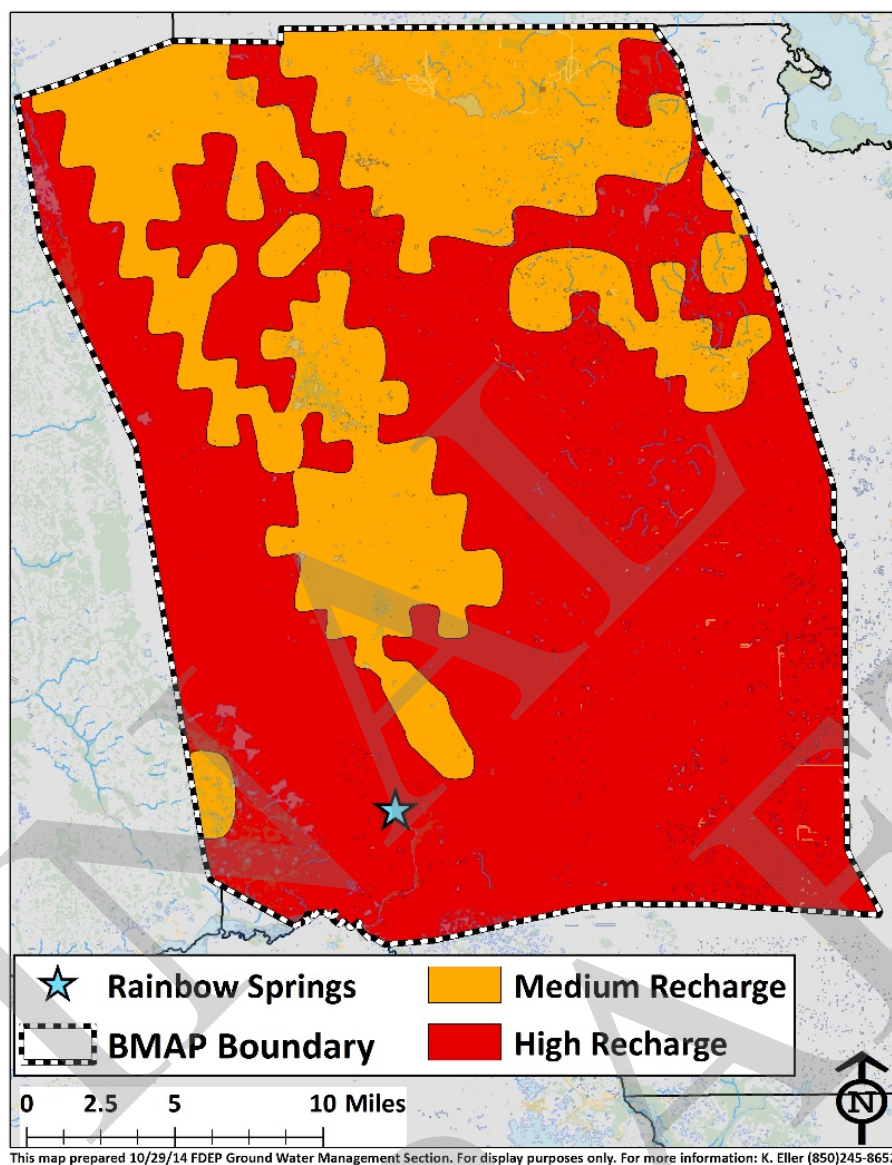


Figure 2: Recharge categories throughout the Rainbow Springs BMAP area

1.3 Land Use

Land use and land cover (LULC) information can vary depending on the delineation methods. For the Department's land use assessment, GIS coverages of land use were obtained from the water management districts and county property appraisers. The land use maps for the water management districts are generated through the analysis of aerial photographs. The Rainbow Springs BMAP area lies within two water management district boundaries (**Figure 3**): the SWFWMD and the Suwannee River Water Management District (SRWMD).

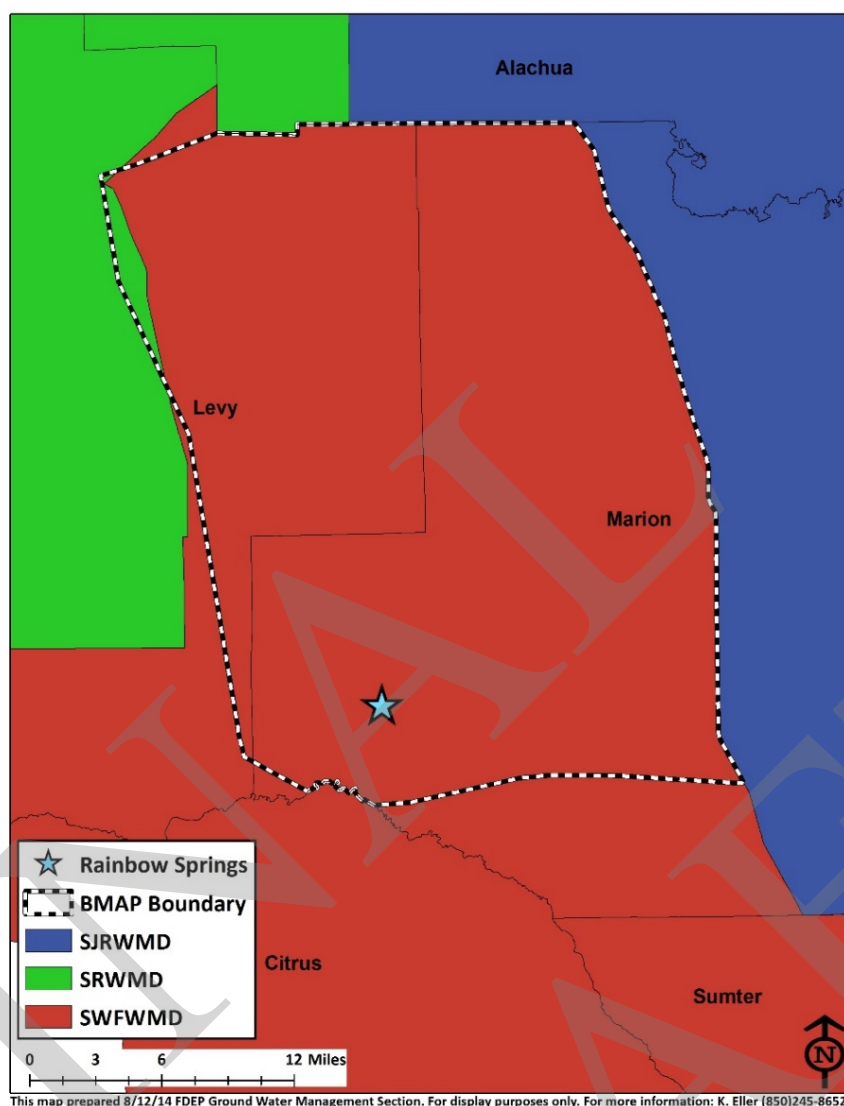


Figure 3: Rainbow Springs BMAP boundary location relative to the state water management districts

All land use classifications used by the water management districts were based on the Florida Land Use/Land Coverage and Forms Classification System (FLUCCS) using the following methods:

- SWFWMD land use was based on 2009 coverage created by district staff that is an update to the 2006 coverage data. The digital imagery was taken during 2007. The land use classifications were determined through a photo interpretation, editing, and quality check process.
- The SRWMD's land use data from 2010–11 are the most recent for the Rainbow Springs BMAP area of all three water management districts. These data were compiled by the

Department's GIS staff. This update was based on true color photography taken in the spring of 2013. After completing the initial updates to land use, ground-truthing efforts were made to ensure the accuracy of these data.

The land use coverage maps were combined for the NSILT for the Rainbow Springs BMAP area. In the cases where two datasets overlapped one another, the SWFWMD data were used because most of the BMAP area lies within the SWFWMD. **Appendix A (Table A.2 and A.3)** provides details of the agricultural and urban land use data for each county, as well as the breakdown for each county within the BMAP boundary. The combined land use map based on information from the two water management districts was used throughout this analysis to evaluate the nitrogen loading for different source categories and is referred to as "WMD" land use. **Figure 4** illustrates the relative distribution of land uses within the BMAP boundary.

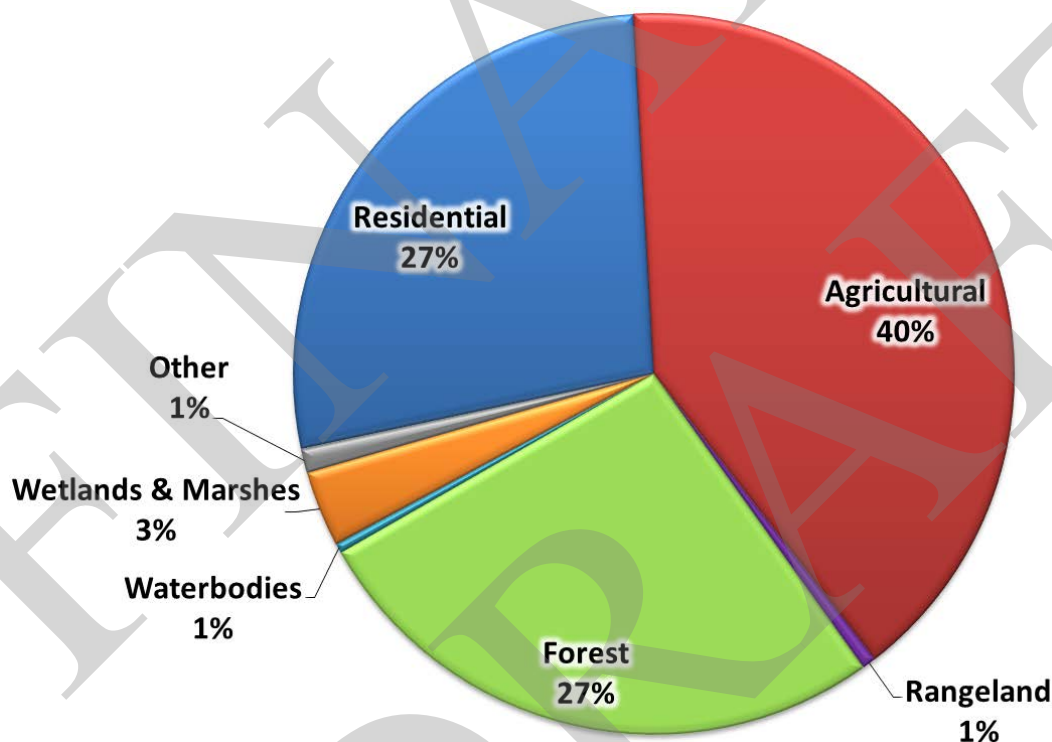


Figure 4: Distribution of land uses within the Rainbow Springs BMAP boundary according to WMD land use coverage

The second type of land use coverage was based on information from county property appraiser offices. Each county provided data specific to the greenbelt or agricultural classifications. Property appraisers in each county visit properties routinely to update and verify the land use classification of parcels for tax purposes. These visits to a given parcel typically occur at least every five years, although most parcels are visited more frequently. This system allows for continual updates, and the land use data from the

property appraisers in this report span the period from November 2013 to January 2014. For this assessment, the property appraisers also provided detailed information about the specific agricultural practices in their respective counties that was very helpful for estimating nitrogen contributions from fertilizer sources and livestock categories. The land use information obtained from property appraisers (**Appendix A, Table A.4 and Table A.5**).

2. ESTIMATING NITROGEN INPUTS TO THE LAND SURFACE

Nitrogen inputs to the land surface in the Rainbow Springs BMAP area were evaluated for atmospheric deposition, wastewater treatment facilities (WWTFs), septic tanks, fertilizers, and livestock waste. The methods used to estimate nitrogen inputs for each source are based on the synthesis of multiple sources of information, including direct water quality measurements, census data, surveys, farm visits, published scientific studies and reports, and meetings with ranchers and growers. In many cases, several assumptions and extrapolations were made for estimating nitrogen inputs for each source, and as a result the estimated nitrogen inputs presented in this report are subject to further refinement as more detailed information becomes available. The approach and sources of information used to estimate the annual nitrogen input (in kilograms per year [kg-N/yr]) to the land surface for each source category are discussed below.

2.1 Atmospheric Deposition

Atmospheric deposition is largely a diffuse, albeit persistent, source of nitrogen to the land surface. Both wet and dry deposition rates were estimated for the Rainbow Springs BMAP area. The National Atmospheric Deposition Program (NADP) monitors wet deposition at numerous sites throughout the United States (available: nadp.sws.uiuc.edu). There are two NADP stations close to the BMAP area: FL03 Bradford Forest and FL05 Chassahowitzka National Wildlife Refuge (**Figure 5**). Annual data for ammonium (NH_4) and nitrate (NO_3) from 2002–12 were downloaded, and annual wet deposition rates for total nitrogen (TN) were calculated for years with complete datasets. These monitoring stations are periodically inoperative, resulting in incomplete datasets that cannot be used to determine annual nitrogen inputs. To ensure the calculations represent a full year of atmospheric deposition, any year with missing data as noted by NADP is not included in estimates of average nitrogen deposition for the range of years. The data from both monitoring stations were averaged together. In cases where one station did not have a complete dataset, the data from the other station were utilized.

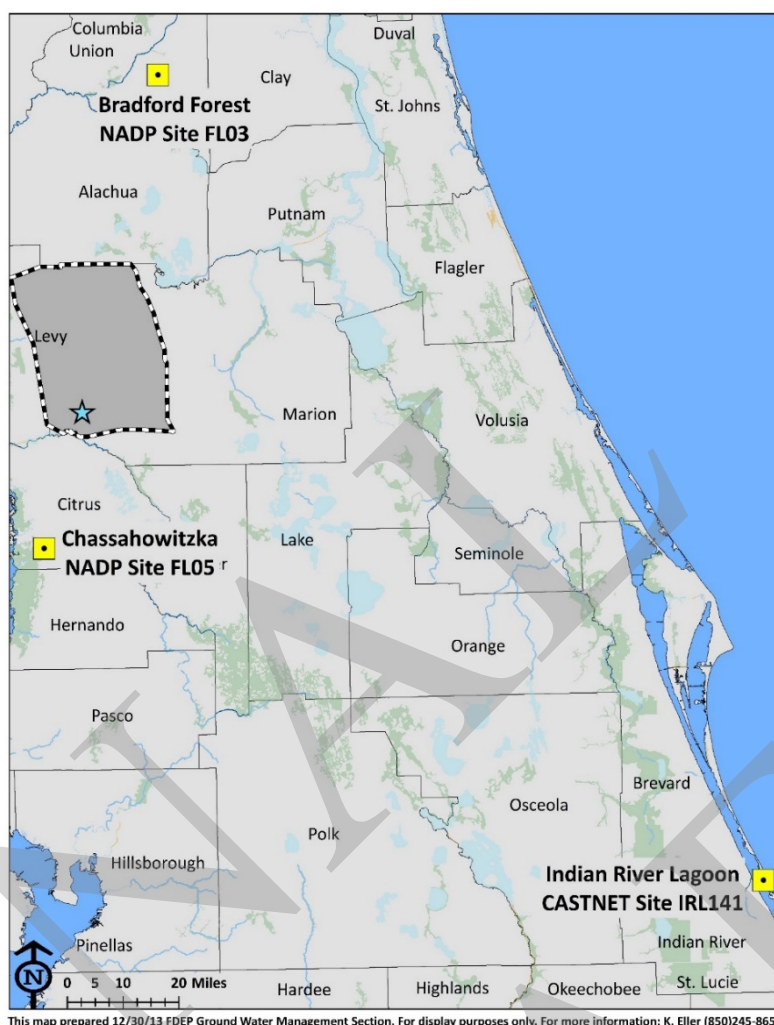


Figure 5: Atmospheric deposition monitoring stations used for the NSILT

NADP reports wet deposition data for NH_4 as kilograms per hectare ($\text{kg-NH}_4/\text{ha}$) and NO_3 as $\text{kg-NO}_3/\text{ha}$. These data were converted to ammonium as nitrogen ($\text{NH}_4\text{-N}$) and nitrate as nitrogen ($\text{NO}_3\text{-N}$) in kilograms of N per hectare using Equations 1 and 2. Annual averages were calculated using data from 2002–10 because there were missing data in 2011 and 2012.

$$\text{Equation 1} \quad \frac{\text{kg-NO}_3}{\text{ha}} \times 0.226 = \frac{\text{kg-N}}{\text{ha}} \text{NO}_3$$

$$\text{Equation 2} \quad \frac{\text{kg-NH}_4}{\text{ha}} \times 0.777 = \frac{\text{kg-N}}{\text{ha}} \text{NH}_4$$

Dry deposition is also monitored throughout the nation through the Clean Air Status and Trends Network (CASTNET) Program (available: epa.gov/castnet). There are only two active CASTNET stations in Florida. The closest of these stations to the BMAP area is at the Indian River Lagoon (Station IRL141). Weekly data were downloaded, and annual average deposition rates were calculated from 2002 to 2012.

As was the case with the wet deposition monitoring stations, the available data were incomplete. Data were missing for several months from IRL141 in 2004. The missing months were projected based on the other 10 months of data.

The TN atmospheric deposition rates were calculated by summing the annual wet and dry deposition. **Table 1** contains the atmospheric deposition data for the NADP and CASTNET monitoring stations. These annual averages were multiplied by the land areas in each of the two recharge areas to estimate the input of nitrogen attributed to atmospheric deposition. **Appendix A (Table A.9 and A.10)** contains a full listing of the data used for these calculations.

Table 1: Atmospheric deposition data in kg-N/ha/yr for the evaluated monitoring stations for the Rainbow Springs BMAP area

+ Data from FL03 Bradford Forest only

* Data from FL05 Chassahowitzka only

Year	Wet NO ₃	Dry NO ₃	Wet NH ₄	Dry NH ₄	Total N
2002	2.53	0.11	1.02	0.12	3.78
2003	2.38	0.11	1.07	0.11	3.68
2004	2.02	0.12	0.85	0.13	3.12
2005	2.59	0.11	1.56	0.13	4.40
2006+	1.13	0.12	0.65	0.13	2.03
2007	1.46	0.12	0.60	0.15	2.34
2008+	1.56	0.11	0.55	0.11	2.33
2009+	1.61	0.09	1.12	0.10	2.92
2010	1.48	0.10	0.91	0.12	2.60
2011*	2.02	0.09	1.31	0.10	3.52
2012*	1.67	0.09	0.92	0.09	2.76
Average ± std. dev.	1.86±0.48	0.11±0.01	0.96±0.30	0.12±0.02	3.04±0.73

2.2 Wastewater Treatment Facilities

WWTFs receive and treat domestic wastewater. In this area, treated effluent containing nitrogen is discharged to sprayfields, rapid infiltration basins (RIBs), or percolation ponds, or is reclaimed and used irrigation water. There are 37 WWTFs located within the Rainbow Springs BMAP boundary, with six discharging more than 100,000 gallons of treated effluent per day. Nitrate and TN data were obtained from the Department's Wastewater Facility Regulation (WAFR) database in order to calculate average annual input from WWTFs.

The required monitoring varies between facilities, and not all facilities report the same type of data. For larger facilities, the annual effluent input 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 (by volume; <0.1 MGD) are not always required to monitor and report effluent concentrations, and therefore not all these facilities had available WAFR data. For these facilities, the TN concentration was estimated at 8.97 mg/L based on effluent data collected by FDEP from 40 domestic WWTFs across the state during a 2009 cooperative study with the Water Reuse Foundation (unpublished in-house data set).

Some facilities reported nitrate rather than TN for their effluent concentrations. For these, the Department estimated TN concentrations by assuming the nitrate concentration was 38.5% of the TN (WRF 2009). Additionally, smaller facilities are not required to report the actual discharge volume, therefore the nitrogen input was estimated assuming the facility was discharging effluent at 50% of its permitted design capacity.

The WWTF data were compiled for each facility for one complete year starting in 2012 through 2013 when available. The reported annual average flows were used to calculate an average discharge for the evaluated year. The nitrogen input for each WWTF was calculated using the average annual TN concentration and the average yearly flow from the facility. The average annual nitrogen inputs were then estimated for all facilities in the Rainbow Springs BMAP area and distributed based on the locations of their application sites relative to the mapped aquifer recharge zones. **Table 2** summarizes the nitrogen input data from the larger facilities in the BMAP area. **Table A.7** in **Appendix A** contains the data from all facilities evaluated.

Table 2: Summary data for WWTFs contributing more than 1,000 kg-N annually (June 2012–May 2013)

* TN data estimated based on available NO₃ data
WRF = Water reclamation facility

WWTF Name	Facility ID	County	Recharge Area	Annual Average TN (mg-N/L)	Annual Flow (MGD)	N Input (kg-N/yr)
City of Ocala WRF #3	FLA190268	Marion	High	4.43	2.15	13,117
Oak Run	FLA012697	Marion	High	3.92	0.62	3,349
On Top of the World*	FLA012683	Marion	High	16.06	0.18	4,018
City of Williston*	FLA012612	Levy	High	9.49	0.20	2,571
City Of Dunnellon	FLA126594	Marion	High	4.39	0.15	904
Rainbow Springs Fifth Replat*	FLA012693	Marion	High	3.40	0.14	638

2.3 Septic Tanks

Onsite sewage treatment and disposal systems (OSTDS), commonly referred to as septic tanks, are widely used throughout the Rainbow Springs BMAP area where municipal sewer service is not available. These systems can contribute to elevated nitrogen concentrations in ground water (Chang *et al.* 2010).

Marion County provided currently available septic tank data for the part of the BMAP that falls within its boundaries. These data were derived using ArcGIS and based primarily on property appraiser and sewer utility service area information. All parcels identified by the property appraiser as improved with septic tanks were included in the dataset if they were located outside a sewer service area and were not located within the vicinity of a Department-permitted domestic WWTF. Parcels identified as improved with a residence or commercial building but having no information regarding sewer or septic were also initially identified as having a septic tank. However, where improved parcels fell within a sewer service area, every effort was made to determine if the property was, in fact, connected to a sewer line by cross-referencing parcel numbers with utility-specific data. If it was determined that the parcel was connected to a sewer line, it was eliminated from the dataset. Data from the Department's WAFR sites were included in the analysis in order to eliminate parcels served by community WWTFs.

For Levy County, another method was used. In 2009, a contractor for the Florida Department of Health (FDOH) developed a model for estimating the number of septic tanks based on tax parcel data and known sewer service areas (Hall and Clancy 2009). This model relied on parcel data with known septic tanks and sewer areas. For parcels without a known waste treatment system, estimations were made based on the information for surrounding parcels. For example, an estimated septic tank parcel was assumed to be located in areas where no sewer service was likely. The output of this model was provided in a GIS geodatabase from which the locations of both the known and the estimated septic tanks can be mapped. These data have been known to overestimate the septic tanks in some areas. An inventory of the septic tanks in this area would be a much better source of septic tank data, and this assessment should be updated if one is conducted.

The Marion County septic tank data were combined with the 2009 FDOH model data for Levy County to estimate the number of septic tanks within the BMAP boundary. **Figure 6** shows the location of septic tanks relative to the areas covered by the two recharge categories.

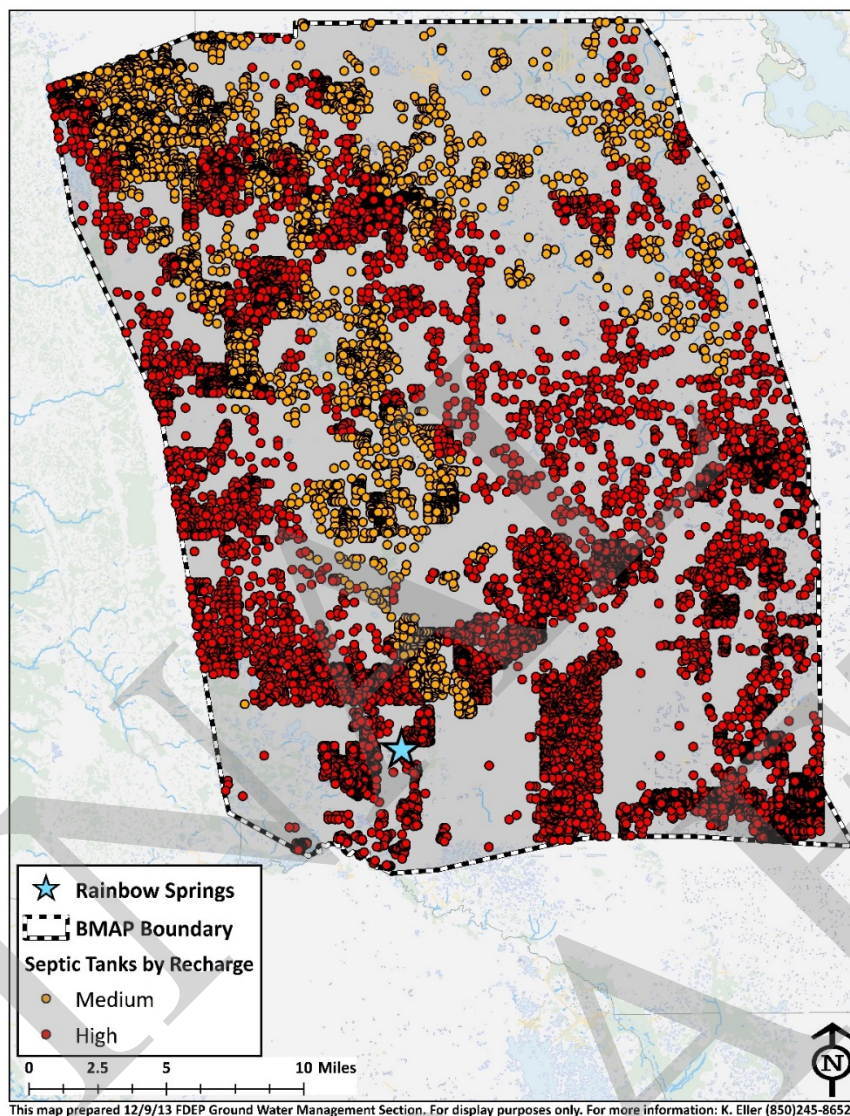


Figure 6: Distribution of septic tanks throughout the Rainbow Springs BMAP area

After the estimated number of septic tanks in the BMAP area was established, the population served by septic tanks was estimated using the 2010 United States Census Bureau data on population and household occupancy in each county (available: <http://www.census.gov>). The Census makes a distinction between occupied and non-occupied households. The populations of counties included in the BMAP area were divided by the number of occupied households in each county, resulting in the average number of people per household. **Table 3** summarizes these data.

Table 3: Population data from the 2010 Census

County	Population	Occupied Households	People Per Household
Marion	331,298	137,726	2.405
Levy	40,801	16,404	2.487

The number of people served by septic tanks within the BMAP area was estimated by multiplying the average number of people in each household (based on county data) by the number of septic tanks in a given area. An annual loading factor of 4.5 kg-N/person was applied to the number of people utilizing septic tanks within the different subdivisions of the BMAP area (United States Environmental Protection Agency [EPA] 2002; Roeder 2008; Toor *et al.* 2011; Viers *et al.* 2012). **Table 4** summarizes the estimated septic tank nitrogen input for each county and by land area representing each recharge category.

Table 4: Estimated number of septic tanks in the Rainbow Spring BMAP area

County	High-Recharge Area	Medium-Recharge Area	Total N Input (kg-N/yr)
Marion	11,990	1,016	140,786
Levy	4,246	4,520	98,115
Total BMAP	16,236	5,536	238,901

2.4 Livestock

The Rainbow Springs BMAP area and surrounding region contains an abundance of livestock. Marion County is the self-proclaimed “horse capital of the world” with more than 70,000 acres of thoroughbred breeding and horse training farms (available: ocalamarion.com/equestrian/). Additionally, the cow-calf industry is prominent throughout the area, with considerable acreage devoted to raising beef cattle. Other miscellaneous types of livestock in the area have a much smaller potential impact and have been combined for the purpose of this evaluation. Livestock information and potential loadings were broken into three categories: horse farms, cattle farms, and miscellaneous livestock. The horse farm and cattle farm categories were also further subdivided into animal waste and fertilizer application subcategories. The practices for each of the farm categories were considered and evaluated to estimate the nitrogen input in the Rainbow Springs BMAP area. **Figure 7** illustrates the distribution of the most likely livestock lands based on WMD land use coverage within the BMAP area.

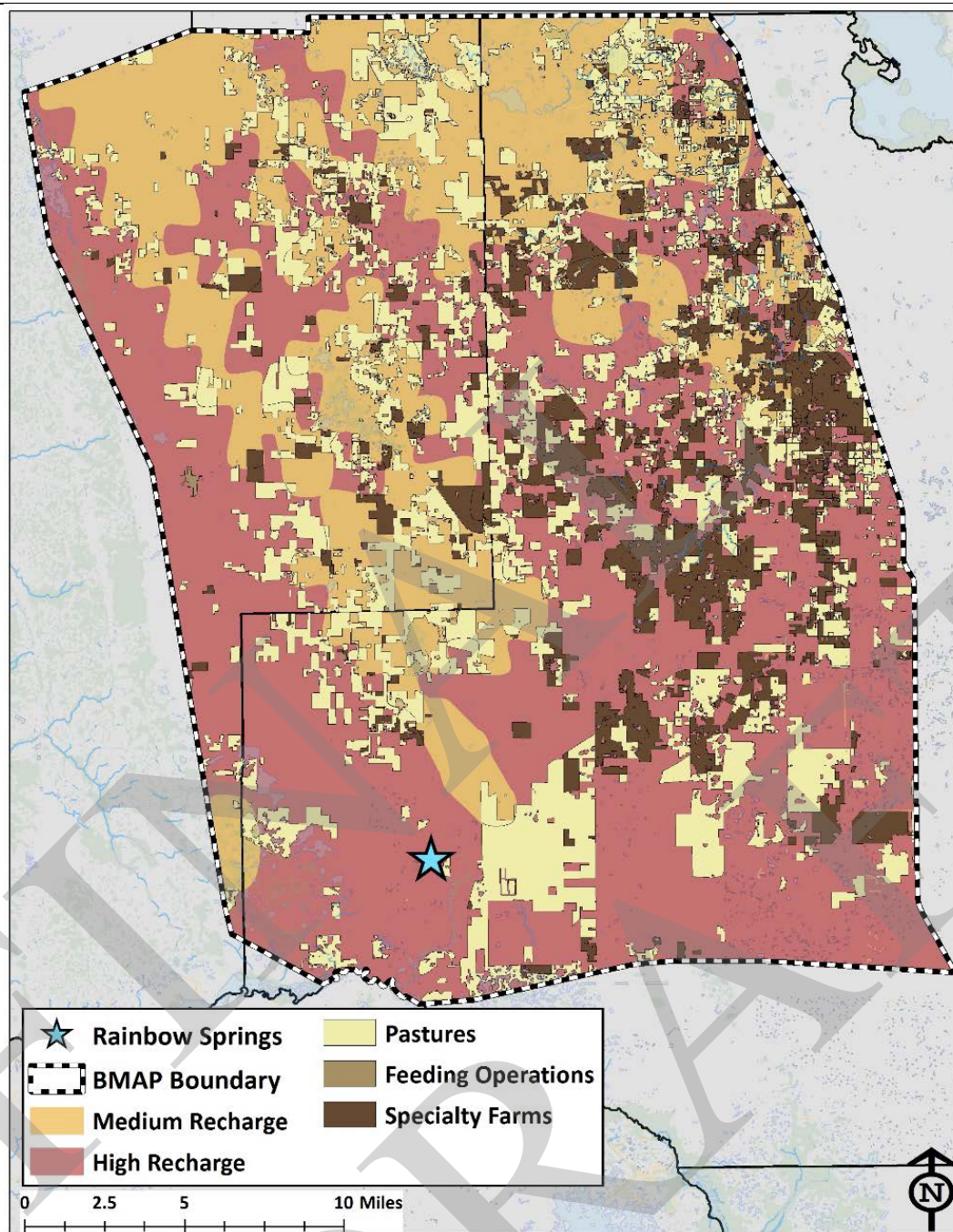


Figure 7: WMD livestock lands within the Rainbow Springs BMAP boundary

2.4.1 Livestock Populations

Every five years the United States Department of Agriculture (USDA) releases a Census of Agriculture (CoA). This comprehensive report summarizes the agricultural practices and livestock populations for each state and county in the United States (available: <http://agcensus.usda.gov/Publications/2012/>). The 2012 census report was used to evaluate livestock populations for this assessment. **Table 5** summarizes the county livestock populations for the entirety of the two counties included in the Rainbow Springs BMAP area.

Table 5: Livestock populations as reported in the 2012 Census of Agriculture

Livestock	Marion	Levy
Horses	37,880	4,720
Cows	30,219	20,375
Calves	17,034	9,415
Broiler Chickens	1,235	476
Layer Chickens	10,441	2,129
Goats	3,538	1,202
Hogs	848	205
Sheep	942	259
Turkey	135	80

2.4.2 Horse Farms

The CoA reports entire county data; however, only a portion of each county is included within the Rainbow Springs BMAP area. To estimate the number of horses contributing to the BMAP area, the WMD land use coverage was used to provide a breakdown of land areas that are likely to contain horses, *i.e.*, specialty farms and horse farms. The land areas were totaled for the entire counties as well as the individual land areas representing the two recharge categories. These summations were used to calculate a land use percentage relative to the entire county for horse farms in the different recharge categories. The percentages were then applied to the populations provided by the CoA to estimate the number of animals in the BMAP area and the recharge-based subdivisions (**Table 5**). For example, if 100,000 horses were reported for a particular county in the CoA, but only 10% of the horse lands in that county were inside the BMAP area, it was assumed that only 10,000 horses would be in the BMAP area. The WMD land use coverage was utilized for these calculations because there is a distinction made between horse farms and other livestock pasturelands, while the property appraiser land use data provide only pasture or livestock land areas without categorizing the type of animals present. **Table 6** lists detailed information on the land areas and land use percentages.

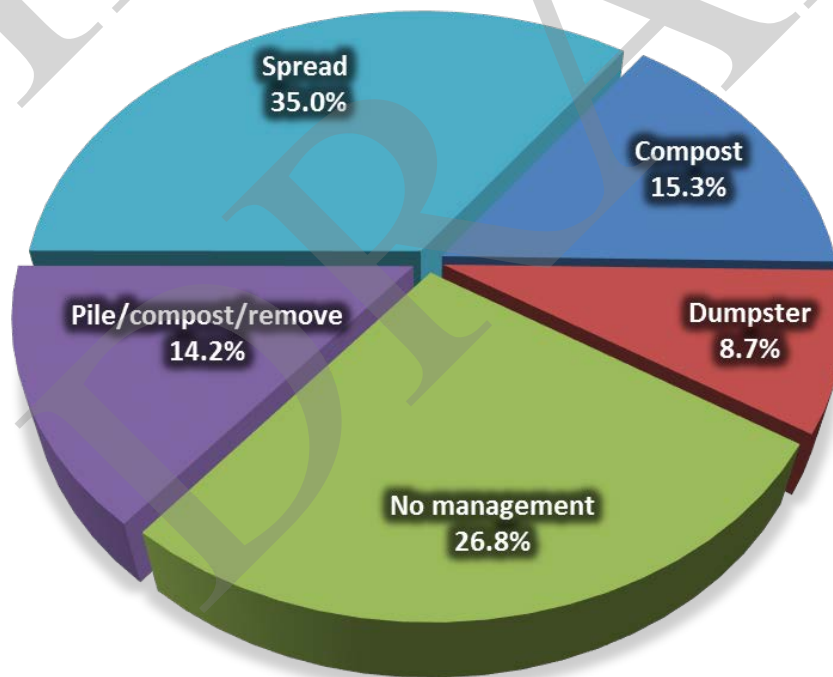
An additional estimation was made for horse farms based on horse farm visits by the Marion County Extension Office during 2011–13. Surveys were conducted during visits to more than 200 individual horse farms during 2011–13 to obtain information on their manure management and fertilizer practices (J. Cohen, Marion County, University of Florida Institute of Food and Agricultural Sciences [UF–IFAS] Extension Service, personal communication, 2013).

Table 6: Land areas used to calculate horse farm land use percentages and estimated BMAP horse populations

- = Empty cell/no data

Land Category	Land Area (ha)	Land Use Percentage	Estimated BMAP Population
Marion County	27,861	-	-
Marion High Recharge	12,872	46%	17,502
Marion Medium Recharge	2,987	11%	4,061
Levy County	2,786	-	-
Levy High Recharge	994	36%	1,684
Levy Medium Recharge	1,353	49%	2,293

Figure 8 summarizes the survey results for manure management, which is an important factor in estimating nitrogen inputs from horse farms. The nitrogen input from horses varies based on the manure management practices used on individual farms. Composting and physically removing the waste (dumpsters) are considered the most effective manure management options. The composting process removes the majority of the nitrogen through biochemical processes that minimize its impact on the environment. The physical removal of the manure outside of the Rainbow Springs BMAP area also prevents onsite nitrogen leaching to ground water. With both practices considered, and extrapolating the UF-IFAS survey results to all of the horse farms in the BMAP area, it is estimated that manure from 62% of the horse population (manure spread and no management of wastes, **Figure 8**) will contribute nitrogen to the land surface within the BMAP area. With the contributing horse population established, a nitrogen

**Figure 8: Manure management from the UF-IFAS horse farm surveys (percent of farms surveyed)**

waste factor was used to quantify the nitrogen input. For this assessment, a horse will produce 0.124 kg-N/day or 45.3 kg-N/yr (Goolsby *et al.* 1999; Ruddy *et al.* 2006; Katz *et al.* 2009). **Table 7** details the estimated nitrogen input from the contributing horse population in the BMAP area and the land areas representing the two recharge categories.

Table 7: Estimated nitrogen input for horse farms within the Rainbow Springs BMAP area.
Nitrogen inputs are based on daily waste factor for horses.

Recharge Category	Contributing Horse Population	N Input (kg-N/yr)
Marion High Recharge	10,851	491,114
Marion Medium Recharge	2,518	113,959
Levy High Recharge	1,044	47,253
Levy Medium Recharge	1,421	64,334
BMAP High Recharge	11,895	538,368
BMAP Medium Recharge	3,939	178,293

The other main source of nitrogen from horse farms is pasture fertilization. For pastures, land use coverages from both WMD and county property appraiser offices were utilized to estimate fertilizer nitrogen inputs. The property appraiser data provided detailed information on pastures, including the varying levels of improvement in each of the counties. However, the property appraiser information does not specifically identify lands grazed by horses, while the WMD land use coverage does. In the WMD livestock land use categories, the distinction between horse farms and pastures is used to distinguish between pastures associated with horse farms and pastures used for cattle. For each county and recharge category, the percentage of horse farmlands was calculated.

The total land area devoted to livestock practices was calculated using the WMD land use data. These land use types included pasturelands, feeding operations, and specialty farms. The total land area was then calculated for the specialty and horse farms. A percentage was computed using these land areas to estimate the percentage of horse farmlands relative to the other livestock land uses. For example, Marion County has 31,984 ha of livestock lands in the high-recharge category in WMD land use. There are 12,872 ha allotted to specialty or horse farms, or 40% of the livestock lands. For high-recharge areas of Marion County, there are 34,425 ha of either improved or semi-improved pastures or hayfields, according to the property appraiser data. Woodland pastures were not included in these calculations because these types of pastures do not receive fertilizer. Hayfields are included because hayfields and pasturelands are used rotationally by livestock farmers. This practice was confirmed in meetings with agricultural producers in the Rainbow Springs BMAP area. Of the 34,425 ha fertilized pasture and hayfields, it was estimated that

40% of this land, or 13,855 ha, is utilized for horse farms, while the remaining 20,570 ha are devoted to cattle operations in the high-recharge area of Marion County. These same assumptions were made for all recharge categories in each county. **Table 8** summarizes these data for the land areas representing the two recharge categories.

Table 8: Comparison of summary WMD and property appraiser pasture land use data for the Rainbow Springs BMAP area

Land Category	WMD Livestock Land (ha)	WMD Horse Farms (ha)	WMD % Horse Farms	PA Fertilized Pasture (ha)	Horse Pasture (ha)	Cattle Pasture (ha)
Marion High Recharge	31,984	12,872	40%	34,425	13,855	20,570
Marion Medium Recharge	8,978	2,987	33%	10,500	3,493	7,007
Levy High Recharge	6,512	993	15%	6,149	939	5,218
Levy Medium Recharge	8,873	1,353	15%	13,468	2,054	11,414

After the land area utilized for horse pastures was established, data synthesized from information obtained from the horse farm visits by the Marion County Extension Office were used to represent fertilizer application practices and rates of application within the Rainbow Springs BMAP area. The UF-IFAS recommended fertilizer rate for pastures is 100 to 150 pounds per acre (lb-N/ac) (112 to 168 kg-N/ha) every two to three years. Information compiled from the UF-IFAS surveys indicated that approximately 21% of horse farms apply fertilizer at least once a year, while 26% apply fertilizer every few years or as needed (**Figure 9**). For this assessment, it was estimated that 21% of the horse pasturelands were fertilized

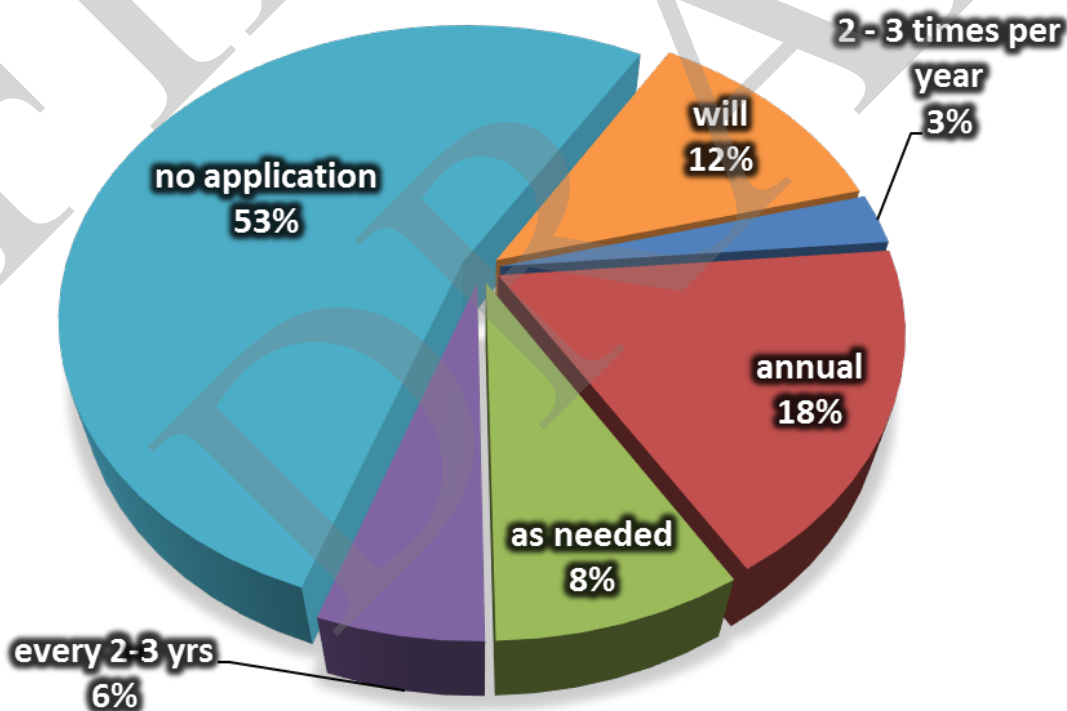


Figure 9: UF-IFAS horse farm survey results for fertilizer application

at 112 kg-N/ha/yr (representing “annual” and “2-3 times per year” categories in the survey) which is the IFAS recommended rate. 26% at an annual rate of 34 kg-N/ha/yr (representing “every 2-3 yrs,” “as needed,” and “will” categories in the survey) which is equivalent to the IFAS recommended rate applied less than every 3 years. The remaining 53% is estimated to not fertilize the fields at all. **Table 9** summarizes the horse farm fertilizer nitrogen input as well as the horse manure input in the BMAP area and its recharge-based subdivisions.

Table 9: Summary of estimated annual horse farm nitrogen input in the Rainbow Springs BMAP area

Recharge Category	112 kg-N/ha Horse Pasture (ha)	34 kg-N/ha Horse Pasture (ha)	No Fertilization Horse Pasture (ha)	Total N from Horse Farm Fertilizer (kg/yr)	Total N from Horse Farm Waste (kg/yr)	Total N Input from Horse Farms (kg/yr)
High	3,107	3,846	7,840	477,529	538,368	1,015,896
Medium	1,165	1,442	2,940	179,074	178,293	357,367
Total BMAP	4,272	5,289	10,781	656,603	716,661	1,373,263

2.4.3 Cattle Farms

The nitrogen input from cattle farms (wastes and fertilizer) was estimated using an approach similar to that used for horse farms. The full county population data and land use percentages were used to estimate the number of cows and calves in the Rainbow Springs BMAP area. The land use percentages were calculated based on the WMD land use coverage data for the following land use categories: pastures, feeding operations, and dairies. There are dairies within both counties; however, they are outside the BMAP area. **Table 10** summarizes the land areas and percentages for cattle farms in the BMAP area by county and recharge-based subdivision.

Table 10: Land areas used to calculate cattle farm land use percentages and estimated BMAP cattle populations. Nitrogen inputs are based on daily waste factors for cows and calves.

- = Empty cell/no data

Land Category	Land Area (ha)	Land Use Percentage	Estimated BMAP Cow Population	Estimated BMAP Calf Population	N Input from Waste (kg-N)
Marion County	51,011	-	-	-	-
Marion High Recharge	19,112	37.5%	11,322	6,382	668,010
Marion Medium Recharge	5,991	11.7%	3,549	2,001	282,848
Levy County	26,892	-	-	-	-
Levy High Recharge	5,518	20.5%	4,181	1,932	244,279
Levy Medium Recharge	7,520	28.0%	5,697	2,633	332,915

Beef cow-calf operations on pasture comprise most of the cattle industry in the Rainbow Springs BMAP area and surrounding areas. Each year, the cows are bred and raise their calves for six to nine months, after which the calves are sold and shipped out of the state to be raised as beef cattle. The nitrogen contributions from adult cows and calves vary because of their differences in body mass and residence time in the BMAP area. Based on a detailed literature review, a calf produces approximately 20% of the nitrogen that its mother produces (Sutton *et al.* 2001; Berry *et al.* 2002; Estermann *et al.* 2002; USDA Agricultural Research Service [ARS] 2003; Hubbard and Lawrence 2005). For this assessment, a cow produces 0.153 kg-N/day or 56 kg-N/yr as waste and contributes nitrogen throughout the year (Chelette *et al.* 2002; Ruddy *et al.* 2006; Katz *et al.* 2009; Meyer 2012; Sprague and Gronberg 2013). A calf produces only 0.031 kg-N/day or 5.7 kg-N as waste in the first 183 days of its life, which is an average residence time in this area for calves (Marion County Cattlemen's Association, personal communication, 2014). These waste factors are multiplied by the populations in the BMAP area to estimate the nitrogen input from cattle waste.

As was the case with horse farms, cattle farm managers also apply fertilizers to pastures and use their lands for forage hay production on a rotational basis. The area of fertilized pasture lands devoted to cattle was calculated in the same manner as for horse farms. **Table 11** lists the estimated land areas fertilized for cattle grazing and hay production. The application rates of fertilizer to cattle lands vary and depend on the use of individual fields (such as hay production, animal forage, or idle between uses). Estimates of average annual fertilizer applications to pasture were developed based on information received in meetings with members of the Marion County Cattlemen's Association, UF-IFAS, and Florida Farm Bureau.

From these discussions it was learned that fertilization rates can vary widely from one year to another but that an average annual rate for a cattle ranch that includes a combination of fertilized pasture and hayfields is approximately 17 lb-N/ac or 19.05 kg-N/ha. This information and the information on cattle waste were used to develop estimates of total inputs from cattle production. **Table 11** contains the estimated annual average nitrogen contribution from cattle farms in the BMAP area and subdivisions based on recharge.

Table 11: Summary of annual TN input to the land surface attributed to cattle farming operations

Recharge Category	Total N from Cattle Farm Fertilizer (kg/yr)	Total N from Cattle Farm Waste (kg/yr)	Total N Input from Cattle Farms (kg/yr)
High	491,369	912,289	1,403,658
Medium	350,998	615,763	966,760
Total BMAP	842,366	1,528,052	2,370,418

2.4.4 Miscellaneous Livestock

While cattle and horses are the most significant livestock animals in the study area, an estimate was made for other livestock animals in the Rainbow Springs BMAP area. The animal populations reported by the 2012 USDA CoA were evaluated for chickens (broilers and layers), goats, hogs, sheep, and turkeys. The livestock land use percentages were utilized to estimate the number of animals in the BMAP area and recharge-based subdivisions (**Table 10**). Nitrogen waste factors were assigned for each animal type and applied to the estimated livestock populations. These nitrogen waste factors included broiler chickens at 0.072 kg-N/day, layer chickens at 0.0012 kg-N/day, goats at 0.016 kg-N/day, hogs at 0.086 kg-N/day, sheep at 0.09 kg-N/day, and turkeys at 0.0025 kg-N/day (Goolsby *et al.* 1999; Katz *et al.* 1999; Chelette *et al.* 2002; Ruddy *et al.* 2006; Meyer 2012; Sprague and Gronberg 2013). **Table 12** summarizes the estimated populations and their nitrogen contribution. **Table A.10** in **Appendix A** contains a complete list of the CoA data for these miscellaneous livestock species.

Table 12: Estimated BMAP populations and associated nitrogen input from miscellaneous livestock in the Rainbow Springs BMAP area. Nitrogen inputs for each type of animal are based on daily waste factors.

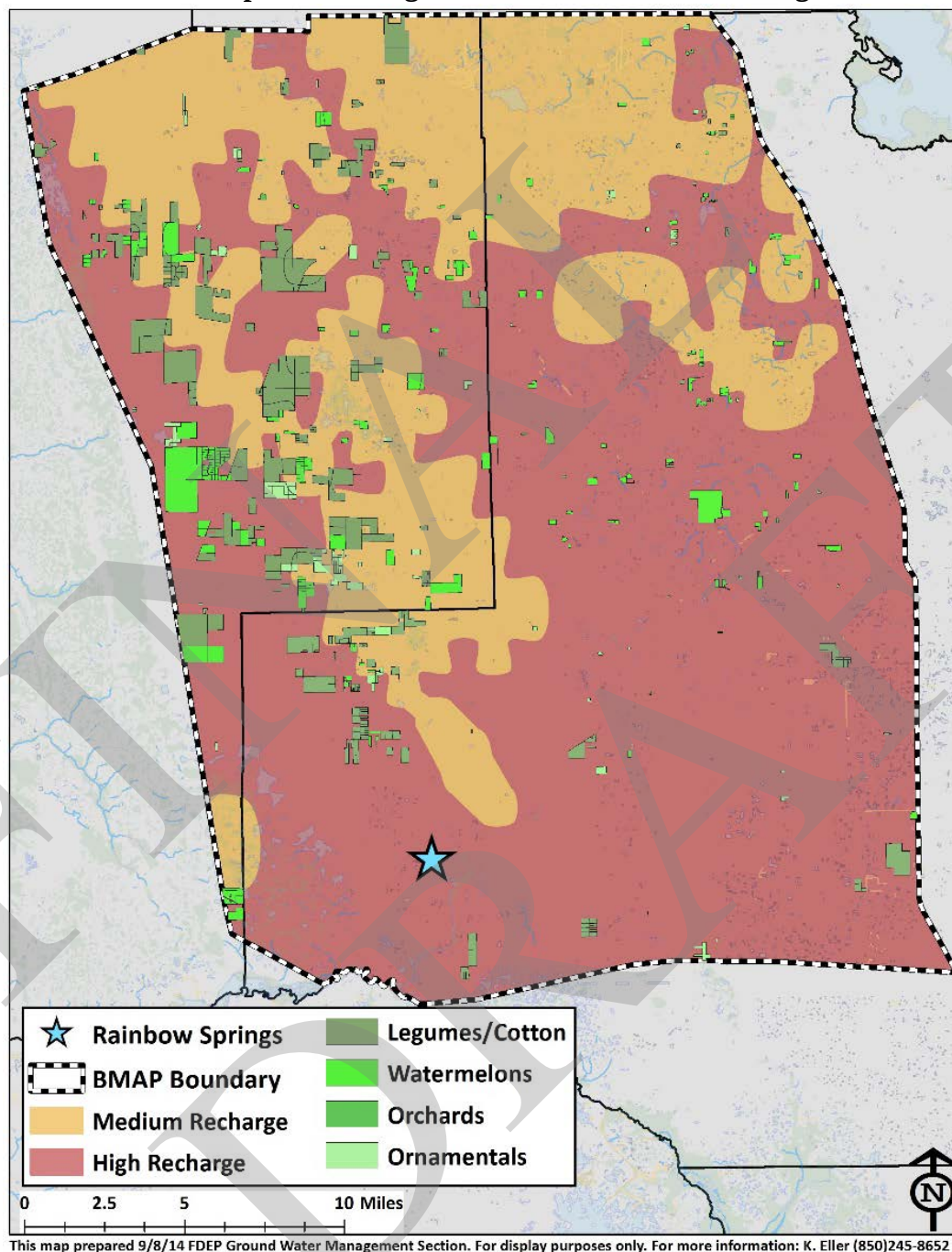
Land Category	Broiler Chickens	Layer Chickens	Goats	Hogs	Sheep	Turkey	Total N input (kg-N/yr)
Marion High Recharge	463	3,912	1,326	318	353	51	43,228
Marion Medium Recharge	145	1,226	416	100	111	16	13,550
Levy High Recharge	98	437	247	42	53	16	7,279
Levy Medium Recharge	133	595	336	57	72	22	9,921
BMAP High Recharge	560	4,349	1,572	360	406	67	50,507
BMAP Medium Recharge	278	1,822	752	157	183	38	23,471

2.5 Crop Fertilizer

Nitrogen contained in inorganic fertilizer is applied to cropland at varying rates, depending on the crop type and individual farm practices. The Marion and Levy county property appraiser offices provided detailed information on the types of crops grown on properties in their respective counties (**Figure 10**). The property code distinctions are made largely based on soil type, and the crops grown in each category are based on personal communication with the agricultural property appraisers for each county. The nitrogen application rates were estimated based on the crops that would be most likely be grown in each area identified by a specific property code assigned by the property appraiser. Fertilizer nitrogen application rates used in the assessment are based on rates recommended by UF-IFAS for those crops

DRAFT Nitrogen Source Inventory and Loading Tool for the Rainbow Springs BMAP Contributing Area, October 2014
(Hochmuth and Hanlon 2000; Hochmuth and Hanlon 2010; Wright *et al.* 2011; Mylavarapu *et al.* 2012; Liu *et al.* 2013; Hochmuth and Hanlon 2013). **Table 13a** and **Table 13b** summarize the data used to estimate crop fertilization in the Rainbow Springs BMAP area and in the two recharge categories.

Figure 10: Distribution of croplands throughout the BMAP area according to the county property



appraiser offices

Table 13a: Summary of crop types and nitrogen application rates in the Rainbow Springs BMAP area for Marion County

- = Empty cell/no data

PA code	Probable Crop	N Application Rate (kg-N/ha)	Medium-Recharge Land Area (ha)	High-Recharge Land Area (ha)	Total Input (kg-N/yr)
51	Peanuts, cotton	0	252	1,078	-
52	Watermelon	135	138	646	105,411
66	Oranges	168	-	2	416
69	Blueberries, Pecans, Ornamentals	90	68	146	19,249

Table 13b: Summary of crop types and nitrogen application rates in the Rainbow Springs BMAP area for Levy County

- = Empty cell/no data

PA code	Probable Crop	N Application Rate (kg-N/ha)	Medium-Recharge Land Area (ha)	High-Recharge Land Area (ha)	Total Input (kg-N/yr)
5100	Watermelons	135	1,089	1,280	318,622
5200	Legumes	0	4,002	1,272	-
6600	Orchards	168	12	-	2,010
6900	Ornamentals	90	357	201	50,031

2.6 Urban Fertilizer

Nitrogen in fertilizer used in urban areas was assumed to be applied mostly to golf courses and residential lawns. Previous studies have used fertilizer sales data compiled by the Florida Department of Agriculture and Consumer Services (FDACS) to estimate the fertilizer nitrogen inputs in urban areas (Chelette *et al.* 2002; Gronberg and Spahr 2012). This method was employed for estimating urban fertilizer inputs in the Rainbow Springs BMAP area, and it assumes that the majority of the fertilizer used was purchased locally and that out-of-county sales of fertilizer were not significant.

Fertilizer quantities sold by county are available from FDACS' Bureau of Compliance Monitoring Fertilizer Section (available: <http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Agriculture-Industry/Fertilizer-Manufacturers/Fertilizer-Consumption-Tonnage-Data>). For this analysis, data from two different FDACS reports were used: *Summary by County* and *Nutrients by County*. These (pdf) documents contain historical annual sales records by county, based on the state fiscal year (July 1 of one year to June 30 of the following year). The annual average fertilizer inputs were calculated using the data for the state fiscal year. For example, the FDACS report from July 2011 to June 2012 was used to calculate the nitrogen inputs for 2012.

The total nonfarm or urban fertilizer sold is listed in the *Summary by County* report, while the TN in the fertilizer sold and total fertilizer sold is available in the *Nutrients by County* report. Fertilizer sales quantities are reported in tons and were converted to kilograms for this assessment. Data for each county were obtained from 2007–12, the most recent reporting period. The TN sold in urban fertilizers was calculated based on the known amount of urban fertilizer and the percent of nitrogen in all of the fertilizers sold in the county. **Table 14** summarizes these data by county.

Table 14: Average county fertilizer sales data (2007–12) used in the Rainbow Springs nitrogen inventory

County	Total Fertilizer Sold (kg)	Total N Sold in Fertilizer (kg)	% N in Fertilizer	Total Urban Fertilizer Sold (kg)	Total N Sold in Urban Fertilizers (kg)
Marion	17,655,113	1,744,203	9.9	5,547,560	567,714
Levy	27,766,443	1,845,557	8.7	511,820	46,858

As is the case with the USDA animal census data used for estimating livestock populations in the Rainbow Springs BMAP area, fertilizer sales data are for the entire county, while only a portion of each county is within the BMAP boundary. Land use percentages were calculated from the WMD land use data based on urban land uses: high-, medium- and low-density residential areas, as well as golf courses, recreational areas, and parks and zoos. **Table 15** summarizes the land use percentages and the TN input attributed to urban fertilizers in the BMAP area and its recharge-based subdivisions. **Table A.3** in **Appendix A** contains a complete list of land use data for urban land uses.

Table 15: Urban land use summary and fertilizer input

- = Empty cell/no data

Land Category	Land Area (ha)	Land Use Percentage	N Input (kg-N/yr)
Marion County	64,407	-	-
Marion High Recharge	19,604	30.4%	172,803
Marion Medium Recharge	2,893	4.5%	25,503
Levy County	20,796	-	-
Levy High Recharge	5,297	25.5%	11,937
Levy Medium Recharge	6,049	29.1%	25,631

2.7 Summary of Estimated Nitrogen Inputs to the Land Surface

Figure 11 summarizes all estimated inputs of nitrogen to the land surface in the Rainbow Springs BMAP area. The total annual nitrogen input from all sources is over 5.4 million kg-N. The most significant inputs to the land surface include cattle farms, horse farms, atmospheric deposition, and septic tanks.

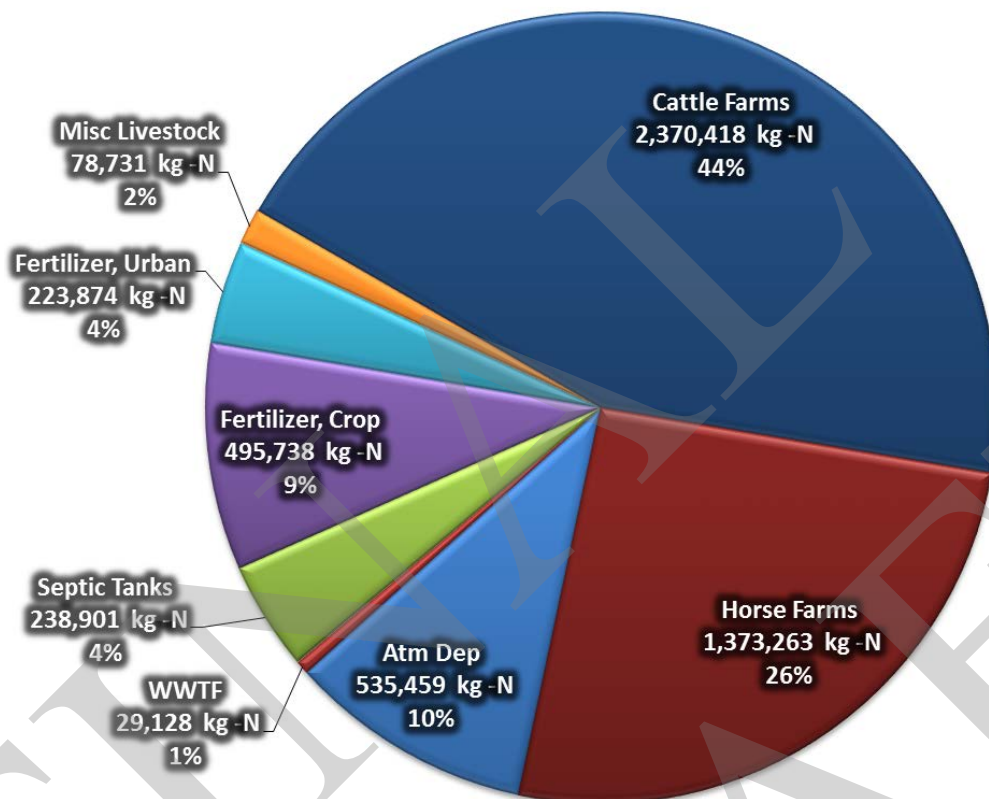


Figure 11: Relative annual nitrogen inputs to the land surface in the Rainbow Springs BMAP area from major anthropogenic source categories

The relative percentages of nitrogen inputs to the land surface from individual nitrogen sources and land uses have changed considerably from those estimated during 1993–95 as part of a SWFWMD nitrate study of Rainbow Springs (Jones *et al.* 1996). **Appendix C** lists several factors that account for these differences and also lists the different methods and estimated nitrogen inputs from the SWFWMD study and those estimated by the NSILT. Although the Rainbow Springs BMAP area is larger than the SWFWMD Rainbow Springs contributing area, this comparison illustrates how the relative contributions of nitrogen sources have changed over the past 20 years.

3. ENVIRONMENTAL ATTENUATION OF NITROGEN AND NITROGEN LOADING TO GROUND WATER

The movement of nitrogen from the surface to groundwater is controlled by biological and chemical processes that are part of the nitrogen cycle as well as hydrogeologic processes. Many of these processes attenuate (impede or remove) the amount of nitrogen that is transported to groundwater.

Therefore, to estimate the amount of nitrogen loading to the aquifer in the Rainbow Springs BMAP area, we apply environmental attenuation factors (EAFs): one that accounts for biochemical processes that remove or transform the different forms of nitrogen, and the other that accounts for the movement of recharge water through the subsurface. The biochemical attenuation is specific for each nitrogen source category, whereas the hydrogeological attenuation varies depending on the spatial differences in the subsurface geologic properties. Both of these attenuation factors control the amount of nitrogen reaching the UFA in the area contributing flow to Rainbow Springs on an annual basis. An understanding of how water moves through the subsurface and the processes that transform the different forms of nitrogen is needed to estimate the loading of nitrogen to ground water from the various sources (Liao et al 2012; Wang et al 2013).

3.1 Biochemical Attenuation

Several near-surface biochemical processes increase nitrogen availability for plants such as fixation (conversion of atmospheric nitrogen to a plant available form), mineralization (conversion of organic nitrogen to ammonium), and nitrification (conversion of ammonium to nitrate). Losses of nitrogen from the root zone can result from denitrification, volatilization, and 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 biochemical attenuation factors were used to account for the various processes that affect the movement of nitrogen from each source category in the subsurface. The EAFs utilized for this assessment were obtained through an extensive literature review of relevant studies throughout Florida as well as other areas with similar environmental characteristics. Additionally, research scientists in Florida (UF–IFAS, universities, and USDA–ARS) and local stakeholders were sought out for their expertise. The biochemical attenuation factors, shown in **Table 16**, represent the average percentage of the nitrogen mass attenuated or removed by processes occurring in the environment and thus prevented from reaching ground water.

As a first step in estimating loading to ground water, the previously mentioned nitrogen inputs at the land surface from each category are multiplied by their associated EAFs. For example, atmospheric deposition has an average 90% environmental attenuation (*e.g.*, uptake by vegetation). This means that an average of 10% of the atmospheric nitrogen input to the land surface has the potential to leach to ground water. The next step in estimating nitrogen loads to ground water takes into account additional attenuation associated with variations in hydrogeological properties in the BMAP area.

Table 16: EAFs applied to the nitrogen input calculations. These percentages represent the amount of nitrogen removed by the environment.

¹ Selected references listed; **Appendix B** contains a full listing.

² Estimation for established turfgrass.

N Source Category	Attenuation Factor	Literature References
Atmospheric Deposition	90%	Katz <i>et al.</i> 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs	60%	Katz <i>et al.</i> 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
Septic Tanks	40%	EPA 2002; Costa <i>et al.</i> 2002; Otis <i>et al.</i> 2007; Katz <i>et al.</i> 2009; Chang <i>et al.</i> 2010; Katz <i>et al.</i> 2010; Toor <i>et al.</i> 2011
Livestock Operations ¹	90%	Dubeux <i>et al.</i> 2007; Silveira <i>et al.</i> 2007; Burns <i>et al.</i> 2009; Dubeux <i>et al.</i> 2009; Obour <i>et al.</i> 2010; Sigua 2010; Sigua <i>et al.</i> 2010; Silveira <i>et al.</i> 2011; Woodard <i>et al.</i> 2011; White-Leech <i>et al.</i> 2013a; White-Leech <i>et al.</i> 2013b
Crop Fertilizer ¹	80%	McNeal <i>et al.</i> 1995; Wang and Alva 1996; Paramasivam and Alva 1997; Newton <i>et al.</i> 1999; Hochmuth 2000a; Hochmuth 2000b; Simonne <i>et al.</i> 2006; He <i>et al.</i> 2011; Liu <i>et al.</i> 2013
Urban Fertilizer ²	70%	Goolsby <i>et al.</i> 1999; Erikson <i>et al.</i> 2001; Barton and Colmer 2006; Katz <i>et al.</i> 2009

3.2 Hydrogeological Attenuation

Any nitrogen remaining after taking into account biochemical attenuation processes, which is usually in the form of nitrate, can readily leach to groundwater. However, leaching to groundwater is a function of the properties of the soil and unsaturated zone, such as composition (particularly the 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 amount of rainfall, evapotranspiration, runoff, as well as subsurface hydrogeologic properties. The final step in estimating nitrogen loads to ground water is to account for additional attenuation associated with the rate of recharge in a given year.

The recharge rate is a parameter that can be geospatially assessed and incorporates soil and unsaturated zone properties (based on a synthesis of the SJRWMD recharge map discussed in **Section 1.2, Aquifer Recharge**). The rate of recharge is used in NSILT as an aggregated indicator of the various hydrogeological

processes that can further attenuate the movement of nitrate to groundwater. In areas with lower recharge potential on an annual basis, the vertical movement of the 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 will spend less time in the soil/root zone decreasing the opportunity for biochemical attenuation. This would likely result in 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).

The recharge weighting factors used in this nitrogen loading assessment are applied as follows: 90% for high-recharge rate areas (≥ 12 in/yr), 50% for medium-recharge rate areas (4 to 11.9 in/yr) and 10% for low recharge areas (0 to 3.9 in/yr). For example, in high-rate recharge areas, 90% of the non-attenuated nitrogen mass (in kg) is assumed to reach the aquifer in a year; while only 50% of the non-attenuated nitrogen mass is assumed to reach the aquifer in any given year in medium-rate recharge areas. These factors are based on the recharge characteristics specific to the aquifer conditions in the Silver Springs BMAP area. Different recharge factors may be assigned to other areas, based on their distinct geological and hydrological characteristics. The associated recharge factors are applied to the non-attenuated nitrogen based on the location of the land use utilized to estimate the nitrogen input.

3.3 Estimated Nitrogen Loads to Ground Water

Table 17a, **Table 17b**, and **Table 17c** summarize estimated annual nitrogen inputs, attenuation factors, and loads to the UFA, respectively, in the BMAP area and its recharge-based subdivisions. The results indicate that there is an estimated 602,405 kg-N load to the UFA in the BMAP area annually. This represents 11% of the amount of nitrogen inputs to the land surface. The difference is due to various nitrogen attenuation processes and variations in the quantity and movement of water that recharges the aquifer.

Table 17a: Estimated nitrogen input to the land surface by source category in the Rainbow Springs BMAP area (kg-N/yr)

Recharge Category	Atmospheric Deposition	WWTFs	Septic Tanks	Horse Farms	Cattle Farms	Misc. Livestock	Crop Fertilizer	Urban Fertilizer	Total
High	365,158	29,084	177,312	1,015,896	1,059,960	50,507	290,590	184,740	3,516,945
Medium	170,302	44	61,589	357,367	966,760	28,227	205,148	39,134	1,828,567
Total Input	535,459	29,128	238,901	1,373,263	2,370,418	78,731	495,738	223,874	5,345,512

Table 17b: Estimated nonattenuated nitrogen by source category in the Rainbow Springs BMAP area (kg-N/yr)

- = Empty cell/no data

Recharge Category	Atmospheric Deposition	WWTFs	Septic Tanks	Horse Farms	Cattle Farms	Misc. Livestock	Crop Fertilizer	Urban Fertilizer	Total
Attenuation Factors	90%	60%	40%	90%	90%	90%	70%	80%	-
High	36,516	11,634	106,387	101,590	140,366	5,051	87,177	36,948	525,668
Medium	17,030	17	36,953	35,737	96,676	2,347	61,544	7,827	258,607
Total	53,546	11,651	143,340	137,326	237,042	7,398	148,721	44,775	784,275

Table 17c: Estimated total and by-category nitrogen loads to ground water in the Rainbow Springs BMAP area

- = Empty cell/no data

Recharge Category	Recharge Factor	Atmospheric Deposition	WWTFs	Septic Tanks	Horse Farms	Cattle Farms	Misc. Livestock	Crop Fertilizer	Urban Fertilizer	Total
High	90%	32,864	10,470	95,759	91,431	126,329	4,546	78,459	33,253	473,101
Medium	50%	8,515	9	18,477	17,868	48,338	1,174	30,772	3,913	129,304
Total Load	-	41,379	10,479	114,225	109,299	174,667	5,719	109,232	37,167	602,405

These results indicate that of the source categories evaluated, the greatest annual load of nitrogen to the UFA in the Rainbow Springs BMAP area is from cattle farms (including manure and fertilizer sources), with 29% of the total estimated load to ground water. Septic tanks, crop fertilizer, and horse farms (combined waste and fertilizer load) are also significant nitrogen loading categories. **Figure 12** shows the distribution of estimated annual loads of nitrogen to the UFA by source category.

Aquifer recharge has a significant influence on the loading of nitrogen to the UFA in the BMAP area.

Figure 13 summarizes the estimated nitrogen loads to the recharge categories, including a breakdown of each source category. The majority of the nitrogen loading to ground water in the BMAP area (78%) occurs in high-rate recharge areas. Within each recharge category, the dominant sources of loading are similar: cattle farms, horse farms, septic tanks, and crop fertilizer are the largest contributors of nitrogen loading to ground water, with a higher percentage of crop fertilizer in the medium-recharge rate category.

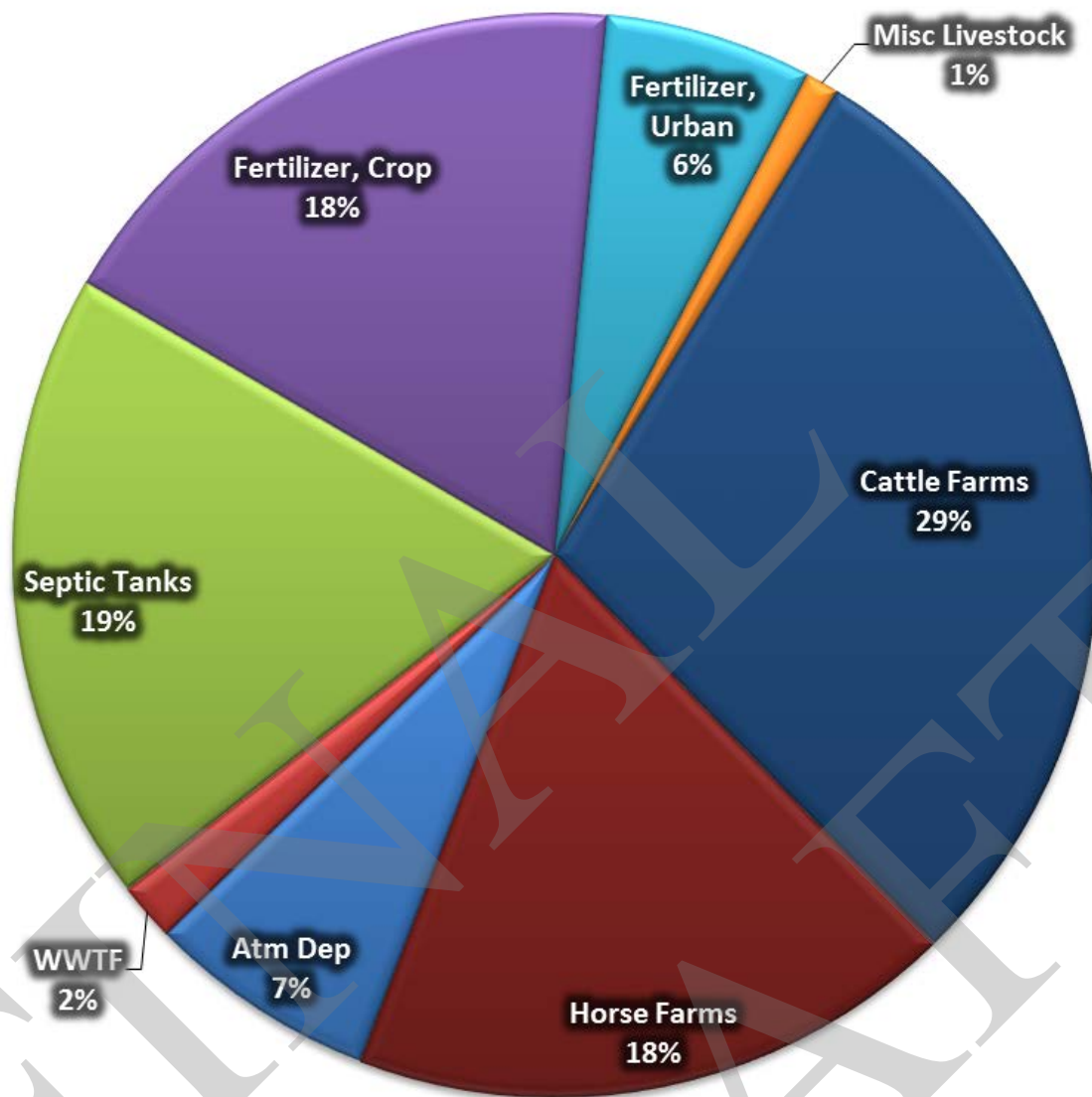


Figure 12: Relative nitrogen contributions based on source category in the Rainbow Springs BMAP area

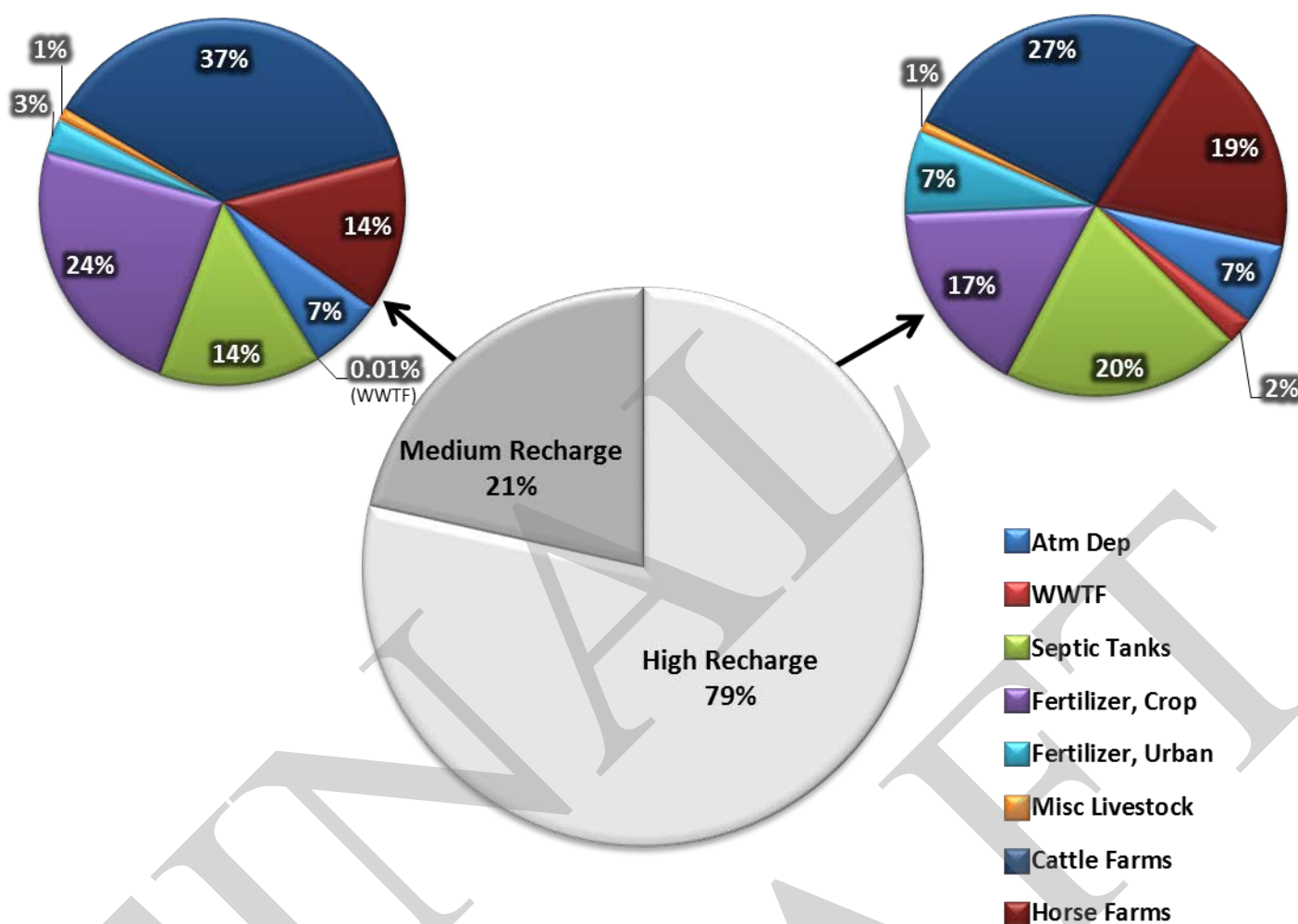


Figure 13: Estimated annual nitrogen loading to ground water by recharge category

3.4 Accounting for Uncertainty in Nitrogen Attenuation Factors in Estimating Loading to Ground Water

The pie charts provided in **Figures 12 and 13** summarize the relative contributions of nitrogen loading to ground water from each source category. If the contribution from one source category were to increase or decrease, the contribution of all other sources would change proportionally. A key variable in this assessment is the environmental attenuation, which was developed for each category based on research studies found in literature searches (**Appendix B**). These attenuation factors reflect the averages of all values found in literature that are representative of conditions in Florida. However, depending on the source category, the range in nitrogen attenuation values from the various references could be rather broad. This is understandable, considering variability between research study sites in soil properties, crop types, agricultural practices, nitrogen storage, volatilization of ammonia to the atmosphere, uptake by vegetation, denitrification, and other removal processes.

Given the relatively broad range in nitrogen attenuation for some of the sources (particularly agricultural sources), the Department opted to use average attenuation factors that were estimated based on land use practices and hydrogeological conditions most representative of the Rainbow Springs BMAP area. Greater emphasis was placed on information about nitrogen attenuation from studies in central Florida, other locations in Florida, or areas with very similar soil and vegetation characteristics. **Table 18** lists the range in nitrogen attenuation for each source, and **Appendix B** contains a list of all references used for developing estimates of attenuation from agricultural sources.

Table 18: Range of environmental attenuation of nitrogen from a detailed literature review

N Source Category	Low-Level Attenuation	Attenuation Used for This Study	High-Level Attenuation
Atmospheric Deposition	85%	90%	95%
WWTFs	50%	60%	70%
Septic Tanks	30%	40%	50%
Livestock Operations	80%	90%	95%
Crop Fertilizers	40%	70%	85%
Urban Fertilizers	40%	80%	85%

Using the range of nitrogen attenuation factors in **Table 18**, the Department estimated the corresponding range of nitrogen loading to ground water from each source in the BMAP area (**Figure 14**). Even with the higher levels of nitrogen attenuation for each source in the BMAP area, the total estimated nitrogen load to ground water would exceed the target load estimated for the Rainbow Springs TMDL. Based on a 550 cubic feet per second (cfs) discharge from Rainbow Springs (based on 2014 data), and the adopted TMDL of 0.35 mg/L, one could estimate the TMDL for nitrogen from Rainbow Springs to be 171,746 kg-N/yr. Using the highest nitrogen attenuation factors, the total estimated load to ground water in the BMAP area is 351,189 kg-N/yr. This nitrogen load is still considerably higher than the TMDL target for the springs and indicates that substantial reductions in nitrogen loads must be achieved to reach the TMDL target for Rainbow Springs and the Rainbow River (**Figure 15**).

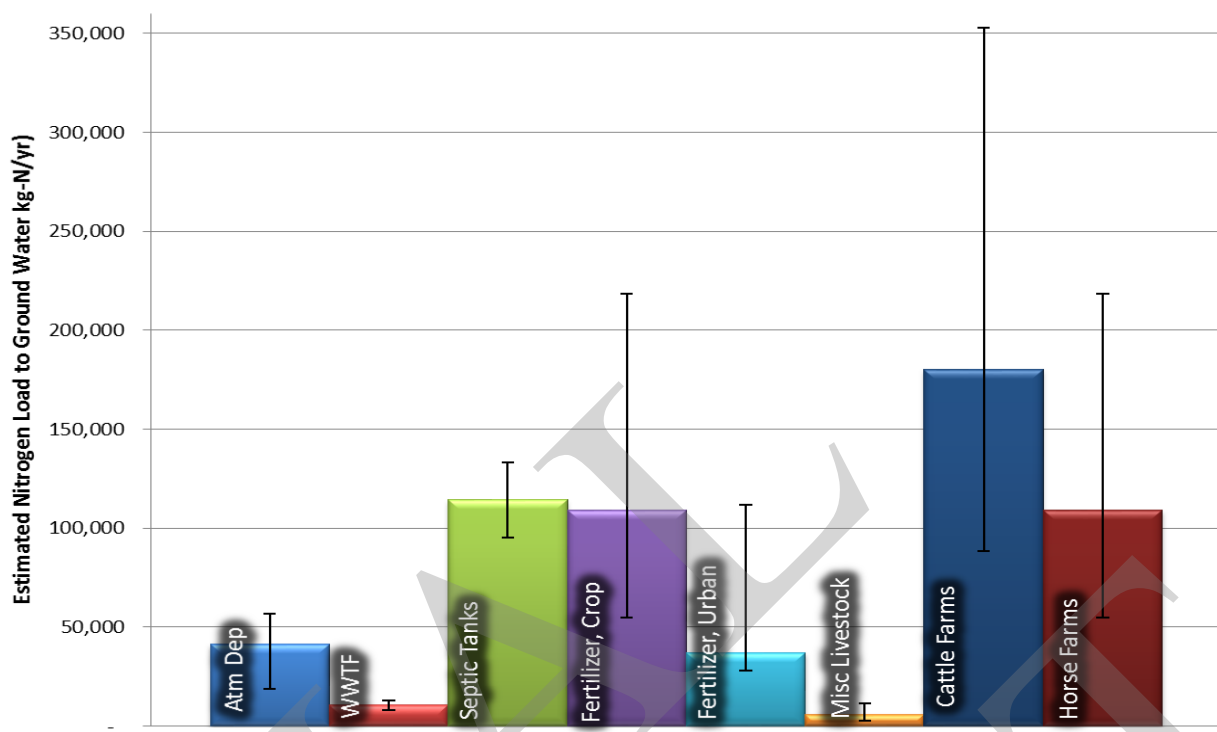


Figure 14: Influence of the range of attenuation factors on estimated nitrogen loads to ground water from each source category in the Rainbow Springs BMAP area

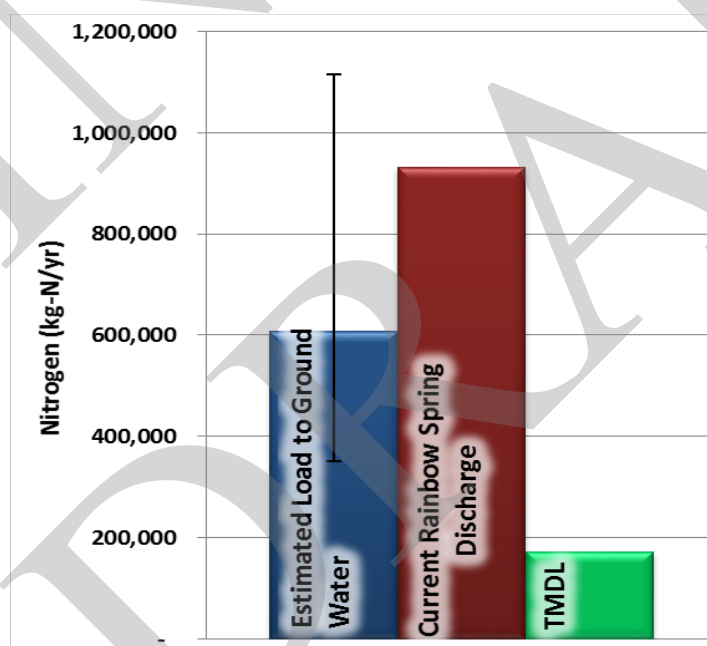


Figure 15: Influence of the range of attenuation factors on estimated nitrogen load to ground water

5. SELECTED REFERENCES

- Angima, S.D., R.L. Kallenbach, and W.W. Riggs. 2009. Optimizing hay yield under lower nitrogen rates for selected warm-season forages. *Journal of Integrative Biosciences* 7(1):1–6.
- Barton, L., and T.D. Colmer. 2006. Irrigation and fertilizer strategies for minimizing nitrogen leaching from turfgrass. *Agricultural Water Management* 80: 160–175.
- Berry, N.R., P.L. Jewell, F. Sutter, P.J. Edwards, and M. Kreuzer. 2002. Selection, intake and excretion of nutrient by Scottish Highland suckler beef cows and calves, and Brown Swiss dairy cows in contrasting Alpine grazing systems. *Journal of Agricultural Sciences* 139: 437–453.
- Bohlke, J.K. 2002. Groundwater recharge and agricultural contamination. *Hydrogeology Journal* 10: 153–179.
- Burns, J.C., M.G. Waggoner, 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*. United States Geological Survey Professional Paper 1403-C.
- Carpenter-Boggs, L., J.L. Pikul, M.F. Vigil, and W.E. Riedell. 2000. Soil nitrogen mineralization influenced by crop rotation and nitrogen fertilization. *Soil Science Society of America Journal* 64: 2038–2045.
- 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.
- 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*. United States Geological Survey Water-Resources Investigations Report 95-4296.
- 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.
- Dyer, Riddle, Mills, and Precourt, Inc. 1984. *Ocala storm water management plan*.
- Eller and Katz 2014. *Nitrogen Source Inventory and Loading Estimates for the Silver Springs BMAP Contributing Area*. 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.
- Estermann, B.L., F. Sutter, P.O. Schlegel, D. Erdin, H.R. Wettstein, and M. Kreuzer. 2002. Effect of calf age and dam breed on intake, energy expenditure, and excretion of nitrogen, phosphorus, and methane of beef cows with calves. *Journal of Animal Science* 80: 1124–1134.
- Estermann, B.L., H.R. Wettstein, F. Sutter, D. Erdin, and M. Kreuzer. 2003. Effect of calving period on herbage intake and nutrient turnover of Simmental and Angus suckler cows with Angus sired calves grazing subalpine and alpine pastures. *Livestock Production Science* 79: 169–182.

Faulkner, G.L. 1970. *Geohydrology of the Cross-Florida Barge Canal with special reference to the Ocala vicinity*. United States Geological Survey Water-Resources Investigations Report I-73.

Florida Department of Agriculture and Consumer Services. Accessed 2014. *Summary by county*.

Bureau of Compliance Monitoring Fertilizer Section. Available:

<http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Agriculture-Industry/Fertilizer-Manufacturers/Fertilizer-Consumption-Tonnage-Data>.

———. Accessed 2014. *Nutrients by county*. Bureau of Compliance Monitoring Fertilizer Section.

Available: <http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Environmental-Services/Agriculture-Industry/Fertilizer-Manufacturers/Fertilizer-Consumption-Tonnage-Data>.

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.

Gronberg, J.A.M., and N.E. Spahr. 2012. *County-level estimates of nitrogen and phosphorus from commercial fertilizer for the conterminous United States, 1987–2006*. United States Geological Survey Scientific Investigations Report 2012-5207.

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.

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. 2000a. Management of nutrients in vegetable production systems in Florida. *Proceedings Soil and Crop Science Society of Florida* 59:11–13.

———. 2000b. *Nitrogen management practices for vegetable production in Florida*. Circular 1222. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.

- Hochmuth, G.J., and Hanlon, E.A. 2000a. *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.
- Holland, K., and Hicks, R. January 15, 2013. *Nutrient TMDL for Rainbow Springs Group and Rainbow Springs Group Run (WBIDs 1320A and 1320B)*. Final report. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Ground Water Management Section.
- 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.
- Hubbard, R.K., and R.R. Lowrance. 2002. Chapter 5: Management of dairy cattle manure. In: R.J. Wright, W.D. Kemper, P.D. Millner, J.F. Power, and R.F. Korcak (Eds.), *Agricultural uses of municipal, animal, and industrial byproducts* (United States Department of Agriculture, Agricultural Research Service, Conservation Research Report No. 44).
- Jones, G.W., S.B. Upchurch, and K.M. Champion. 1996. *Origin of nitrate in ground water discharging from Rainbow Springs*. Southwest Florida Water Management District, Ambient Ground-Water Quality Monitoring Program.
- Katz, B.G. 1992. *Hydrochemistry of the upper Floridan aquifer, Florida*. United States 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. Mokray. 1999. *Sources and chronology of nitrate contamination in spring waters, Suwannee River Basin, Florida*. United States 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.
- Katz, B.G., H.S. Harden, E. Wade, R. W. Hicks, and J. Chanton. 2010. Fate of effluent-borne contaminants beneath septic tank drainfields overlying a karst aquifer. *Journal of Environmental Quality* 39:1181-1195.
- Kesner, B.T., and V. Meentemeyer. 1989. A regional analysis of total nitrogen in an agricultural landscape. *Landscape Ecology* 2(3): 151–163.
- Knowles, L. 1996. *Estimation of evapotranspiration in the Rainbow Springs and Silver Springs basins in north-central Florida*. United States Geological Survey Water-Resources Investigations Report 96-4024.
- Liao, L., Green, C.T., Bekins, B.A., Bohlke, J.K. 2012. Factors controlling nitrate fluxes in groundwater in agricultural areas. *Water Resources Research* 48, W00L09 doi:10.1029/2011WR011008.
- 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.
- Mattos, D., Jr., A.K. Alva, S. Paramasivam, and D.A. Graetz. 2003. Nitrogen volatilization and mineralization in a sandy entisol of Florida under citrus. *Communications in Soil Science and Plant Analysis* 34(13-14): 1803–1824.
- 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.

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.

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*. United States Geological Survey Scientific Investigations Report 2006-5012.

Scanlon, B.R., Healy, R.W., Cook, P.G. 2002. Choosing appropriate techniques for quantifying groundwater recharge. *Hydrogeology Journal* 10:18-39.

- Sebilo, M., B. Mayer, B. Nicolardot, G. Pinay, and A. Mariotti. 2013. Long-term fate of nitrate fertilizer in agricultural soils. *Proceedings of the National Academy of Sciences*. Available: www.pnas.org/cgi/doi/10.1073/pnas.1305372110.
- 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.
- Sigua, G.C., C.C. Chase, and K.D. Foulks. 2012. *Managing cow-calf operations: Implication to nitrogen and phosphorus level in surface and ground water*. State of Animal Manure Management and Related Technologies on Water Resources and the Environment, American Society of Agronomy Conference, October 22, 2012, Madison, WI.
- 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.
- Smith, K.A., and J.P. Frost. 2000. Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 1: Cattle and sheep. *Bioresource Technology* 71:173–181.
- 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*. United States Geological Survey Scientific Investigations Report 2012-5241.
- Stout, W.L. 2003. Effect of urine volume on nitrate leaching in the northeast USA. *Nutrient Cycling in Agroecosystems* 67: 197–203.

- Stout, W.L., S.L. Fales, L.D. Muller, R.R. Schnabel, and S.R. Weaver. 2000. Water quality implications of nitrate leaching from intensively grazed pasture swards in the northeast U.S. *Agriculture, Ecosystems, and Environment* 77: 203–210.
- Sumner, S., W. Wade, J. Selph, J. Southwell, and V. Hoge *et al.* 1992. *Fertilization of established bahiagrass pasture in Florida*. Circular 916. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.
- Sutton, A.L., D.D. Jones, B.C. Joern, and D.M. Huber. 2001. *Animal manure as a plant nutrient resource*. Purdue University Cooperative Extension Service ID-101.
- 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.
- United States Census Bureau. 2010. Available: <http://www.census.gov/>.
- United States Department of Agriculture, Agricultural Research Service. *Manure production and characteristics proposal for ASAE D384.1*.
- United States Environmental Protection Agency. 1999. Chapter 5: Livestock manure management. In: *U.S. methane emissions 1990–2020: Inventories, projections, and opportunities for reductions*. EPA 430-R-99-013.
- . 2002. *Onsite wastewater treatment systems manual*. EPA/625/R-00/008. Washington, DC: Office of Water.
- . 2013. Clean Air Status and Trends Network (CASTNET). Available: <http://epa.gov/castnet/javaweb/index.html>.
- University of Massachusetts Extension Service. 2009. *Manure inventory*. CDLE Pub. 08-20.
- Upchurch, S.B., and M.D. Farrell. 2005. *Strategies and recommendations for protecting Silver and Rainbow Springs*. A report to the Marion County Board of County Commissioners by Water Resources Associates in association with SDII Global Corporation.
- 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.

- Volk, G.M., and C.E. Bell. 1945. *Some major factors in the leaching of calcium, potassium, sulfur, and nitrogen from sandy soils: A lysimeter study*. University of Florida Agricultural Research Station Technical Bulletin 416.
- 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., Butcher, A.S., Stuart, M.E., Gooddy, D.C., Bloomfield, J.P. 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., 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.
- 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 BMP 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.
- 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.

APPENDIX A: TABLES

Table A.1: Useful conversion factors

Convert from	To	Multiply by
kilograms	pounds	2.204623
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

Convert from	To	Multiply by
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 land use compiled from the water management district data for agricultural lands

- = Empty cell/no data

Land Use Code	Land Use Description	Marion County	Marion High Recharge	Marion Medium Recharge	Levy County	Levy High Recharge	Levy Medium Recharge
2100	Cropland and Pastureland	22,517	16,256	3,498	15,730	5,298	5,807
2110	Improved Pastures	23,263	2,324	1,905	10,377	133	1,609
2120	Unimproved pastures	1,537	130	62	75	-	11
2130	Woodland pastures	3,593	402	525	527	33	58
2300	Feeding operations	-	-	-	80	53	-
2310	Cattle feeding operations	28	-	-	35	-	26
2320	Poultry feeding operations	26	-	-	-	-	-
2500	Specialty farms	12,076	9,811	2,101	2,574	994	1,353
2510	Horse farms	15,785	3,062	885	211	-	0
2520	Dairies	47	-	-	68	-	8
2140	Row crops	935	328	438	3,849	2,368	1,310
2143	Potatoes and cabbage	4	1	3	-	-	-
2150	Field crops	7,848	552	238	1,333	-	99
2153	Hay Fields	-	-	-	9,953	177	-
2160	Mixed crop	296	1	-	7	-	7
2200	Tree crops	57	1	1	15	10	5
2210	Citrus groves	709	-	-	-	-	-
2230	Other Groves	-	-	-	18	-	-
2240	Abandoned tree crops	24	-	-	-	-	-
2400	Nurseries and vineyards	294	132	152	292	70	218
2410	Tree nurseries	228	41	-	674	-	-
2420	Sod farms	510	-	-	-	-	-
2430	Ornamentals	192	3	4	6	-	-

Table A.3: Summary of land use compiled from the water management district data for urban lands

- = Empty cell/no data

Recharge Category	Low-Density Residential	Medium-Density Residential	High-Density Residential	Recreational	Golf Courses
Marion County	43,056	16,506	2,747	176	1,923
Marion High Recharge	14,320	3,552	748	134	852
Marion Medium Recharge	2,861	5	6	-	21
Levy County	19,203	1,253	75	156	109
Levy High Recharge	4,837	319	14	69	59
Levy Medium Recharge	5,938	95	7	9	-

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

* Only property codes with land inside the Rainbow Springs BMAP boundary are listed

- = Empty cell/no data

Property Code*	Description	High-Recharge Area	Medium-Recharge Area
51	Cropland Class 1	1,078	252
52	Cropland Class 2	646	138
53	Cropland Class 3	3,822	445
60	Grazing Class 1	87	-
61	Grazing Class 2	135	34
62	Grazing Class 3	14,776	6,422
63	Grazing Class 4	15,585	3,595
64	Grazing Class 5	5,206	1,314
65	Grazing Class 6	1,205	132
66	Citrus grove, orchard	2	-
67	Bees, fish, rabbits, etc	19	3
69	Ornamentals, miscellaneous agricultural	146	146

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

* Only property codes with land inside the Rainbow Springs BMAP boundary are listed

- = Empty cell/no data

Property Code*	Description	High-Recharge Area	Medium-Recharge Area
5100	Cropland soil capability Class I	1,280	1,089
5200	Cropland soil capability Class II	1,272	4,002
6000	Grazing land soil capability Class I	3,886	6,090
6100	Grazing land soil capability Class II	2,263	7,378
6600	Orchard groves, citrus, etc.	-	12
6700	Poultry, bees, tropical fish, rabbits, etc.	8	-
6900	Ornamentals, miscellaneous agricultural	201	357

Table A.6: NADP data from wet deposition monitoring station FL03 Bradford Forest

+ Data excluded from average calculations because of missing data

- = Empty cell/no data

Year	Missing Months	NH ₄ (kg-NH ₄ /ha)	NH ₄ (kg-N/ha)	NO ₃ (kg-NO ₃ /ha)	NO ₃ (kg-N/ha)	Precipitation (cm)
2002	-	1.48	1.15	11.26	2.54	125.30
2003	-	1.49	1.16	11.27	2.55	149.13
2004	-	1.18	0.92	8.54	1.93	146.27
2005	-	1.38	1.07	9.60	2.17	153.29
2006	-	0.84	0.65	4.99	1.13	86.84
2007	-	0.73	0.57	5.11	1.15	85.99
2008	-	0.70	0.54	6.94	1.57	119.38
2009	-	1.46	1.13	7.20	1.63	133.87
2010	-	0.83	0.64	5.25	1.19	93.76
2011	6	0.85+	0.66+	2.83+	0.64+	44.04+
2012	4	0.88+	0.68+	5.14+	1.16+	124.40+

Table A.7: NADP data from wet deposition monitoring station FL05 Chassahowitzka

+ Data excluded from average calculations because of missing data

- = Empty cell/no data

Year	Missing Months	NH ₄ (kg-NH ₄ /ha)	NH ₄ (kg-N/ha)	NO ₃ (kg-NO ₃ /ha)	NO ₃ (kg-N/ha)	Precipitation (cm)
2002	-	1.17	0.91	10.89	2.46	137.91
2003	-	1.33	1.03	9.84	2.22	145.85
2004	-	1	0.78	9.21	2.08	145.57
2005	-	2.69	2.09	13.26	3.00	171.48
2006	1	0.85+	0.66+	8.81+	1.99+	125.32+
2007	-	0.79	0.61	7.15	1.62	135.6
2008	1	0.82+	0.64+	7.83+	1.77+	132.94+
2009	1	1.02+	0.79+	6.54+	1.48+	114.17+
2010	-	1.55	1.20	8.18	1.85	137.31
2011	-	1.71	1.33	8.26	1.87	149.1
2012	-	1.2	0.93	7.01	1.58	159.66

Table A.8: CASTNET data from dry deposition monitoring station IRL141

§ Contains projected data

- = Empty cell/no data

Year	Missing Months	NH ₄ (kg-NH ₄ /ha)	NH ₄ (kg-N/ha)	NO ₃ (kg-NO ₃ /ha)	NO ₃ (kg-N/ha)
2002	-	0.268	0.117	0.584	0.108
2003	-	0.263	0.115	0.605	0.111
2004	2	0.305§	0.133§	0.639§	0.118§
2005	-	0.300	0.131	0.619	0.114
2006	-	0.302	0.132	0.626	0.115
2007	-	0.332	0.145	0.659	0.122
2008	-	0.254	0.111	0.606	0.112
2009	-	0.239	0.104	0.500	0.092
2010	-	0.264	0.116	0.540	0.100
2011	-	0.231	0.101	0.487	0.090
2012	-	0.206	0.090	0.467	0.086
2013	-	0.184	0.080	0.405	0.075

Table A.9: WAFR data used to calculate annual average input for WWTFs* TN data estimated based on available NO₃ data

+ Effluent data not available; average TN value from Department study used

§ Discharge data not available; 50% of design capacity used

- = Empty cell/no data

WWTF Name	Facility ID	County	Recharge Area	Annual Average TN (mg-N/L)	Annual Average NO ₃ (mg-N/L)	Annual Flow (MGD)	N Input (kg-N/yr)
City of Ocala WRF #3	FLA190268	Marion	High	4.43	2.39	2.15	13,117
Oak Run	FLA012697	Marion	High	3.92	3.72	0.62	3,349
On Top of the World	FLA012683	Marion	High	16.06*	6.19	0.18	4,018
City of Williston	FLA012612	Levy	High	9.49*	3.66	0.20	2,571
City Of Dunnellon	FLA126594	Marion	High	4.39	1.28	0.15	904
Rainbow Springs Fifth Replat	FLA012693	Marion	High	3.40*	1.31	0.14	638
Marion Landing	FLA012699	Marion	High	14.71*	5.66	0.05	915
Juliette Falls WWTF	FLA490415	Marion	High	8.97+	-	0.05§	620
Saddle Oak Club MHC WWTF	FLA012694	Marion	High	2.37	0.91	0.02	75
Fairfield Village Of Ocala	FLA012706	Marion	High	1.22*	0.47	0.02	37
Dogwood Acres MHP	FLA012663	Marion	High	27.82*	10.71	0.01	461
Foxwood Farms MHP	FLA012664	Marion	High	8.97+	-	0.03	322
Sweetwater Oaks MHP	FLA012705	Marion	High	2.89*	1.11	0.01	40
Oak Tree Village and Campground	FLA012676	Marion	High	1.48*	0.57	0.02	38
Classic Oaks Village	FLA012665	Marion	High	15.04*	5.79	0.01	191
Crownwood	FLA012680	Marion	High	1.89*	0.73	0.02	51
Falls Of Ocala MHP	FLA012698	Marion	High	16.57*	6.38	0.01	181
Dunnellon High School	FLA012658	Marion	High	11.43*	4.40	0.004	70
Golden Hills MHP	FLA012696	Marion	High	0.98*	0.38	0.02	30
I-75 FDOT Rest Area	FLA012716	Marion	High	8.97+	-	0.02	278
White Oaks MHP	FLA012677	Marion	High	0.66*	0.25	0.02	16
Rio Vista	FLA012674	Marion	High	6.05*	2.33	0.005	38
Westwood MHP	FLA012685	Marion	High	1.25*	0.48	0.01	16
Centers, Inc.	FLA012708	Marion	High	20.92*	8.05	0.01	260
Howard Johnson Inn	FLA012670	Marion	High	10.53*	4.05	0.01	160
Jasmine Plaza	FLA012703	Marion	High	1.03*	0.40	0.01	12
Ocala RV Camp Resort	FLA012667	Marion	High	14.82*	5.71	0.01	102
Circle Square Shopping Center	FLA012707	Marion	High	17.54*	6.75	0.01	158
Marion County - Northwest Regional	FLA272060	Marion	High	8.97+	-	0.02	229
Rainbow Springs State Campground	FLA012717	Marion	High	8.97+	-	0.004	43
103 rd Street Square Center	FLA012687	Marion	High	5.75*	2.21	0.004	33

WWTF Name	Facility ID	County	Recharge Area	Annual Average TN (mg-N/L)	Annual Average NO ₃ (mg-N/L)	Annual Flow (MGD)	N Input (kg-N/yr)
Crystal Springs MHP	FLA012662	Marion	High	10.69*	4.12	0.001	15
Magnolia Garden Estates	FLA012668	Marion	High	1.56*	0.60	0.01	17
Ocala Jockey Club	FLA012686	Marion	High	5.26*	2.02	0.004	30
Sateke Village	FLA012682	Marion	High	4.18*	1.61	0.01	29
Romeo Elementary School	FLA012657	Marion	High	4.40*	1.70	0.004	22
Reddick RV	FLA012660	Marion	Medium	8.10*	3.12	0.004	44

Table A.10: 2012 CoA livestock populations for miscellaneous livestock waste category

CoA Population	Marion County	Levy County
Broiler Chickens	1,235	476
Layer Chickens	10,441	2,129
Goats	3,538	1,202
Hogs	848	205
Sheep	942	259
Turkey	135	80

APPENDIX B: REFERENCES PERTAINING TO NITROGEN INPUT AND ATTENUATION FOR AGRICULTURAL ACTIVITIES

Legend

† Cow-Calf Loading

§ Pasture/Hay Fertilization

* Manure Distribution

◇ Crop Fertilization

Study Area Located in Florida

- | | | |
|--------------------------------------|---------------------------------|--|
| § Angima <i>et al.</i> 2009 | ◇ Liu <i>et al.</i> 2013 | § Sumner <i>et al.</i> 1992 |
| † Berry <i>et al.</i> 2002 | ◇ Mattos <i>et al.</i> 2003 | † Sutton <i>et al.</i> 2001 |
| §◇ Bohlke 2002 | ◇ McNeal <i>et al.</i> 1995 | † University of Massachusetts Extension 2009 |
| § Burns <i>et al.</i> 2009 | § Newton <i>et al.</i> 1995 | † <u>USDA Agricultural Research Service 2003</u> |
| ◇ Carpenter-Boggs <i>et al.</i> 2000 | § Newton <i>et al.</i> 1999 | † EPA 1999 |
| †§* Dubeux <i>et al.</i> 2007 | †§* Obour <i>et al.</i> 2010 | ◇ Volk and Bell 1945 |
| †§* Dubeux <i>et al.</i> 2009 | ◇ Sebilo <i>et al.</i> 2013 | ◇ Wang and Alva 1996 |
| † Esterman <i>et al.</i> 2002 | †§* Sigua <i>et al.</i> 2010 | §* White-Leech <i>et al.</i> 2013a |
| † Estermann <i>et al.</i> 2003 | †§* Sigua 2010 | §* White-Leech <i>et al.</i> 2013b |
| *◇ Goolsby <i>et al.</i> 1999 | †§* Sigua <i>et al.</i> 2012 | § Woodard and Sollenberger 2011 |
| ◇ He <i>et al.</i> 2011 | †§* Silveira <i>et al.</i> 2007 | § Woodard <i>et al.</i> 2006 |
| ◇ Hochmuth 2000a | †§* Silveira <i>et al.</i> 2011 | |
| ◇ Hochmuth 2000b | ◇ Simonne <i>et al.</i> 2006 | |
| ◇ Hochmuth and Hanlon 2000a | † Smith and Frost 2000 | |
| ◇ Hochmuth and Hanlon 2000b | †* Stout 2003 | |
| † Hubbard and Lowrance 2002 | †§* Stout <i>et al.</i> 2000 | |
| ◇ Kesner and Meentemeyer 1989 | | |

APPENDIX C: METHODS AND RESULT COMPARISON WITH JONES ET AL. (1996)

During 1993–95, the Ambient Ground-Water Quality Monitoring Program at the SWFWMD conducted a study to determine the sources of increasing nitrate concentrations in Rainbow Springs (Jones *et al.* 1996). The objectives of the SWFWMD study 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 the nitrate loading to ground water in the Rainbow Springs contributing area. This appendix compares the differences in methods and estimated nitrogen inputs between the SWFWMD study and those from the present Department’s NSILT (described in the previous sections). In addition, several factors are listed to account for the differences in nitrogen inputs estimated by the two studies. This comparison provides insights into how the relative contributions of nitrogen may have changed for the various potential nitrogen sources and land uses over the past 20 years.

Study Area

- The NSILT is evaluated for the BMAP area, which encompasses 175,919 ha, including portions of Marion and Levy Counties.
- The Jones *et al.* (1996) study area within Marion County was 90,650 ha (350 square miles).
- The difference between the two study areas is 85,270 ha, which includes mostly agricultural lands. The SWFWMD study area lies mainly within the BMAP area.

Atmospheric Deposition

- NSILT used multiyear data from the nearby NADP and CASTNET monitoring stations for both wet and dry deposition, respectively. An average of 3.04 kg-N/ha for total deposition (wet plus dry) is used for the BMAP area, which results an estimated annual nitrogen input to the land surface of 535,459 kg-N.
- The SWFWMD study (Jones *et al.* 1996) used an average wet deposition concentration of 1.0 mg/L based on nine rainfall samples collected from a station in northwestern Citrus County. Using an annual rainfall of 56 inches, they estimated a total of 1,442 tons of nitrogen in the study area. This equates to 13.45 kg-N/ha and 1,308,160 kg-N over the study area.

- The SWFWMD larger estimate by 772,701 kg-N/yr is related to the higher nitrogen concentrations in rainfall used in their study. Several factors may account for these differences, such the period when rainfall was collected and differences in collection and analytical methods.

Septic Tanks

- NSILT relies on the number of septic tanks estimated by Hall and Clancy (2009) as well as Marion County data. It is estimated that there are an average of 2.41 people per septic tank in Marion County and 2.49 in Levy County. With an annual input of 4.5 kg-N/person, this equals an input of 10.85 kg-N/yr in Marion County and 11.21 kg-N/yr in Levy County. There are an estimated 21,772 septic tanks in the BMAP area with an average density of 0.12 tanks/ha. The total contribution equals 238,901 kg-N/yr.
- The Jones *et al.* (1996) estimation is based on an average of two people per septic tank and an annual input of 25 lb-N/yr or 11.3 kg-N/yr. They estimated approximately 5,000 septic tanks, which equates to 0.06 tanks/ha. The annual input to the land surface from septic tanks was 57,152 kg-N/yr.
- The main factor in the difference between the calculated nitrogen input values from septic tanks in the two reports is the larger number of septic tanks used by the Department for the study area (a difference of 16,772 septic tanks) and the corresponding nitrogen inputs (a difference of 181,749 kg-N/yr). This can be attributed to the size difference of the study areas and increased urbanization and development in the Rainbow Springs area since the earlier report was released.

Urban Fertilizers

- NSILT relies on county fertilizer sales data assigned to the BMAP study area based on the distribution of urban land uses. These include high-, medium- and low-density residential areas as well as golf courses totaling 33,844 ha. The estimated TN input is 223,874 kg-N/yr.
- Jones *et al.* (1996) separated urban (residential) fertilizers and golf courses into two different categories. For residential fertilizers, the percentage of turfgrass on a home site was estimated based on aerial photography. They estimated 5,000 ac or 2,023 ha of

turfgrass in the study area, and assumed that 60% of the turfgrass was fertilized at an application rate of 2 lb-N/1,000 square feet, which equated to an input of 71,668 kg-N/yr. For golf courses, there was a total of 1,309 acres, of which Jones *et al.* (1996) estimated 916 acres were fertilized at 119 tons/yr or 107,955 kg-N/yr. In total, this is an estimation of 179,623 kg-N/yr.

- The higher NSILT estimate (a difference of 44,251 kg-N/yr) is related to different methods and land areas used by the two studies, as well as an increase in the acreage of urban landscapes since the SWFWMD report was produced.

Wastewater Treatment Facilities

- NSILT used reported effluent data from the 37 permitted facilities in the BMAP area. These have a combined actual flow of 3.97 MGD, with an average nitrogen concentration of 7.99 mg/L. The estimated annual input is 29,128 kg-N. The loadings from domestic wastewater treatment facility residuals and septage were not included in the assessment because of the small areas involved in these practices.
- Jones *et al.* (1996) evaluated WWTFs in three different categories: sewage effluent disposal, land disposal of sewage sludge, and land disposal of septage sludge. For the 47 WWTFs in the contributing area, they used an annual average flow of 1.4 MGD and an average concentration of 8 mg/L. This equated to an annual input of 15,422 kg-N for WWTFs and an additional nitrogen input of 74,389 kg from the additional sludge categories.
- During the past 20 years, there has been a decrease in the number of WWTFs in the area but an increase in the overall flow. A direct comparison of these results from the two studies is difficult because of the differences in methods and categories evaluated.

Row Crops

- NSILT uses property appraiser data, known crops grown in the area, agricultural producer feedback, in addition to UF-IFAS recommended fertilizer application rates, to obtain nitrogen inputs from row crop fertilizers. There are almost 11,000 ha of cropland (mostly watermelons and peanuts) in the BMAP area that contribute 495,738 kg-N/yr.

- Jones *et al.* (1996) estimated row crop acreage from SWFWMD land use maps. This included an estimated 2,800 acres (1,133 ha) comprising 800 acres (324 ha) of watermelons and 2,000 acres (809 ha) of peanuts. Application rates of 120 lb-N/yr for watermelons and 40 lb-N/yr for peanuts were used, resulting in an estimated input of 39,916 kg-N/yr.
- There is a difference of 455,822 kg-N/yr (higher for the BMAP area), which can be attributed to the larger size and higher amount of crop acreage in the BMAP area compared with the SWFWMD study area.

Cattle Waste

- NSILT uses county livestock population data from the 2012 CoA that are assigned to the BMAP area based on the distribution of livestock lands (such as improved pastures). The estimated cow and calf population of 39,642 in the BMAP area contributes 1,604,064 kg-N/yr based on a daily input of 0.153 kg-N for cows and 0.031 kg-N for calves. Calves are also estimated to spend only 183 days of a year within the BMAP boundary before being sold, while cows remain.
- Jones *et al.* (1996) estimated a cattle population of 21,000 in the study area. The daily input factor is approximately 0.15 kg-N/1,000 lb of body weight, which equals a total input of 1,139,424 kg-N/yr.
- The difference of 464,650 kg-N between the two studies is mainly due to the difference in estimated livestock populations over different areas. Additionally, NSILT considers the calf population, which was not included in the Jones *et al.* (1996) study.

Horse Waste

- NSILT used the same method described for cattle farms to estimate the BMAP horse populations. However, only 62% of the BMAP horse population is assumed to contribute nitrogen to the land surface based on waste management practices utilized by horse farmers (based on horse farm survey data collected by the Marion County Extension office). An estimated 15,834 horses contributing nitrogen at a daily rate of 0.124 kg-N generates a nitrogen input of 716,661 kg-N/yr.

- Jones *et al.* (1996) estimated 23,500 horses in the SWFWMD study area with a daily input of 0.16 kg-N/ 1,000 lb of body weight. This equates to a nitrogen input of 1,361,684 kg-N/yr to the land surface.
- This lower amount of nitrogen input from horse waste in the BMAP area (by 645,023 kg-N/yr) results from a smaller contributing horse population (taking into account waste management practices) and differences in daily waste factors.

Pasture Fertilizer

- The NSILT fertilized pasture acreage of 64,549 ha is estimated based on property appraiser data. The application rate varied based on the pasture usage between 0 and 112 kg-N/yr, according to local information. The total estimated nitrogen introduced within the BMAP boundary from pasture fertilizer is 1,498,969 kg-N/yr.
- Jones *et al.* (1996) estimated 79,296 ac (32,090 ha) of pastureland that were fertilized at an average of 100 lb-N/ac (40.5 kg-N/ha). This acreage is based on land use derived by the SWFWMD. They estimated that pasture fertilizers contributed 3,595,173 kg-N/yr input to the land surface.
- The differences in application rates as well as the land areas evaluated result in a higher input (by 2,096,204 kg-N/yr) in the SWFWMD study compared with the NSILT.

Comparison of Total Nitrogen Inputs

The total nitrogen inputs to the land surface estimated by Jones *et al.* (1996) were 7,770,944 kg-N/yr (based on 90,649 ha of land area, this results in an average of 86 kg-N/ha). The three sources that contribute the largest percentages of nitrogen to the land surface are pasture fertilizer (46.2%), cattle and horse farm wastes (32.1%), and rainfall (16.8%).

The NSILT estimates total nitrogen inputs of 5,421,525 kg-N/yr to the land surface (175,919 ha) in the Rainbow Springs BMAP area, which is an average of 31 kg-N/ha (NSILT also includes a miscellaneous livestock category, which was not included in Jones *et al.* [1996]). The three sources that contribute the largest percentages of nitrogen inputs to the land surface are cattle and horse farms (70%), atmospheric deposition (10%), and crop fertilizer (9%). **Table C.1** compares the relative percentages estimated from both methods.

As described above, there were notable differences in methods used to estimate nitrogen inputs to the land surface between the two studies. Furthermore, differences in land area and changes in land use during the past 20 years also have resulted in large differences in the relative contribution of nitrogen from various sources.

Table C.1: Comparison of nitrogen input percentages calculated by NSILT and Jones *et al.* (1996) to the land surface

N Loading Category	NSILT (2014)	Jones <i>et al.</i> (1996)
Atmospheric Deposition	10%	17%
Septic Tanks	4%	1%
WWTFs	1%	1%
Residential Fertilizers	4%	2%
Crop Fertilizers	9%	1%
Livestock Operations	72%	78%

The SWFWMD study (Jones *et al.* 1996) provided an important baseline for comparison with the nitrogen inventory for the Rainbow Springs BMAP. Current information on the nitrogen source inventory and nitrogen loads to ground water generated from NSILT for the Rainbow Springs BMAP will be used to determine where reductions in present-day nitrogen loading to ground water can be made to achieve the restoration of Rainbow Springs and the Rainbow River.