Nitrogen Source Inventory and Loading Estimates for the Kings Bay Springs Basin Management Action Plan Area

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

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

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Summary of Findings

Most of the freshwater inflow to tidal Kings Bay originates from more than 70 springs that discharge water from the karstic Upper Floridan aquifer (UFA). The Kings Bay Springs Group is the fourth largest spring group (by magnitude) in Florida and in 2009 had an average flow of 466 million gallons per day (mgd) (Vanasse Hangen Brustlin [VHB] 2010).

Several of these springs in Kings Bay were identified as impaired because of ecological imbalances attributed to elevated nitrate concentrations in spring water. Previous studies have estimated that approximately 94% of the total nitrogen (TN) entering the bay originates from spring discharge (Jones *et al.* 1998). In 2014, a Total Maximum Daily Load was developed to establish water quality restoration thresholds of 0.28 milligrams per liter (mg/L) of TN for the bay and 0.23 mg/L of nitrate-nitrite nitrogen for the impaired spring vents (Bridger 2014). Elevated nitrate concentrations in the springs are a result of current and historical land use practices that have contributed nitrogen to the UFA system.

The Florida Department of Environmental Protection developed the Nitrogen Source Inventory and Loading Tool (NSILT) to help provide information on the significant sources of nitrogen in the ground water contribution area for the springs of Kings Bay and estimate their loads to ground water in the area covered by the Basin Management Action Plan (referred to as the Kings Bay BMAP area). The NSILT is an ArcGIS- 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 Kings Bay BMAP area. This information is provided as a planning tool for the development and implementation of the Kings Bay BMAP to address the nitrate impairment.

The Kings Bay BMAP utilizes the NSILT to identify source categories and 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 treatment plants.
- Urban fertilizers.

— Septic systems.

— Livestock waste.

— Agricultural 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. The UFA in areas where recharge rates are high is more vulnerable to contamination than in areas where recharge rates are low. In the Kings Bay BMAP area, aquifer recharge falls into three categories: high, medium, and discharge. To account for recharge rates to the UFA, nonattenuated nitrogen inputs in high-recharge areas (greater than 10 inches per year [in/yr]) are multiplied by a weighting factor of 0.9, while nitrogen inputs are multiplied by a weighting factor of 0.5 for medium-recharge areas (4 to 10 in/yr). In areas of discharge there is no recharge, and thus these areas are not evaluated for this analysis.

The NSILT results indicate an estimated total annual load of 830,633 pounds of nitrogen to the UFA in the Kings Bay BMAP area, representing an estimated 21% of the 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 various nitrogen attenuation processes and variations in the rate of recharge to the aquifer. The highest estimated loads of nitrogen in the Kings Bay BMAP area are from septic systems (40%), followed by urban fertilizers (31%) and farm fertilizers (13%). Percentages from the other assessed source categories are as follows: atmospheric deposition (10%), livestock waste (4%), and land application of treated wastewater (3%).

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 in the Kings Bay BMAP area.

1. Introduction

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

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

To help identify and quantify the most significant contributing nitrogen sources to ground water, the Florida Department of Environmental Protection developed the Nitrogen Source Inventory and Loading Tool (NSILT). This tool, as described in this report and based on the current best available data, provides summary information on nitrogen inputs and estimated loads of nitrogen to ground water, as well as information on the relative loads from regions in spring contributing areas based on their ground water recharge rates and the attenuation of nitrogen from various sources. The results of this tool can be used in the development and implementation of the Kings Bay Springs Basin Management Action Plan to help focus on specific areas and nitrogen source categories to achieve the greatest improvement in water quality.

The technical approach in applying this tool involves the following steps:

- Identifying the area to be assessed.
- Characterizing the ground water recharge in that area.
- Identifying specific land uses and categories of land use that are potential nitrogen sources.

— Calculating estimated nitrogen inputs to the land surface from those potential sources.

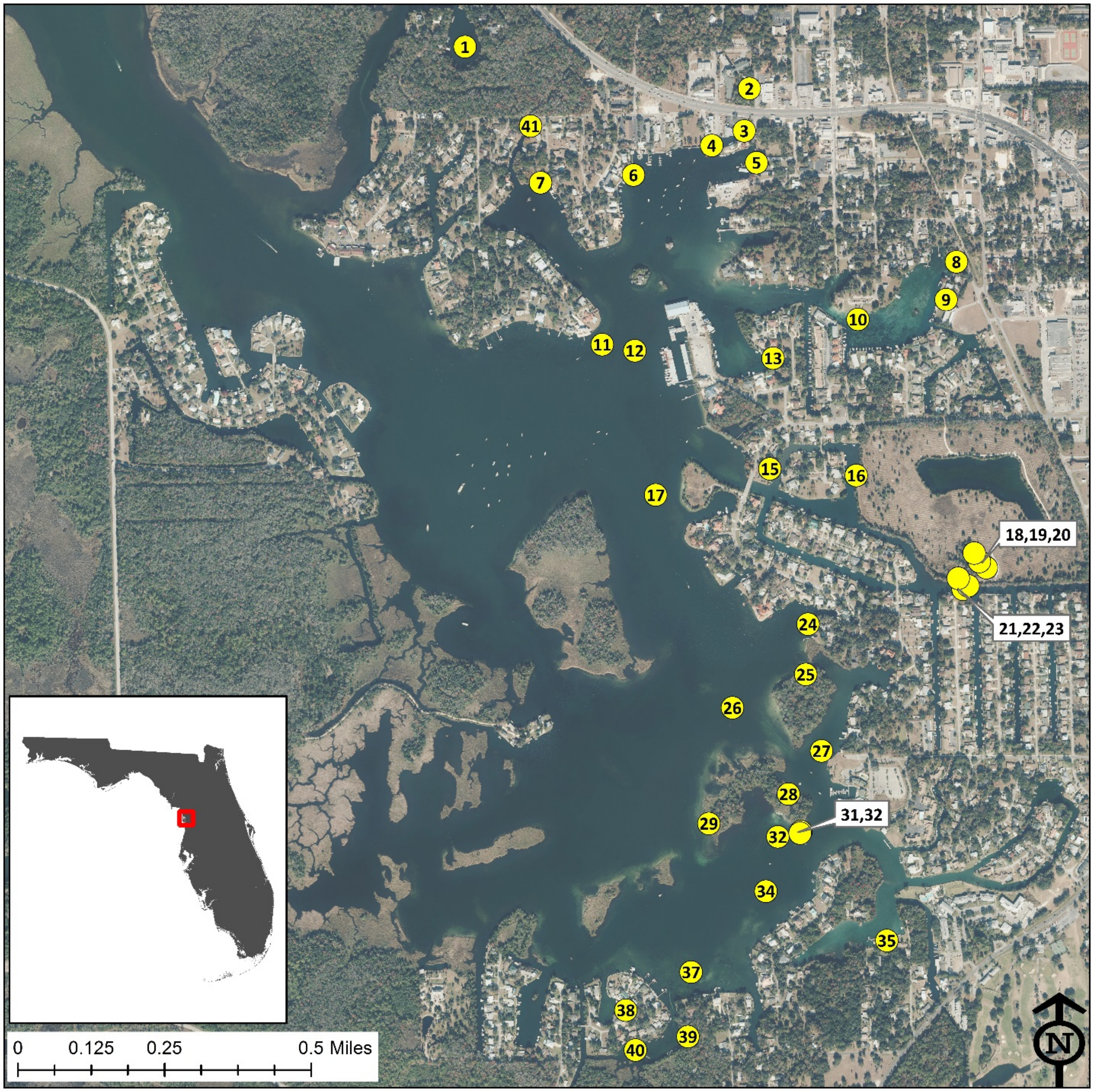
— Finally, calculating estimated nitrogen loads to the aquifer.

1.1 Kings Bay Springs Group

Kings Bay is a spring-fed, tidal bay on the western coast of central Florida. The latest count of springs influencing Kings Bay is in excess of 70, with approximately 37 providing significant and consistent discharge. **Figure 1** provides a map of these major springs, many of which are known by more than one name (see **Table A.2** for aliases) (VHB 2010).

In 2012, Kings Bay was verified as impaired, as were five of the springs that discharge to the bay (Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring) because of ecological imbalances attributed to elevated nitrate concentrations. In 2014, a Total Maximum Daily Load was developed to establish a water quality restoration threshold for nitrate-N of 0.28 milligrams per liter (mg N/L) in the bay and 0.23 mg N/L for the individual springs (Bridger 2014).

Elevated nitrate in the springs is a result of current and historical land use practices that have contributed nitrogen to the UFA, the highly transmissive limestone aquifer that is the source of water flowing from the springs. The NSILT is being used to provide stakeholders with current information on the sources of nitrogen in the Kings Bay contributing area and their relative contributions of nitrogen to the UFA. It provides a planning tool for the development and implementation of the Kings Bay BMAP to address the water quality impairment.



The Springs of Kings Bay							
1	Miller's Creek Spring	11	Magnolia Circle Spring	22	Idiots Delight #2	32	King Spring
2	City Hall Spring	12	Pete's Pier Spring	23	Idiots Delight #3	34	Dave's Quest Springs
3	Charlie's Fish House Spring	13	Moray Spring	24	Parker Island North Spring Complex	35	Golfview
4	Birds Underwater Spring	15	Paradise Isles	25	Parker Island Spring	37	Wynn Court Springs
5	Pool Spring	16	Manatee Sanctuary	26	Banana Island North Spring Complex	38	Black Spring
6	Catfish Spring	17	Buzzard Island Spring	27	FWS Spring Complex	39	Sid's Springs
7	NW 9th Avenue Springs	18	Three Sisters Spring #1	28	Banana Island East Springs	40	Gary's Grotto
8	House Spring	19	Three Sisters Spring #2	29	Banana Island West Springs	41	Hammett 24
9	Jurassic Spring	20	Three Sisters Spring #3	30	Tarpon Hole #2		
10	Hunters Spring	21	Idiots Delight #1	31	Tarpon Hole		

This map was prepared on 09/25/15 by FDEP Ground Water Management Section. For display purposes only. For more information: K.Eller (850)245-8652.

Figure 1: Map of the major springs contributing to Kings Bay (VHB 2010)

1.2 Kings Bay Contributing Area

Kings Bay is located in Citrus County near the city of Crystal River. The BMAP area (**Figure 2**) is largely based on the Kings Bay ground water contributing area or springshed delineated by the Southwest Florida Water Management District (SWFWMD) (Jones *et al.* 1998). It covers 178,753 acres and comprises 45% urban landscapes, 23% forested areas, 17% wetlands and marshes, 8% agriculture, 4% waterbodies, and 3% miscellaneous.

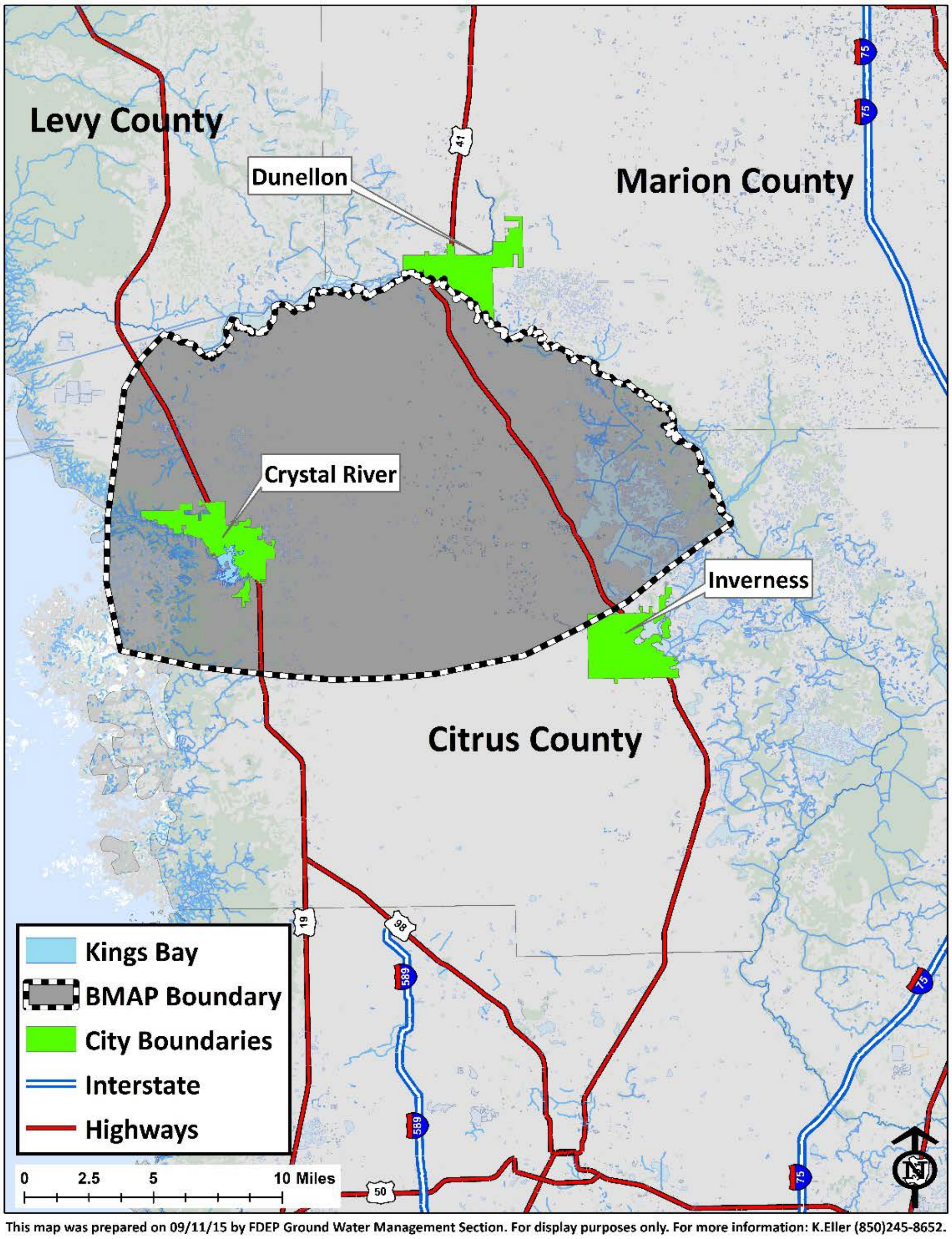


Figure 2: Map of the Kings Bay BMAP contributing area

1.3 Hydrogeology and 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. In the ground water contributing area for Kings Bay, the UFA is the predominant source of ground water discharging from springs to the bay. Water discharging from springs originates predominantly from the upper 100 feet of the UFA (Jones *et al.* 1998; Faulkner 1970).

The dissolution of the carbonate rocks comprising the UFA has created numerous karst features (sinkholes, caves, and conduits) over geologic time in this area. These features, in the absence of confining sedimentary layers, allow water from the land surface to move directly and relatively rapidly into the aquifer. Consequently, the movement of ground water in the UFA responds relatively quickly to changes in rainfall and recharge, and ground water flows directly to springs where conduits are present. Ground water discharging from springs originates from both nearby source areas or from more distant areas in the springshed. As a result, springs represent a mixture of ground water that has resided in the aquifer for different amounts of time, ranging from days to several decades.

The predominant source of ground water in this area is the UFA. In many areas of Florida, a surficial aquifer is present on top of the UFA due to a confining layer; however, these features are largely absent in the Kings Bay BMAP area, where the majority of the recharging water directly enters the UFA system. Jones *et al.* (1998) and Bridger (2014) describe the hydrogeologic framework for this area in greater detail. Recharge rates to the UFA are affected by spatial variations in the hydrogeological characteristics of the surficial aquifer and intermediate confining unit, karst features, and average annual rainfall.

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 (Sepulveda 2002). The model area spans over 40,000 square miles of peninsular Florida and is composed of uniform model grid dimensions of 5,000-foot cells. The USGS raster-based data were smoothed to create three main recharge categories in the Kings Bay Springs BMAP area: discharge or no-recharge; medium recharge (4 to 9.9 inches per year [in/yr]) and high recharge (10 in/yr or greater) (**Figure 3**). The amount of annual recharge affects the transport of nitrogen to the aquifer. Therefore, the department estimates that more nitrogen would reach the aquifer annually in high recharge rate areas than in lower recharge rate areas, given that both areas receive similar nitrogen inputs to the land surface.

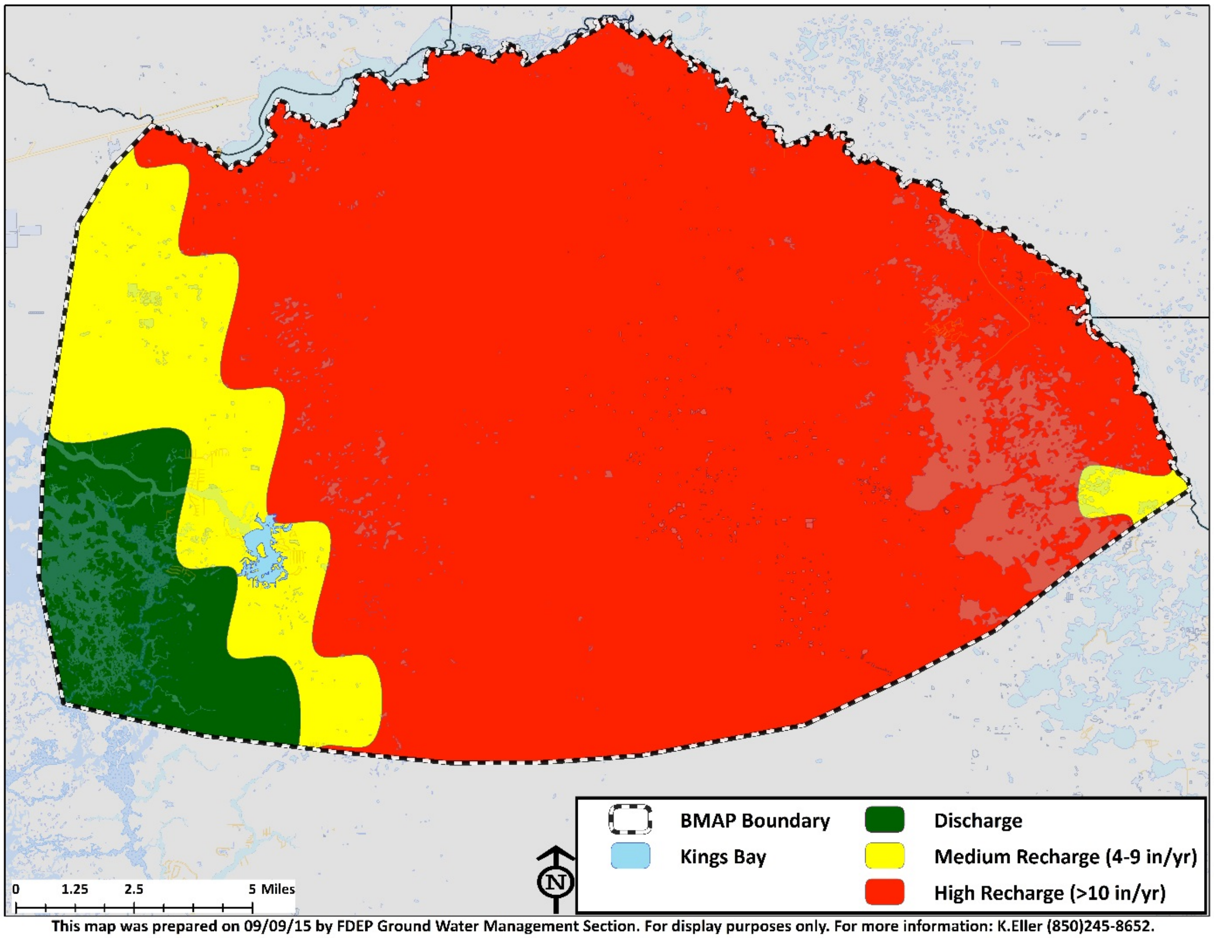


Figure 3: Recharge categories throughout the Kings Bay Springs BMAP area

1.4 Land Use

Land use/land cover (LULC) information can vary depending on the delineation methods. For this assessment, the most recent land use ArcGIS coverages were obtained from the SWFWMD and county property appraisers. The land use maps for the water management districts are generated through the analysis of aerial photographs. The Kings Bay Springs BMAP area lies completely within the SWFWMD boundary. All land use classifications used by the SWFWMD were based on the Florida Land Use/Land Coverage and Forms Classification System (FLUCCS) using the following method. The 2011 land use was created through the interpretation of digital imagery taken in December 2010. The land use classifications were determined through photo interpretation, editing, and quality check processes. **Table A.3** contains details of these data.

Additional land use information was obtained from the Citrus County Property Appraiser's office. Staff from the Property Appraiser's office conduct routine field visits to update and verify the land use classification of parcels for tax purposes. These visits occur at least every five years, although most parcels are visited more frequently. This system allows for continual updates and for 2014 data to be utilized for this analysis (**Table A.4**). For this assessment of current land use, the property appraisers also provided detailed information about specific agricultural practices that was very useful for estimating nitrogen contributions from fertilizer use on farmland. The land use information obtained from property appraisers is designated as "PA" in this report.

2. Estimating Nitrogen Inputs to the Land Surface

Nitrogen inputs to the land surface in the BMAP area were evaluated for atmospheric deposition, wastewater treatment facility (WWTF) land application sites (including reclaimed water), septic systems, urban and agricultural fertilizer application, and livestock waste. The methods used to estimate nitrogen inputs for each source are based on the synthesis of information, including direct water quality measurements, United States Census Bureau data, surveys, farm visits, published scientific studies and reports, and information obtained in meetings with ranchers and growers. In many cases, several assumptions and extrapolations were made for estimating nitrogen inputs from 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 pounds per year [lb-N/yr]) to the land surface for each source category are discussed below.

2.1 Atmospheric Deposition

Atmospheric deposition is largely a diffuse, albeit continual, source of nitrogen. Nitrogen species and other chemical constituents are measured in wet and dry deposition at discrete locations around the United States. In Florida, the Clean Air Status and Trends Network (CASTNET) has two stations that collect and analyze dry deposition. Wet deposition data currently are collected at nine stations around the state as part of the National Atmospheric Deposition Program (NADP) National Trends Network (NTN). Recently, Schwede and Lear (2014) developed a hybrid model for estimating the total atmospheric deposition of nitrogen and sulfur for the entire United States, referred to as TDEP. Deposition data from several monitoring networks—including CASTNET, the NADP Ammonia Monitoring Network, the Southeastern Aerosol Research and Characterization Network, and modeled data from the Community Multi-scale Air Quality Model—are combined in a multi-step process with NTN wet deposition values to model total deposition in 16-kilometer (km) grid cells.

Multiple TDEP model runs are available, providing atmospheric data for individual and multiple years, with average values calculated for the multiyear models. The TDEP model run utilized for the NSILT includes data from 2011 to 2013. These total nitrogen (TN) data are available in a nationwide coverage (.e00) file and were converted into ArcGIS shapefiles for the purpose of this analysis. **Figure 4** illustrates the model results for TN deposition in the Kings Bay Springs BMAP area. The total deposition for high and medium recharge rate areas was calculated using ArcGIS and is 815,247 lb-N/yr and 123,373 lb-N/yr, respectively.

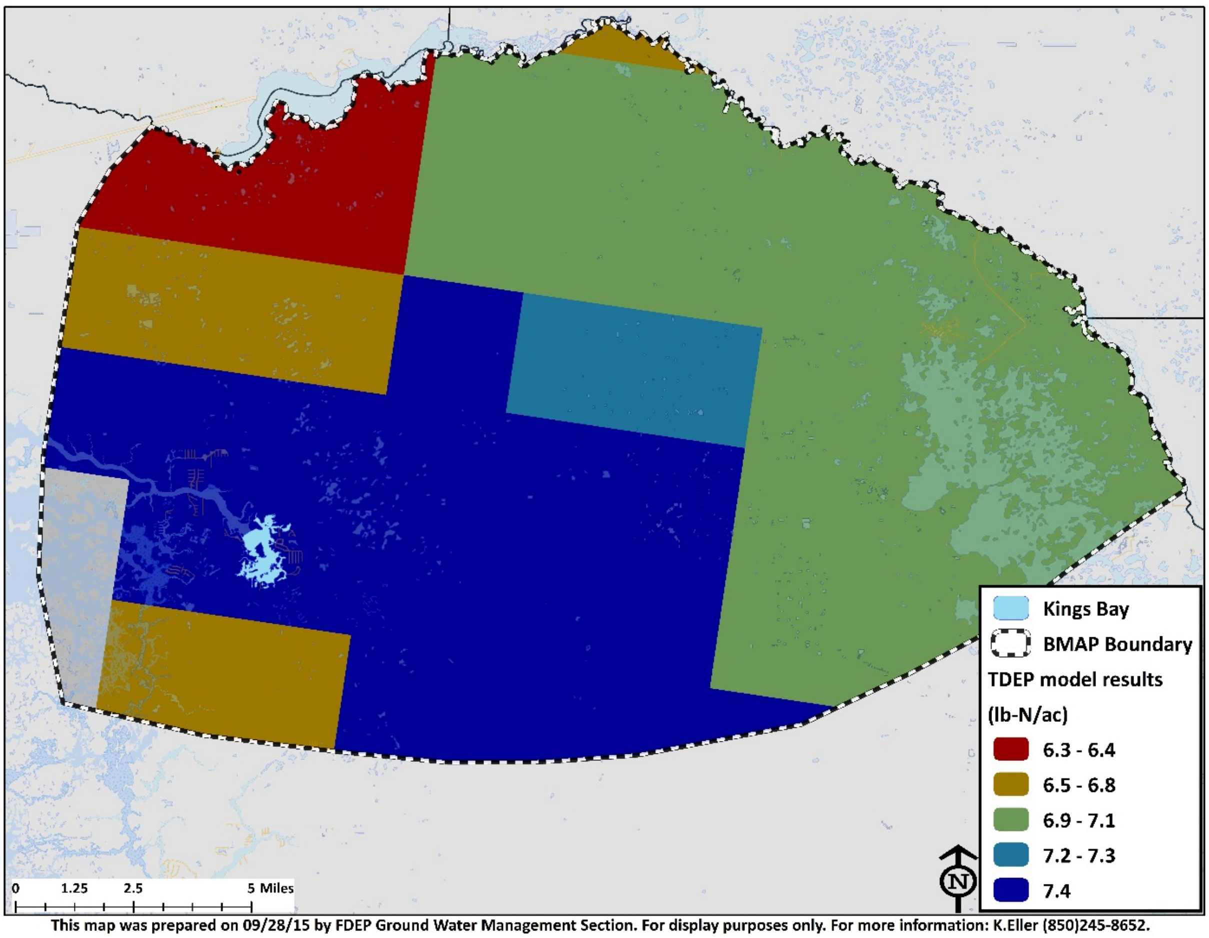


Figure 4: Atmospheric deposition model results used for the NSILT

2.2 Wastewater Treatment Facilities

WWTFs receive and treat domestic wastewater. In the Kings Bay BMAP area, treated effluent containing nitrogen is discharged to sprayfields, rapid infiltration basins (RIBs), and percolation ponds, and is reused for irrigation water. There are 29 WWTFs located in the Kings Bay Springs BMAP area, including five WWTFs discharging more than 100,000 gallons of treated effluent per day (**Figure 5**). Nitrate and TN data were obtained from the department's Wastewater Facility Regulation (WAFR) database and used to calculate average annual input from WWTFs that discharge treated effluent in the BMAP area.

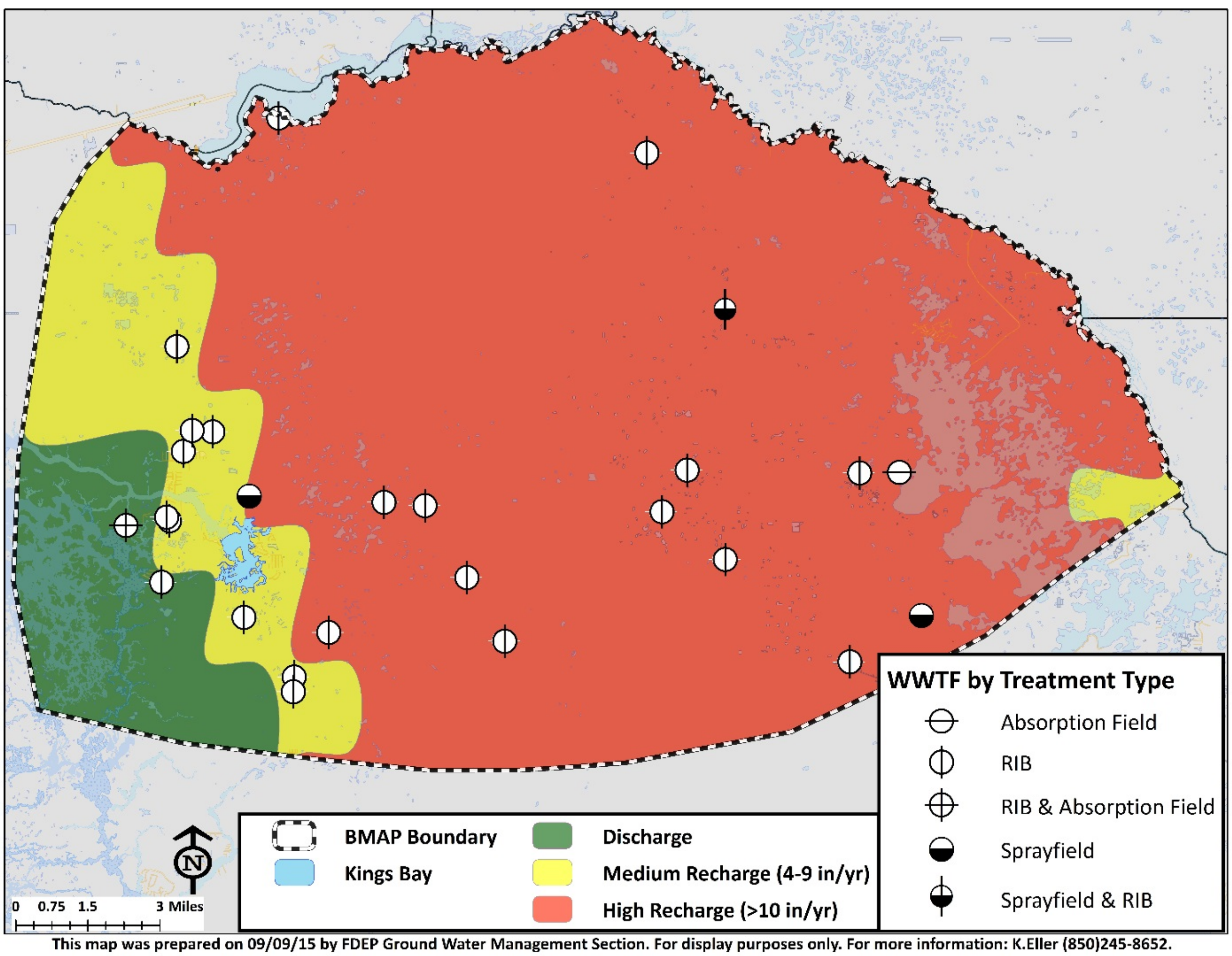


Figure 5: Distribution of WWTFs in the Kings Bay BMAP area

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 (<0.1 million gallons per day [mgd] by volume) are not always required to monitor and report TN effluent concentrations, and therefore not all these facilities had available WAFR data. For these, the department estimated TN concentrations by extrapolating from the NO_3-N data (assuming the NO_3-N concentration was 38.5% of the TN based on a 2009 cooperative study with the Water Reuse Foundation of 40 domestic WWTFs across the state). For this calculation, the NO_3-N value is divided by 0.385, resulting in an estimating TN concentration.

The WWTF data were compiled for each facility and include the most recent complete year of data. The years of data vary with the individual facilities; however, the majority of the data ranges from 2013 to 2014. Most of these facilities discharge all of their treated wastewater to various land application sites; however, some of the larger facilities also provide treated wastewater for reuse through public access systems for irrigation on urban landscapes or agricultural fields. Specifics on the operation of the facilities providing water for reuse were obtained from their permits.

Recent funding from the state Legislature has allowed local governments to design and construct measures to reduce nitrogen discharge and provide reclaimed water for irrigation. These projects may not be reflected in the available WWTF data used in this assessment and will be addressed in future iterations of the model.

2.2.1 Land Application of Treated Wastewater

For facilities permitted for the land application of treated wastewater, the reported annual average flows were used to calculate an average discharge for the evaluated year applied to sprayfields, RIBs, and absorption fields. For the purpose of this analysis, absorption fields are categorized with RIBs because of the similar biological uptake of nitrogen. The nitrogen inputs for each WWTF were calculated using the average annual TN concentration and the average yearly flow from the facility. The average annual nitrogen inputs from wastewater facilities were estimated for each recharge rate category based on the location of the effluent treatment sites in the BMAP area. **Table 1** summarizes the nitrogen input data from the larger facilities in the BMAP area for land application only. Additional data for all WWTFs is included in **Table A.5** in **Appendix A**. In total, an estimated 39,102 lb-N/yr are applied to the land surface from these facilities in the high recharge rate areas, and an additional 2,751 lb-N/yr are applied in the medium recharge rate areas.

Table 1: Summary data for WWTFs contributing more than 500 lb-N annually for land application

* TN data estimated based on available NO_3 data.

WWTF Name	Facility ID	Treatment Type	Recharge Area	Annual Average TN (mg-N/L)	Annual Flow (mgd)	Nitrogen Input (lb-N/yr)
City of Beverly Hills	FLA011869	RIB	High	6.26	0.460	8,782
Meadowcrest	FLA011845	RIB	High	8.64	0.267	7,025
City of Crystal River	FLA011848	Sprayfield	High	3.29	0.674	6,750
Brentwood Regional	FLA011844	RIB	High	4.59	0.330	4,610
Citrus Springs	FLA011877	RIB	High	8.45*	0.085	2,184
Indian Springs	FLA011876	RIB	Medium	8.14*	0.034	854
Crystal Isle	FLA011923	RIB	Medium	13.04*	0.016	633

2.2.2 Public Access Reuse Systems

Within the Kings Bay Springs BMAP boundary, there is currently one facility permitted for reuse distribution to a local golf course. Meadowcrest WWTF (FLA011845) is permitted for 2.0 mgd to be utilized as reuse irrigation water for the Black Diamond Golf Course, which is located in the high recharge rate area. From March 2013 to February 2014, an average of 0.331 mgd of reuse water was applied to the golf course at a TN concentration of 8.64 mg/L, contributing 8,708 lb-N/yr.

2.3 Septic Systems

Onsite sewage treatment and disposal systems (OSTDS), commonly referred to as septic systems, are widely used throughout the Kings Bay Springs BMAP area where municipal sewer is not available. These systems can contribute to elevated nitrogen concentrations in ground water (Chang *et al.* 2010). In 2009, a contractor for the Florida Department of Health (FDOH) developed a statewide model for estimating the number of septic systems based on tax parcel data and known sewer service areas (Hall and Clancy 2009). This model relied on septic system permit data from FDOH, as well as information from public utilities about their sewer collection systems and service areas, to estimate the type of service provided to individual land parcels not accounted for by a permit or sewer connection. For example, an estimated septic system parcel was assumed to be located in an area where sewer service was unlikely. The output of this model was provided in an ArcGIS geodatabase from which the locations of both the known and the estimated septic systems can be mapped.

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

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

- Parcels identified as single-family residential were reduced to only one septic systems per parcel.
- Parcels with three or fewer septic systems and an associated land use likely to contain more than one septic tank (*i.e.*, condominiums, multifamily dwellings, or businesses) were left unchanged.
- All remaining parcels were individually assessed using current aerial imagery to verify or correct the number of septic systems within the parcel boundary.
- Modeled septic systems shown to be within an existing sewer service area were also evaluated, with data provided by Citrus County.

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

After the number of septic systems in the BMAP area was established, the population served by septic systems was estimated using the 2010 United States Census Bureau data on population and household occupancy in each county. The Census makes a distinction between occupied and nonoccupied households. The Citrus County population was divided by the number of occupied households in the county, resulting in the average number of people per occupied household of 2.23. However, many people with a home septic system potentially have access to a sewer system during their weekly routine (*i.e.*, work, school), reducing the nitrogen input to the septic system. In order to estimate the effective people per household, county age population distribution data were obtained from the 2010 Census. In Citrus County, 48.1% of the population is of school or working age and, according to the Bureau of

Labor Statistics, estimated to spend 43.5 hours or 25.9% of their week away from their septic system. This reduces the people per household using septic systems of 2.23 by 12.5%, resulting in an effective rate of people per household of 1.95.

The total population in the BMAP area served by septic systems was estimated by multiplying the estimated people per household by the number of septic systems. Several literature sources have reported a per capita contribution of 9.92 lb-N/year, and this value was applied to the estimated number of people utilizing septic tanks within the different regions of the BMAP area (United States Environmental Protection Agency [EPA] 2002; Roeder 2008; Toor *et al.* 2011; Viers *et al.* 2012). In total, septic systems contribute an estimated input of 52,249 lb-N/yr in medium recharge rate areas and 586,688 lb-N/yr in high recharge rate areas.

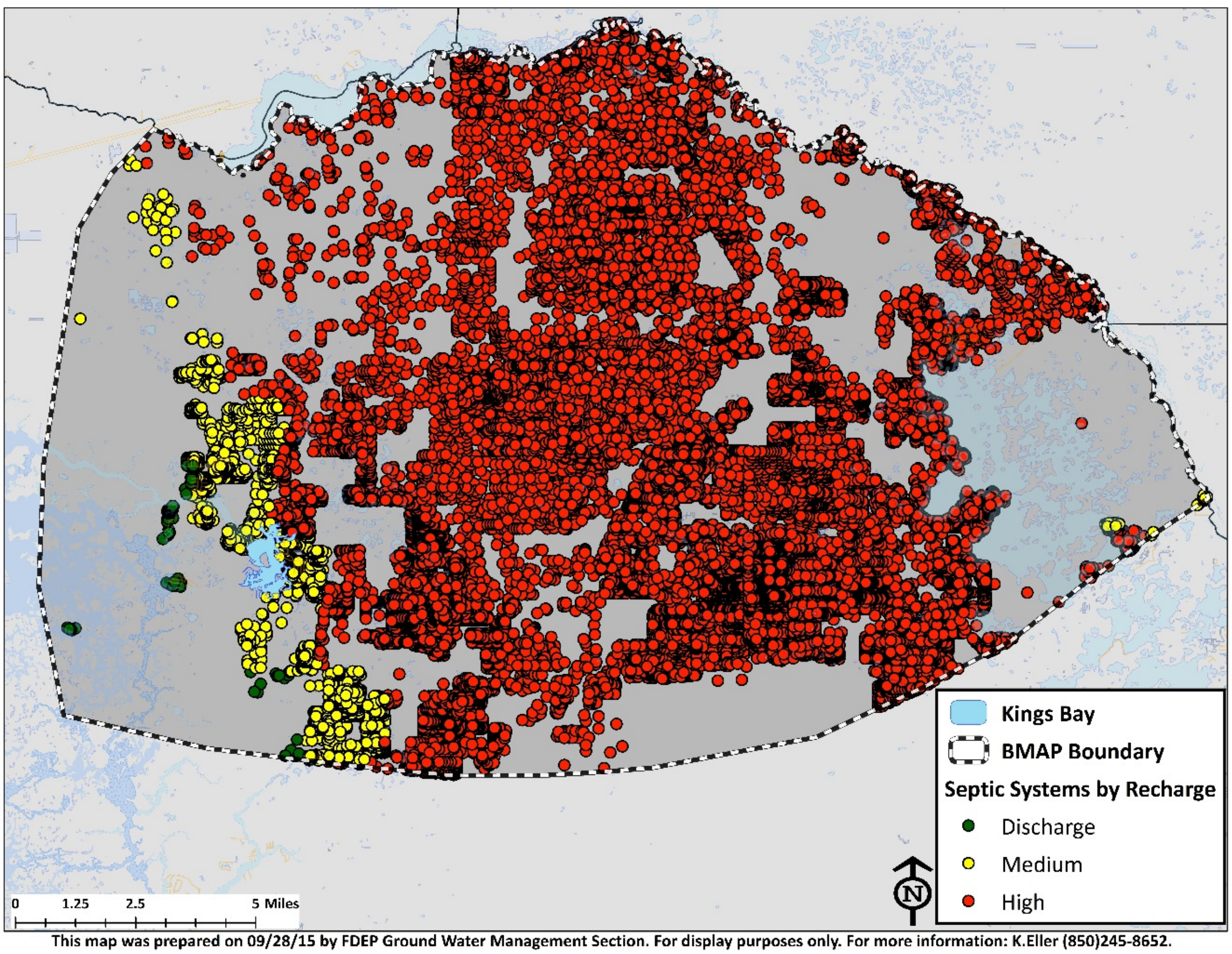


Figure 6: Distribution of septic systems throughout the Kings Bay Springs BMAP area

2.4 Urban Fertilizers

Fertilizers applied to turfgrass typically found in residential and urban areas (including residential lawns, golf courses, and public green spaces) are categorized as urban fertilizers (**Figure 7**). Surveys were used to estimate the nitrogen application rates for three different turf categories: residential, nonresidential, and golf course. For residential parcels, fertilizer is applied by either the homeowner or a hired lawn service company. Based on a telephone survey conducted in Citrus County and southern Marion County for the SWFWMD, 68% of the population manage their own lawn care, fertilizing their lawn about three times a year at rates varying from 0 pounds of nitrogen per acre (lb-N/ac), or no fertilization, to 45.56 lb-N/ac (**Table 2**), while 32% hire a lawn service company that applies 21.78 lb-N/ac, 4.27 times a year (Martin 2008). Fertilizer application rates on nonresidential parcels were assumed to be applied by lawn service companies at the same rate and frequency as residential parcels.

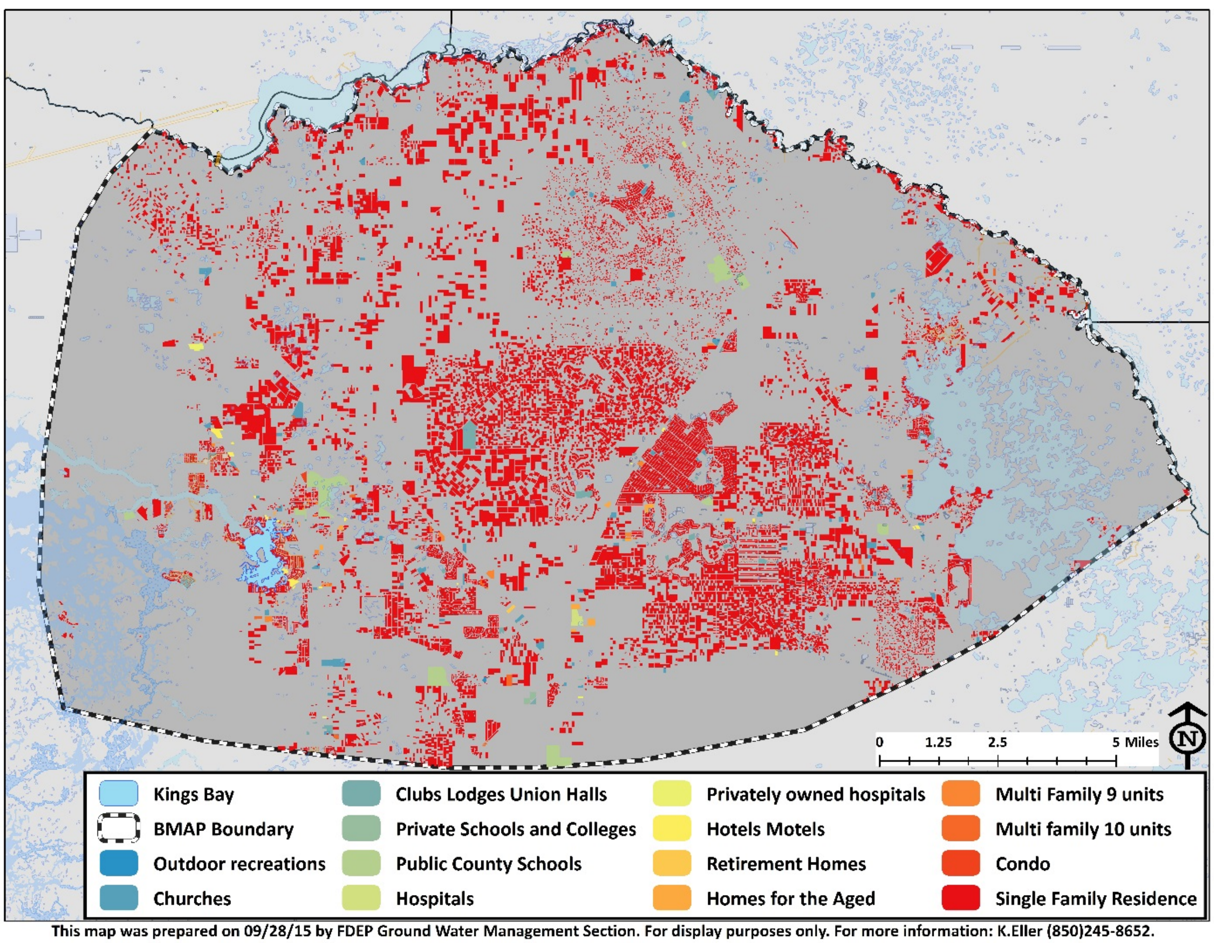


Figure 7: Urban noncommercial lands in the Kings Bay BMAP area according to county property appraiser data

Table 2: Estimated fertilizer application rates based on surveys completed in the Kings Bay area

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

2.4.1 Nonresidential parcels

The acreage of nonresidential parcels to which fertilizer would be applied was estimated prior to calculating the nitrogen inputs from fertilizer applications listed in **Table 2.** Parcel types assessed using the PA data include (but are not limited to) businesses, hotels, and schools. These data were combined with county zoning data provided by the Citrus County Board of County Commissioners, Department of Planning and Development. The zoning attributed with each parcel contains information on the amount of impervious surfaces (*i.e.*, structures, pavement, *etc.*), referred to as the "max lot coverage." For each parcel, the max lot coverage is used to estimate the acreage of impervious and pervious land areas. For this analysis, it is assumed that all pervious acreage is fertilized by lawn service companies at the above listed rate and frequency. Details of the PA data and max lot coverages can be found in **Appendix A**, **Table A.4** and **Table A.5**, respectively. **Table 3** summarizes these data.

Table 3: Summary of the urban fertilizers attributed to nonresidential parcels

Parcel Type	Medium Recharge Fertilizable Land Area (acres)	High Recharge Fertilizable Land Area (acres)	Total Input (lb-N/yr)
Clubs/Lodges/Union Halls	12.03	125.84	12,822
Public County Schools		191.59	17,818
Churches	54.41	184.36	22,206
Hotels/Motels	15.79	5.74	2,002
Private Schools and Colleges	0.13	9.37	884
Hospitals		13.49	1,255
Outdoor Recreation	1.86	7.05	829
TOTAL	**84**	**537**	**57,815**

2.4.2 Residential Parcels

For residential parcels such as single and multifamily homes, the acreage receiving fertilizer applications is estimated in the same manner as nonresidential parcels. Prior to applying the fertilizer application rates to the pervious land area, one other factor is taken into account: the probability that a homeowner will fertilize the lawn. Based on socioeconomic studies, property value can be used as an indicator of landscape fertilization in a residential setting (Kinzig *et al.* 2005; Law *et al.* 2004; Zhou *et al.* 2008; Cook *et al*. 2012). The range of property values for single-family homes was evaluated for the Kings Bay BMAP area and subdivided into three categories based on property value: high, medium, and low. **Table 4** lists the estimated probability of fertilization for each property value category.

Table 4: Distribution of property values and the probability of fertilization for the Kings Bay BMAP area

Property Value Label	Property Value	Probability of Fertilization
High	> $150,000	90%
Medium	$50,000-$150,000	75%
Low	< $50,000	10%

The probability of fertilization percentage represents the probability that a homeowner will fertilize some or all of a property in a given year. These percentages were assigned based on socioeconomic studies of lawn care trends in urban environments (Kinzig *et al.* 2005; Grove *et al.* 2006; Carey *et al.* 2012). These factors are applied to the pervious acreage of residential properties to estimate the land area presumed to be fertilized. The land area potentially receiving fertilizer is multiplied by the application rate and frequency listed in **Table 2** to obtain the total input of nitrogen to the land surface from residential parcels. **Table 5** summarizes these data.

Table 5: Summary of urban fertilizer data attributed to residential parcels

- = Empty cell/no data

Parcel Type	Medium Recharge Fertilizable Land Area (acres)	High Recharge Fertilizable Land Area (acres)	Total Input (lb-N/yr)
Condo	4	10	1,295
Homes for the Aged	4	46	4,581
Multifamily 10 units	16	55	6,478
Multifamily 9 units	12	29	3,727
Retirement Homes	-	3	245
Single-Family Residence	856	12,695	1,236,023
Vacant Single-Family Residence	283	3,401	-
TOTAL	**1,175**	**16,240**	**1,252,349**

2.4.3 Golf Courses

Golf courses in the BMAP area are also potential sources of nitrogen from fertilizer application and were assessed based on specific feedback from course managers and superintendents. In a survey distributed by the department to golf course superintendents in central Florida, 44% provided detailed information about their fertilizer use (see **Appendix B** for the survey). The results indicate that the golf courses with information apply nitrogen fertilizer at an average rate of 43.0 lb-N/ac/yr. For the remaining 56% of the golf courses, a statewide annual average application rate that was vetted by golf course professionals of 141.1 lb-N/ac/yr (or 72% of course area at 4.5 lb-N/1,000 ft^2) was used (Sartain 2002; Department 2007) . In total, all golf courses in the BMAP area contribute an estimated 188,589 lb-N/yr to the land surface. **Table 6** summarizes the input to the land surface from each golf course in the BMAP area.

Table 6: Summary of urban fertilizer input attributed to golf courses

† = Facility receives reuse water in addition to applied fertilizer

* = Received response to survey

Golf Course	Medium-Recharge Fertilizable Land Area (acres)	High-Recharge Fertilizable Land Area (acres)	Average Application Rate (lb-N/ac)	Total Input (lb-N/yr)
Black Diamond†*		544	2.1	1,130
Citrus Hills		284	141.1	40,077
Citrus Springs		241	141.1	33,942
Lakeside*		185	13.4	2,483
Pine Ridge*		222	141.1	31,318
Seven Rivers*		163	25.8	4,204
Skyview		203	141.1	28,594
Twisted Oaks		134	141.1	18,931
Plantation Inn	198		141.1	27,911

2.5 Livestock Waste

Livestock operations are a minor land use in the Kings Bay BMAP area, with most of the land dedicated to cow-calf operations. Agricultural practices specific to this area were obtained through meetings with agricultural producers and stakeholders. Typical cattle stocking rates in Citrus County are estimated as one cow per six to eight acres of pasture (Public stakeholder discussion, Lecanto, Florida, July 2014). The pasture acreage is estimated using property appraiser data and includes improved, semi-improved, and native pastures. **Table 7** lists the estimated pasture acreage and the associated cattle populations within the BMAP boundary.

Table 7: PA pasture data and estimated cattle populations based on stocking rates

Property Code	PA Land Description	Estimated Improvement	High-Recharge Area (acres)	Medium-Recharge Area (acres)	High-Recharge Cattle Population	Medium-Recharge Cattle Population
60	Grazing Land	Improved	1,869	1,488	267	213
61	Grazing Land	Semi-improved	3,133	2,817	448	402
62	Grazing Land	Semi-improved	3,665	3,133	524	448
63	Grazing Land	Native	1,941	1,928	277	275

For other livestock animals, the populations were estimated using data from the United States Department of Agriculture (USDA), which publishes a Census of Agriculture (CoA) every five years. This comprehensive report provides summary data on the agricultural practices and livestock populations for each state and county in the United States. The 2012 CoA report was used to provide data on livestock populations for this assessment; however, since the CoA reports entire county data, additional analyses were conducted.

To estimate the number of livestock animals in the BMAP area, the SWFWMD land use coverage was used to provide land use categories likely to contain livestock, *i.e.*, pastures, feeding operations, and specialty farms. These land areas were totaled for the entire counties as well as the individual land areas for the two recharge rate categories. The summations were used to calculate a land use percentage relative to the entire county for livestock operations in the two recharge rate categories. These percentages were applied to the populations provided by the CoA to estimate the number of animals in the BMAP area and for the medium and high recharge rate areas (**Table 8**). For example, if 100,000 horses were reported for a particular county in the CoA, but only 10% of the livestock lands in that county were inside the BMAP area, it was assumed that the BMAP area would contain 10,000 horses. **Table A.6** lists total county populations from the CoA.

Nitrogen waste factors were assigned for each animal type and applied to the estimated livestock populations to estimate the nitrogen input to the land surface. These nitrogen waste factors in lb-N/day per animal were as follows: cattle, 0.337; broiler chickens, 0.159; layer chickens, 0.003; goats, 0.035; hogs, 0.190; sheep, 0.198; turkeys, 0.006; and horses, 0.273 (Goolsby *et al.* 1990; Katz *et al.* 1999; Chelette *et al.* 2002; Ruddy *et al.* 2006; Meyer 2012; Sprague and Gronberg 2013). The TN input to the land surface attributed to livestock waste is listed in **Table 9** for the medium and high recharge rate areas within the BMAP boundary.

Table 8: WMD land use percentages and miscellaneous livestock population data

Land Category	Land Area (acres)	Land Use Percentage	Broiler Chickens	Layer Chickens	Goats	Hogs	Sheep	Turkeys	Horses
Citrus County	28,860		348	1,775	903	196	279	27	1,159
Total BMAP	10,790	37%	130	664	338	73	104	10	433
High Recharge	9,330	32%	113	574	292	63	90	9	375
Medium Recharge	1,460	5%	18	90	46	10	14	1	59

Table 9: Estimated nitrogen applied as animal waste to the land surface in the BMAP area

Land Category	Cattle	Broiler Chickens	Layer Chickens	Goats	Hogs	Sheep	Turkeys	Horses	Total N Input (lb-N/yr)
High Recharge	186,412	6,529	628	3,729	4,394	6,518	19	37,335	**245,565**
Medium Recharge	164,586	1,022	98	583	688	1,020	3	5,841	**173,841**
Total BMAP	**350,998**	**7,550**	**727**	**4,313**	**5,082**	**7,538**	**22**	**43,176**	**419,406**

2.6 Crop Fertilizer

Nitrogen in agricultural fertilizer is applied at varying rates, depending on the crop and individual farm practices. The county property appraiser offices provided detailed information on the types of crops common to the area. Rates of nitrogen applied were estimated based on the most likely crops grown in each PA land use code group. Fertilizer nitrogen application rates are based on those recommended by the University of Florida Institute of Food and Agricultural Sciences (UF–IFAS) (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 10** summarizes the data used to estimate nitrogen inputs to the land surface from fertilizers applied to cropland for the medium and high recharge rate areas within the BMAP boundary.

2.7 Summary of Estimated Nitrogen Inputs to the Land Surface

Figure 8 summarizes the amount and relative percentages of nitrogen inputs to the land surface contributed from the major sources in the BMAP area. The total nitrogen input from all sources is 3.9 million lb-N/yr. Urban fertilizers contributed about 38% of the TN input to the land surface in the BMAP area. Other sources in order of decreasing contributions of nitrogen inputs to the land surface included atmospheric deposition (24%), septic tanks (16%), farm fertilizers (11%), and livestock wastes (10%).

Table 10: Summary of crop types and nitrogen application rates for the Kings Bay BMAP area

Property Code	PA Land Description	Estimated Crop Type	N Application Rate (lb-N/ac)	High Recharge Area (ac)	Medium Recharge Area (ac)	Total Input (lb-N/yr)
51	Cropland Soil Class 1	Hay	80	1,319	11	106,389
52	Cropland Soil Class 2	Hay	80	7		525
53	Cropland Soil Class 3	Hay	80	53		4,224
66	Orchard Groves Citrus	Orchards, Citrus	150	23		3,489
69	Ornamentals Miscellaneous Agriculture	Ornamentals	80	148		11,859

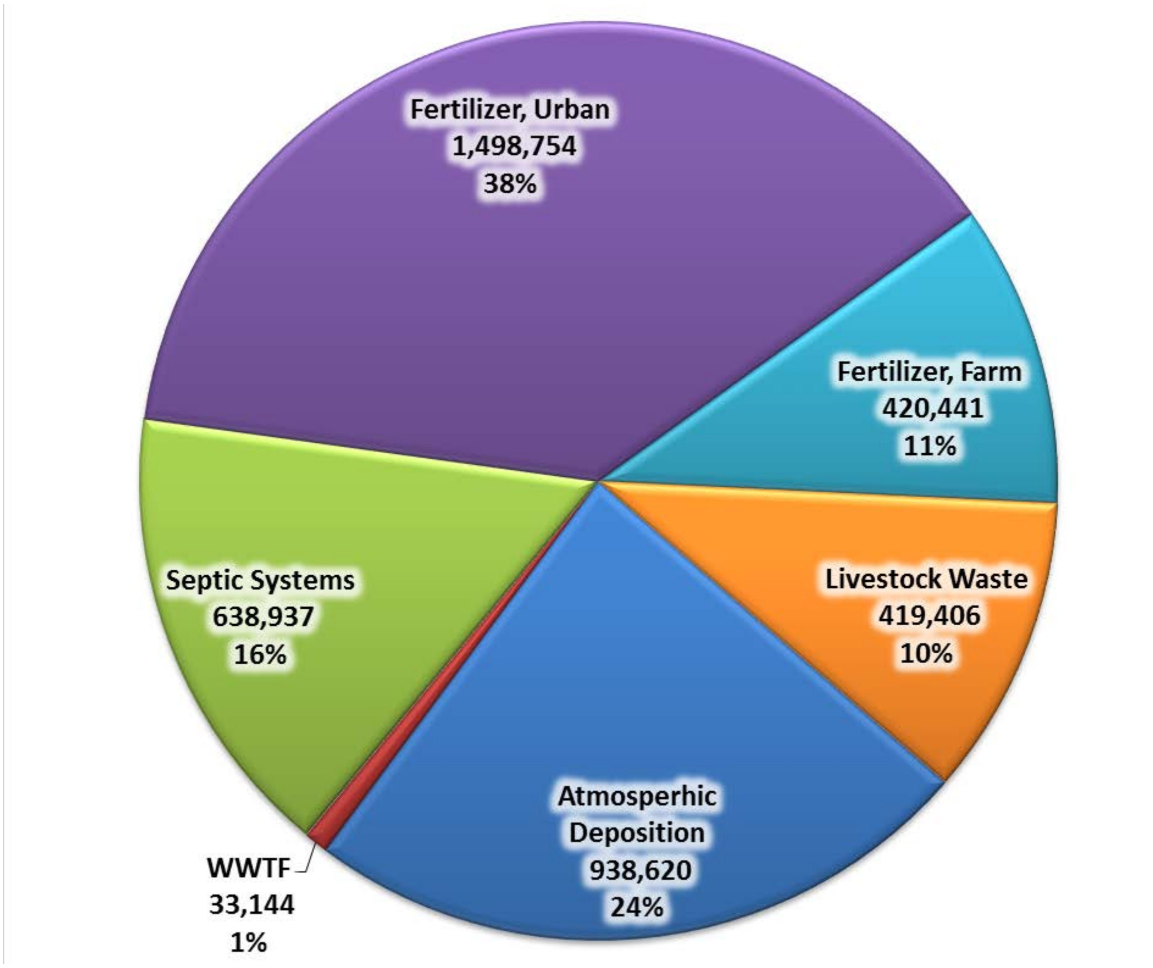


Figure 8: Relative nitrogen inputs to the land surface in the Kings Bay Springs BMAP area from major anthropogenic source categories in lb-N/yr

3. Environmental Attenuation, Recharge Rates, and Nitrogen Loading to Ground Water

The movement of nitrogen from the surface to ground water is controlled by biological and chemical processes that are part of the nitrogen cycle, as well as hydrogeological processes. Many of these processes attenuate (impede or remove) the amount of nitrogen transported to ground water. Therefore, to estimate the amount of nitrogen loading to the aquifer in the Kings Bay BMAP area, the department applied two environmental attenuation factors (EAFs): the first accounts for biochemical processes that remove or transform the different forms of nitrogen, and the second accounts for the movement of recharge water through the subsurface. The biochemical attenuation is specific for each nitrogen source category, while the hydrogeological attenuation varies depending on the spatial differences in the subsurface geological properties. Both attenuation factors control the amount of nitrogen reaching the UFA annually and hence contributing flow to Kings Bay springs. An understanding of how water moves through the subsurface and the processes that transform the different forms of nitrogen is essential for estimating the nitrogen loading to ground water from various sources (Liao *et al.* 2012; Wang *et al.* 2013).

3.1 Biochemical Attenuation

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

Specific 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 Agricultural Research Service [USDA–ARS]) and local stakeholders were sought out for their expertise. The biochemical attenuation factors, shown in **Table 11**, represent the average percentage of the nitrogen attenuated or removed by subsurface processes and thus reducing the amount of nitrogen reaching ground water.

As a first step in estimating loading to ground water, the 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 10% of the atmospheric nitrogen input to the land surface has the potential to infiltrate 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 11: EAFs applied to the nitrogen input calculations for various sources. These percentages represent the average amount of nitrogen removed by the environment by soils with varying characteristics.

N Source Category	Attenuation Factor	Literature References
Atmospheric Deposition	90%	Katz *et al.* 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs RIBs	25%	Merritt and Toth 2006; Sumner and Bradner 1996
WWTFs Sprayfield	60%	Katz *et al.* 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTF Reuse	75%	Jordan *et al 1997*; Candela *et al.* 2007; Rahil and Antonopoulos 2007
Urban Fertilizer	80%	Goolsby *et al.* 1999; Erikson *et al.* 2001; Barton and Colmer 2006; Katz *et al.* 2009
Septic Systems	40%	EPA 2002; Costa *et al.* 2002; Otis *et al.* 2007; Katz *et al.* 2009; Chang *et al.* 2010; Katz *et al.* 2010; Toor *et al.* 2011
Livestock Waste	90%	Dubeux *et al.* 2007; Silveira *et al.* 2007; Burns *et al.* 2009; Dubeux *et al.* 2009; Obour *et al.* 2010; Sigua 2010; Sigua *et al.* 2010; Silveira *et al.* 2011; Woodard *et al.* 2011; White-Leech *et al.* 2013a; White-Leech *et al.* 2013b
Crop Fertilizer	70%	McNeal *et al.* 1995; Wang and Alva 1996; Paramasivam and Alva 1997; Newton *et al.* 1999; Hochmuth 2000a; Hochmuth 2000b; Simonne *et al.* 2006; He *et al.* 2011; Liu *et al.* 2013

3.2 Hydrogeological Attenuation

Any nitrogen remaining (usually in the form of nitrate) after taking into account biochemical attenuation processes can readily leach to ground water. However, leaching to ground water 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 ground water recharge (from rainfall or irrigation water) ultimately controls how rapidly nitrogen moves from below the root zone to the UFA. The amount of water recharging the UFA each year also depends on the amount of rainfall, evapotranspiration, and runoff, as well as subsurface hydrogeological 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 (recharge rates are based on a USGS recharge map discussed in **Section 1.3, Aquifer Recharge**). The rate of recharge is used in the NSILT as an aggregated indicator of the various hydrogeological processes that can further attenuate the movement of nitrate to ground water. In areas with lower annual recharge rates, the vertical movement of water and associated chemical constituents is impeded, which may allow for increased biological uptake and denitrification (Liao *et al.* 2012; Wang *et al.* 2013). In contrast, for areas with higher recharge rates, water spends less time in the soil/root zone, decreasing the opportunity for biochemical attenuation. This likely results in the increased leaching of nitrogen as well as a higher potential for nitrogen transport to the aquifer in a given year (Scanlon *et al.* 2002; Liao *et al.* 2012).

Recharge weighting factors used in this nitrogen loading assessment are as follows: 90% for high-recharge rate areas (≥10 in/yr) and 50% for medium-recharge rate areas (4 to 9.9 in/yr) (Sepulveda 2002). For example, in high-rate recharge areas, 90% of the nonattenuated nitrogen mass is assumed to reach the aquifer in a year, while only 50% of the nonattenuated 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 Kings Bay 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 nonattenuated nitrogen based on the location of the land use utilized to estimate the nitrogen input.

3.3 Estimated Nitrogen Loads to Ground Water

Table 12, Table 13, and **Table 14** 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 830,633 lb-N load to the UFA in the BMAP area annually. This represents 21% 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 recharging the aquifer. These results indicate that of the source categories evaluated, the greatest annual load of nitrogen to the UFA in the BMAP area is from septic systems, with 40% of the total estimated load to ground water, followed by urban fertilizers at 31%.

Figure 9 shows the distribution of estimated annual loads of nitrogen to the UFA by source category. The NSILT results indicate that most of the nitrogen load to ground water originates from septic systems and fertilizers; this is consistent with isotopic and other chemical data. Nitrogen isotopes signatures in water samples collected from 11 springs indicated that elevated nitrate concentrations originate from a mix of both inorganic sources (fertilizer) and organic sources (human and animal waste) (Bridger 2014). Also, sucralose, an artificial sweetener and a useful indicator of domestic wastewater, was detected in the six springs with the highest nitrate concentrations (Bridger 2014).

Aquifer recharge has a significant influence on the loading of nitrogen to the UFA in the BMAP area. **Figure 10** summarizes the estimated nitrogen loads to ground water for the medium and high recharge rate areas, including a breakdown for each source category. The majority of the nitrogen loading to ground water in the BMAP area (94%) occurs in high rate recharge areas. For both the medium and high recharge rate areas, the dominant sources of nitrogen loading to ground water are septic systems and urban fertilizers.

Table 12: Estimated inputs to land surface by nitrogen source category in the Kings Bay BMAP area (lb-N/yr)

Recharge Category	Atmospheric Deposition	WWTF-RIB	WWTF-Sprayfield	WWTF-Reuse	Septic Systems	Urban Fertilizers	Crop Fertilizers	Livestock Waste	Total
High	815,247	23,593	6,800	8,708	586,688	1,381,661	358,121	245,565	3,426,384
Medium	123,373	2,751			52,249	117,093	62,319	173,841	531,626
TOTAL	**938,620**	**26,344**	**6,800**	**8,708**	**638,937**	**1,498,754**	**420,441**	**419,406**	**3,958,010**

Table 13: Attenuation estimates by source category in the Kings Bay BMAP area (lb-N/yr)

Recharge Category	Atmospheric Deposition	WWTF-RIB	WWTF-Sprayfield	WWTF-Reuse	Septic Systems	Urban Fertilizers	Crop Fertilizers	Livestock Waste	Total
Attenuation Factors	***90%***	***25%***	***60%***	***75%***	***40%***	***80%***	***70%***	***90%***	
High	81,525	17,695	2,720	2,177	352,013	276,332	107,436	24,556	**864,455**
Medium	12,337	2,063			31,349	23,419	18,696	17,384	**105,248**
TOTAL	**93,862**	**19,758**	**2,720**	**2,177**	**383,362**	**299,751**	**126,132**	**41,941**	**969,703**

Table 14: Load to ground water with recharge factors applied by nitrogen source category in the Kings Bay BMAP area (lb-N/yr)

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

Recharge Category	Atmospheric Deposition	WWTF§	Septic Systems	Urban Fertilizers	Crop Fertilizers	Livestock Waste	Total
High (90%)	73,372	18,373	316,812	248,699	96,693	22,101	**776,050**
Medium (50%)	6,169	1,032	15,675	11,709	9,348	8,692	**52,624**
TOTAL	**79,541**	**21,364**	**332,486**	**260,408**	**106,041**	**30,793**	**830,633**

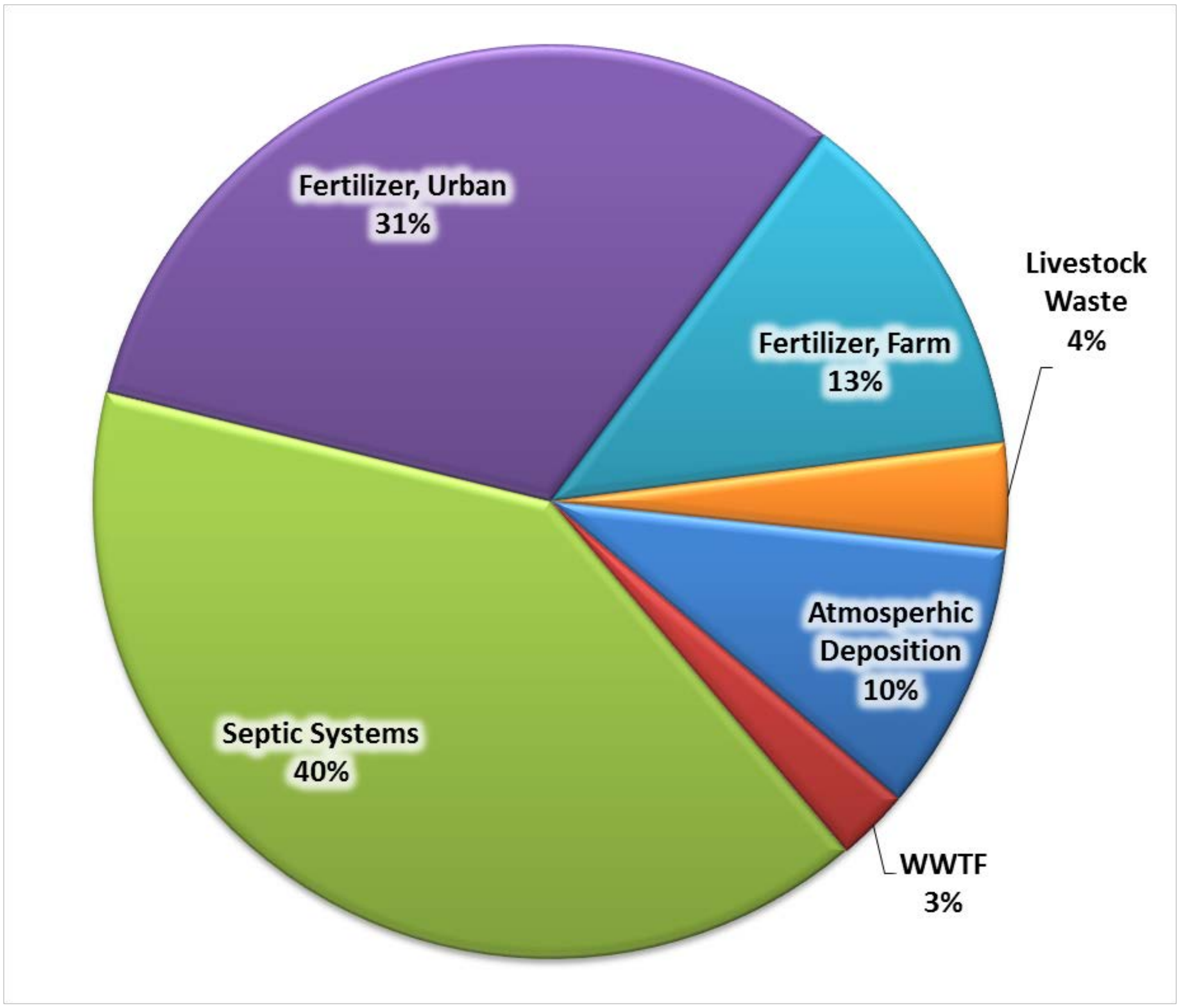


Figure 9: Relative contributions of nitrogen loading to ground water based on source category in the Kings Bay BMAP area

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

The pie charts in **Figure 10** only provide information about the relative estimated contribution of nitrogen loading to ground water from each source. If the contribution from one source category were to increase or decrease, the contribution of all other sources would change proportionally. The environmental attenuation of nitrogen from specific sources within the categories can vary substantially, both spatially and with depth in the subsurface, and will affect the amount of nitrogen leaching to ground water and the relative contribution of nitrogen from each source category. This range in nitrogen attenuation can result from variability in soil properties, crop types, agricultural practices, nitrogen storage, volatilization of ammonia to the atmosphere, uptake by vegetation, denitrification, and other removal processes.

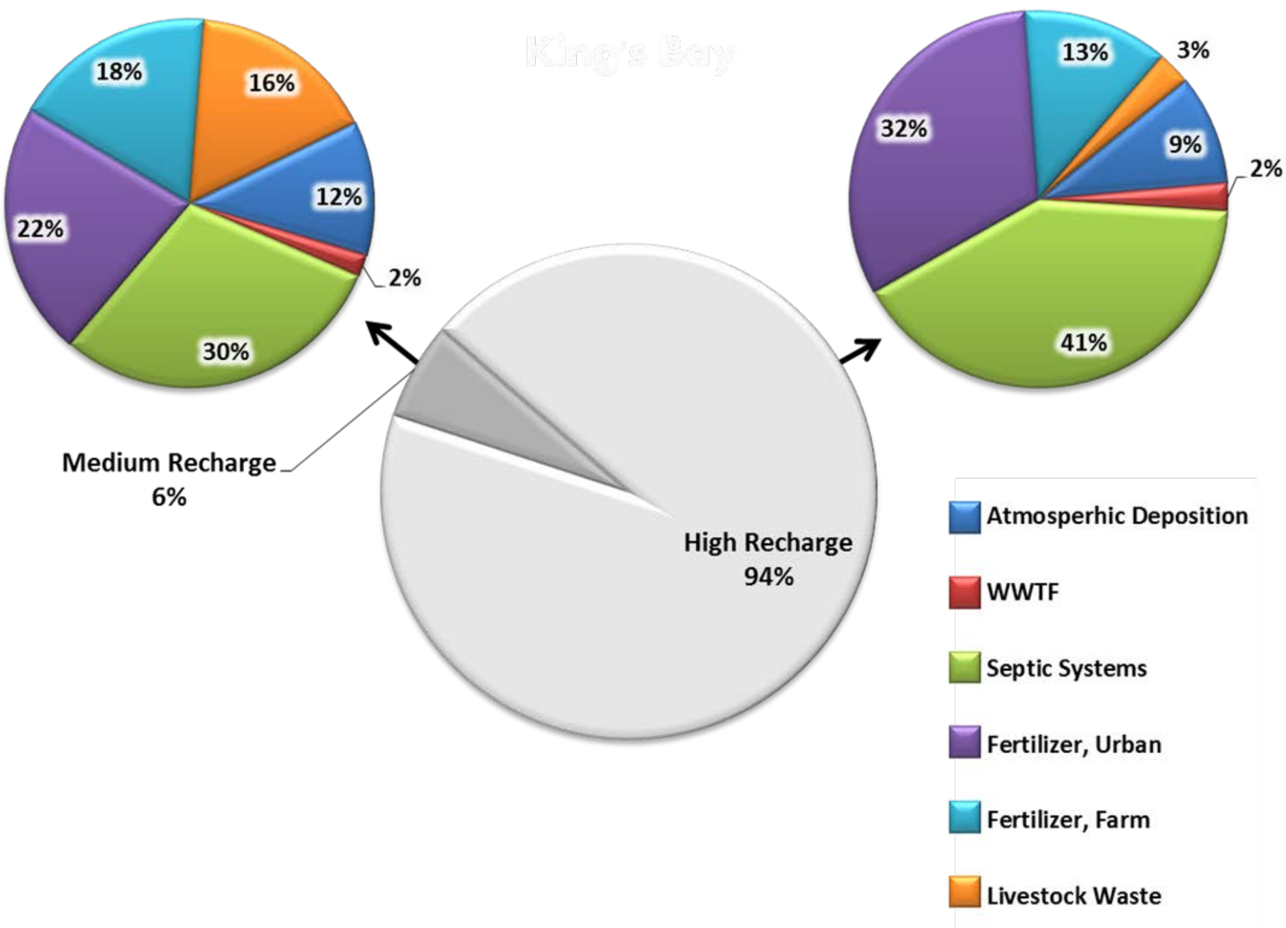


Figure 10: Estimated annual nitrogen loading to ground water by recharge category

Given the relatively large range in nitrogen attenuation for each source, the department opted to use an average attenuation factor that was estimated based on land use practices and hydrogeological conditions in the Kings Bay 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 15** lists the range in nitrogen attenuation for each source.

Table 15: Range of environmental attenuation of nitrogen from a detailed literature review

N Source Category	Low-Level Attenuation	Attenuation Used for This Analysis	High Level Attenuation
Atmospheric Deposition	85%	90%	95%
WWTFs-RIBs	10%	25%	40%
WWTFs-Sprayfield	50%	60%	75%
WWTF-Reuse	75%	70%	85%
Septic Tanks	30%	40%	50%
Livestock Operations	80%	90%	95%
Crop Fertilizers	50%	70%	85%
Urban Fertilizers	50%	80%	85%

Using the range of nitrogen attenuation factors in **Table 15**, the department estimated the corresponding range of nitrogen loading to ground water from each source in the BMAP area (**Figure 11**). Even with the large range in nitrogen attenuation for each source in the BMAP area, the total estimated nitrogen load to ground water greatly exceeds the target load estimated for the TMDL for the Kings Bay springs. Based on the current discharge of the Kings Bay springs, estimated at 466 cubic feet per second (cfs), and the adopted TMDL of 0.23 mg/L, the target nitrogen load for the Kings Bay BMAP boundary is 210,648 lb-N/yr (VHB 2010; Bridger 2014). Using the high-level nitrogen attenuation factors for each source, the total estimated load to ground water in the BMAP area is 596,836 lb-N/yr, which is considerably higher than the TMDL target (**Figure 12**).

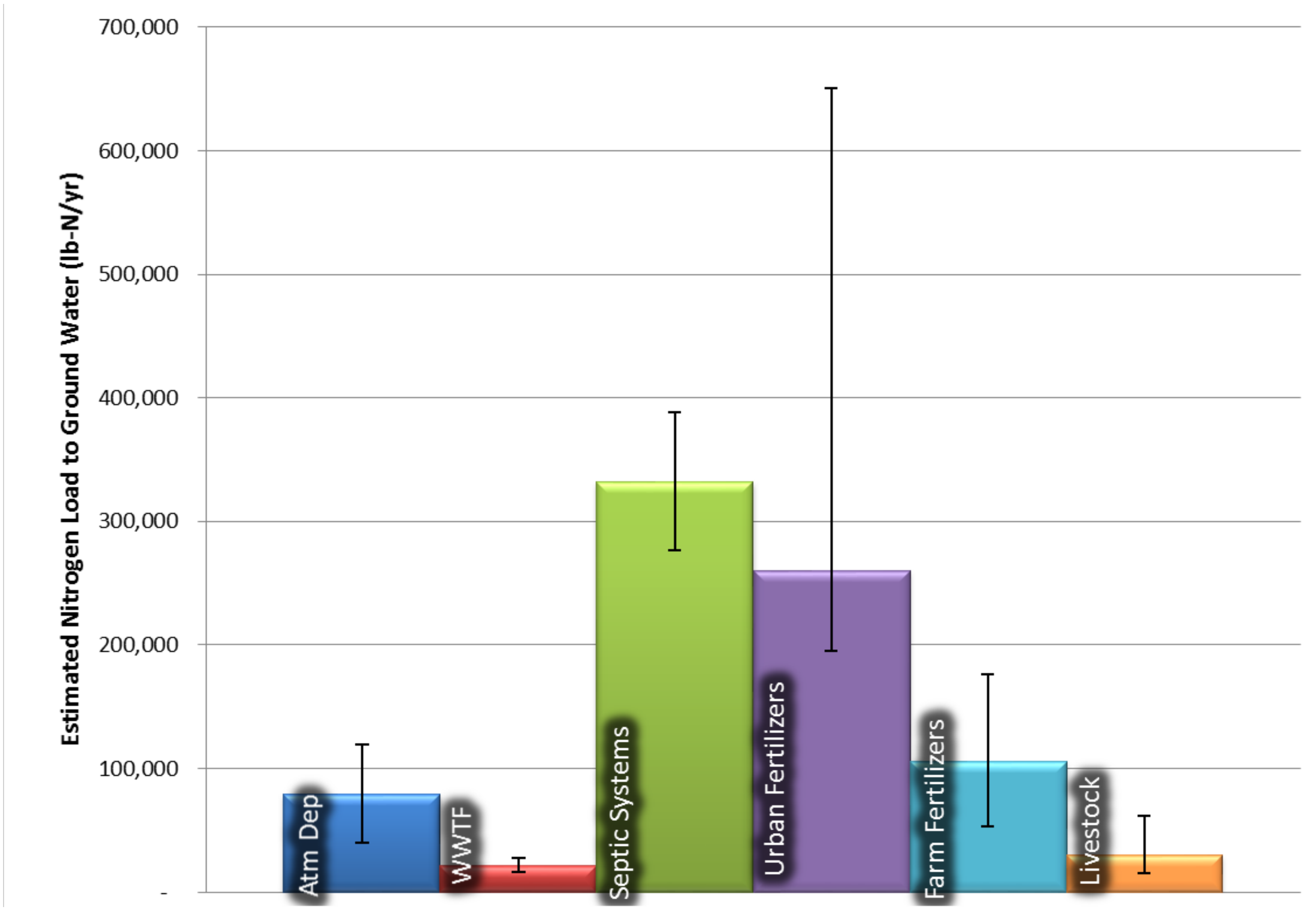


Figure 11: Influence of the range of attenuation factors on estimated nitrogen loads to ground water from each source category in the Kings Bay BMAP area

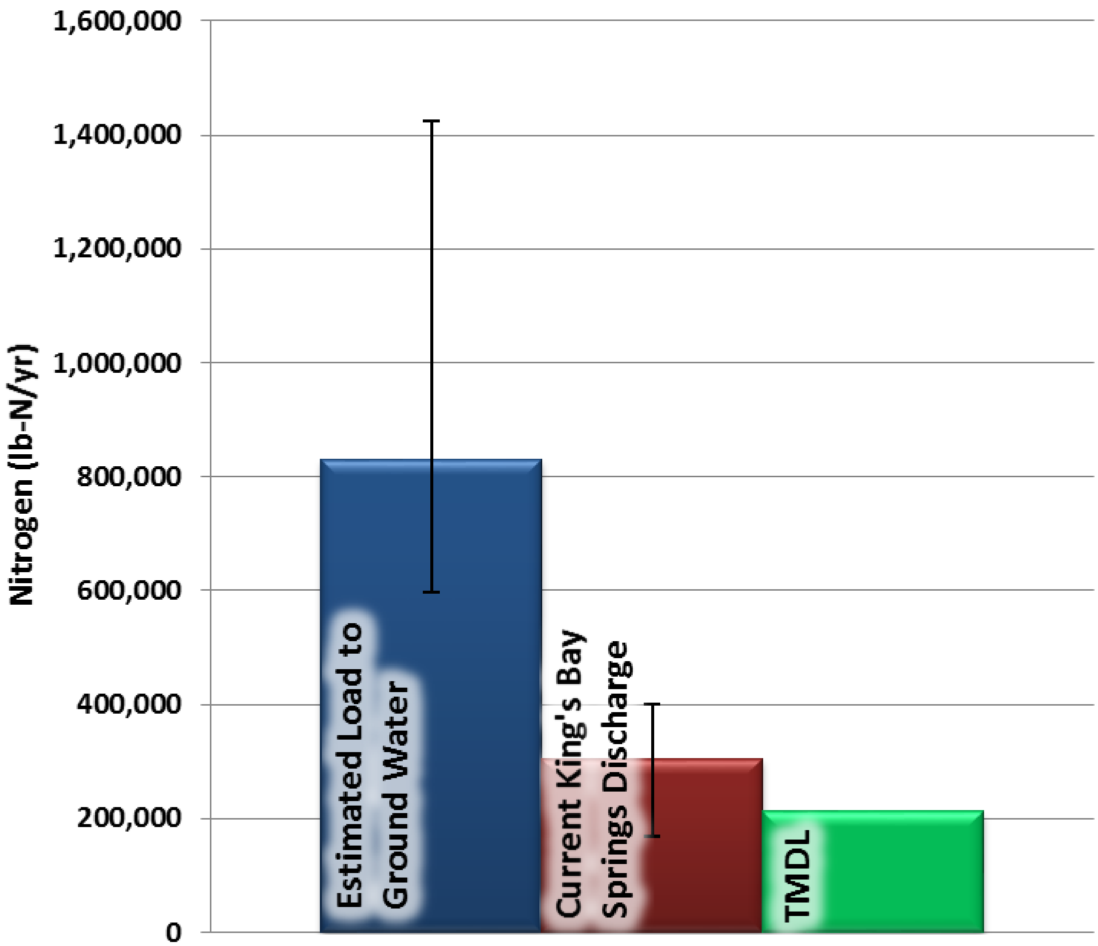


Figure 12: Estimated nitrogen load to ground water compared with current nitrogen discharging from the springs of Kings Bay and TMDL goal

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Appendices

Appendix A: Tables

Table A.1: Useful conversion factors

Convert from	To	Multiply by
Pounds	kilograms	0.4535924
NO_3 milligrams per liter	NO_3 grams-nitrogen per liter	2.260 X 10-4
NH_4 milligrams per liter	NH_4 grams-nitrogen per liter	7.765 X 10-4
milligrams	grams	0.001
grams	kilograms	0.001
milligrams	kilograms	1 X 10-6
acre	hectares	0.4046873
square meters	hectares	0.0001
cubic centimeters	liters	0.001
tons	kilograms	907.1847
cubic feet	liters	28.31685
second	year	3.170979 X 10-8
rainfall (centimeters)	rainfall (liters per hectare)	104

Table A.2: List of Kings Bay springs with associated aliases and average discharge

Name	List of Aliases	2009 Average Discharge (cfs)
Miller's Creek Spring	Hammett 23	2.54
City Hall Spring	Fountain Spring, Little Spring	12.52
Charlie's Fish House Spring	None	0.02
Birds Underwater Spring	Hammett 25	0.09
Pool Spring	Hammett 27	2.25
Catfish Spring	Hammett 1	11.45
NW 9th Avenue Springs	Hammett 26	0.79
House Spring	Hammett 4	5.23
Jurassic Spring	Hammett 5	23.96
Hunters Spring	Hammett 3, American Legion Spring	31.02
Magnolia Circle Spring	Hammett 21	1.94
Pete's Pier Spring	None	1.5
Moray Spring	Hammett 6	1.95
Paradise Isles	Hammett 7	0.88
Manatee Sanctuary	Hammett 8, Gator Hole, Magnolia Spring	50.03
Buzzard Island Spring	None	0.61
Three Sisters Spring #1	Hammett 10, Middle Springs #1	7.39
Three Sisters Spring #2	Hammett 28, Middle Springs #2	25.83
Three Sisters Spring #3	Hammett 28, Middle Springs #3	45.25
Idiots Delight #1	Hammett 9, Kings Bay #1	4.84
Idiots Delight #2	Hammett 11	3.46

Name	List of Aliases	2009 Average Discharge (cfs)
Idiots Delight #3	Hammett 11A, Three Sisters Run	0.75
Parker Island North Spring Complex	None	10.98
Parker Island Spring	Hammett 12, Little Hidden Spring	1.74
Banana Island North Spring Complex	Banana Island North Spring Complex	3.83
FWS Spring Complex	Hammett 13	2.37
Banana Island East Springs	None	0.34
Banana Island West Springs	None	0.46
Tarpon Hole #2	Hammett 15, Mullets Gullet Spring	28.91
Tarpon Hole	Hammett 2, Big Hole, Crystal Spring	42.83
King Spring	Hammett 16, Grand Canyon Spring	53.91
Dave's Quest Springs	None	5.17
Golfview	Hammett 17	19.71
Wynn Court Springs	Hammett 19	0.34
Black Spring	Hammett 18	5.89
Sid's Springs	Hammett 19	11.25
Gary's Grotto	None	14.85
Hammett 24	Hammett 24	28.93

Table A.3: Summary of SWFWMD land use data

Land Use Code	Land Use Description	Citrus County	High Recharge	Medium Recharge	Discharge
2100	Cropland and Pastureland	28,128	8,977	1,460	0
2300	Feeding Operations	19	0	0	0
2500	Specialty Farms	699	339	0	0
2550	Tropical Fish Farms	15	15	0	0
2140	Row Crops	533	69	0	0
2200	Tree Crops	231	0	0	0
2400	Nurseries and Vineyards	316	86	0	0
1100	Residential Low Density <2 Dwelling Units	72,347	44,743	2,102	91
1200	Residential Medium Density 2-5 Dwelling Units	18,189	6,783	1,133	69
1300	Residential High Density	3,848	2,381	134	47
1800	Recreational	837	351	78	34
1820	Golf Courses	2,521	1,718	177	0

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

Property Code	Description	High-Recharge Area (ac)	Medium-Recharge Area (ac)	Discharge Area (ac)
0	Vacant Single Family Residence	32,037	29,081	2,625
1	Single Family Residential	26,777	24,685	1,891
3	Multi Family 9 Units	85	61	24
4	Condo	56	25	8
6	Retirement Homes	9	9	
8	Multi Family 10 Units	163	128	36
30	Florist Greenhouses	0.4	0.4	
38	Golf Courses Driving Ranges	2,352	2,154	198
39	Hotels Motels	21	58	
50	Improved Ag	6,263	3,726	2,537
51	Cropland Soil Class 1	1,330	1,319	11
52	Cropland Soil Class 2	7	7	
53	Cropland Soil Class 3	53	53	
51	Cropland Soil Class 1	1,330	1,319	11
60	Grazing Land	1,869	1,488	381
61	Grazing Land	3,133	2,817	316
62	Grazing Land	3,665	3,133	491
63	Grazing Land	1,941	1,928	13
66	Orchard Groves Citrus	23	23	
67	Poultry Bees Fish Rabbits	44	31	13
68	Dairies Feed Lots	25	25	
69	Ornamentals Misc Ag	148	148	
71	Churches	405	102	
72	Private Schools and Colleges	32	0	
74	Homes for the Aged	85	77	8
77	Clubs Lodges Union Halls	286	29	22
83	Public County Schools	683		21
85	Hospitals	50		
97	Outdoor Recreation	10	3	
71	Churches	405	102	

Table A.5: Citrus County zoning data

Zoning Code	Zoning Description	% Maximum Lot Coverage	Exception
AGR	Agricultural District	0.1%	0.3 if < 1.0 ac
AGR MH	Agricultural District with Mobile Homes	0.1%	0.3 if < 1.0 ac
CG	General Commercial	0.7%	
CH	High Intensity Commercial	0.7%	
CITY	Within City Limits	0.7%	
CL	Low Intensity Coastal and Lakes District	0.25%	0.3 if < 1.0 ac
CL MH	Low Intensity Coastal and Lakes District with Mobile Homes	0.25%	0.3 if < 1.0 ac
CLC	Coastal and Lakes Commercial District	0.35%	
CLC MH	Coastal and Lakes Commercial District with Mobile Homes	0.35%	
CLR	Coastal and Lakes Residential District	0.35%	0.4 if < 10,000 sq ft
CLR M	Coastal and Lakes Residential District with Mobile Homes	0.35%	0.4 if < 10,000 sq ft
CLR MH	Coastal and Lakes Residential District with Mobile Homes	0.35%	0.4 if < 10,000 sq ft
CON	Conservation District	0.1%	0.3 if < 1.0 ac
CON MH	Conservation District with Mobile Homes	0.1%	0.3 if < 1.0 ac
CRR	Central Ridge Residential District	0.35%	
CRR MH	Central Ridge Residential District with Mobile Homes	0.35%	
CW	Waterfront Commercial	0.7%	
EXT	Extractive District	0.7%	
EXT MH	Extractive District with Mobile Homes	0.7%	
GNC	General Commercial District	0.7%	
GNC MH	General Commercial District with Mobile Homes	0.7%	
HDR	High Density Residential District	0.55%	
HDR MH	High Density Residential District with Mobile Homes	0.55%	
IND	Heavy Industrial District	0.7%	
LD	Low Density Residential District	0.35%	
LDR	Low Density Residential District	0.35%	
LDR MH	Low Density Residential District with Mobile Homes	0.35%	
LIN	Light Industrial District	0.7%	
MDR	Medium Density Residential District	0.5%	
MDR MH	Medium Density Residential District with Mobile Homes	0.5%	
MHP	Mobile Home PARK	0.4%	
NBR	Neighborhood Business Residential	0.7%	
NEC	Neighborhood Commercial District	0.7%	
PDR	Planned Residential Development District		
PDR MH	Planned Residential Development District with Mobile Homes		
PDR-SC	Planned Residential Development District		
PI	Public Institutional	0.7%	
PORT	Port District	0.5%	
PSI	Public/Semi-public, Institutional District	0.7%	
PSI MH	Public/Semi-public, Institutional District with Mobile Homes	0.7%	
PSO	Professional Services/Office District	0.7%	
PSO MH	Professional Services/Office District with Mobile Homes	0.7%	

Zoning Code	Zoning Description	% Maximum Lot Coverage	Exception
PUD	Planned Unit Development		
R-1	Low Density Residential	0.35%	
R-2	Medium Density Residential	0.5%	
R-3	High Density Residential	0.55%	
R-C	Residential Conservation	0.5%	
REC	Recreation District	0.25%	
REC MH	Recreation District with Mobile Homes	0.25%	
RUR	Rural Residential District	0.2%	0.3 if < 1.0 ac
RUR MH	Rural Residential District with Mobile Homes	0.2%	0.3 if < 1.0 ac
RVP	Recreational Vehicle Park/Campground District	0.4%	
R-W	Residential Waterfront	0.5%	
TCU	Transportation/Communication/Utilities District	0.7%	
TCU MH	Transportation/Communication/Utilities District with Mobile	0.7%	

Table A.6: WAFR data used to calculate annual average input for WWTFs

* TN data estimated based on available NO3 data
Ab field = Absorption field

Facility ID	WWTF Name	Treatment Type	Recharge Area	Annual Average NO_3 (mg-N/L)	Annual Average TN (mg-N/L)	Annual Flow (mgd)	N Input (lb-N/yr)
FLA011869	Beverly Hills WWTF	RIB	High	2.17	6.26	0.460	8,782
FLA011915	Forest View	RIB	Medium	1.88	4.89*	0.029	432
FLA011846	New Horizons WWTF	RIB	High	2.11	5.49*	0.004	67
FLA011921	Canterbury Lake Estates	RIB	High	1.17	3.05*	0.025	231
FLA011913	River Cove Landings WWTF	RIB/ Ab field	Discharge	1.94	5.03*	0.002	28
FLA011872	Imperial Gardens MHP	RIB	Medium	1.54	4.00*	0.003	30
FLA011922	Quality Inn	RIB	Medium	5.63	14.62*	0.005	231
FLA011918	Citrus Center Shopping Center WWTF	RIB	High	0.59	1.54*	0.017	78
FLA011856	Anchorage WWTF	RIB	Medium	4.96	12.89*	0.002	76
FLA011920	Inverness Park	Sprayfield	High	0.93	2.42*	0.002	17
FLA011861	Seven Rivers Regional Medical Center	RIB	Medium	2.41	6.25*	0.020	383
FLA011863	Lake Rousseau RV Park and Fishing Resort, LLC	RIB	High	3.02	7.85*	0.003	62
FLA011876	Indian Springs Utilities	RIB	Medium	3.13	8.14*	0.034	854
FLA011909	Florida Power Nuclear Operations Training Center	RIB	High	1.58	4.11*	0.001	8
FLA011854	Pelican Bay Apartments	RIB	Medium	1.79	4.64*	0.006	91
FLA011848	Crystal River City Of WWTF	Sprayfield	High	6.08	3.29	0.674	6,750
FLA011844	Brentwood Regional WWTF	RIB	High	3.08	4.59	0.330	4,610
FLA011928	Ventura Village Apartments WWTF	Ab field	High	1.93	5.01*	0.002	32
FLA011855	Sandy Oaks RVP and MHC WWTF	Sprayfield/ RIB	High	2.08	5.39*	0.002	33
FLA011924	Lecanto Hills MHP WWTF	RIB	High	1.15	2.99*	0.005	49
FLA033065	Island Condominiums WWTF	RIB	Discharge	2.40	6.23*	0.015	293
FLA011895	Thunderbird MHP WWTF	RIB	Medium	0.89	2.32*	0.003	22
FLA011845	Meadowcrest WWTF (RIB)	RIB	High	6.84	8.64	0.267	7,025
FLA011845	Meadowcrest WWTF (Golf Course)	RIB	High	6.84	8.64	0.331	8,708
FLA011914	Greenbriar Of Citrus Hills	RIB	High	1.99	5.18*	0.027	422

Table A.7: 2012 CoA livestock populations for Citrus County

CoA Population	Citrus County
Broiler Chickens	348
Layer Chickens	1,775
Goats	903
Hogs	196
Sheep	279
Turkey	27
Horses	1,159

Table A.8: Measured NO_3 concentrations (in mg/L) from the springs listed as impaired from 2009

NO_3 Concentrations	Mean	Minimum	Maximum
Hunter Spring	0.52	0.46	0.58
House Spring (2010)	0.45	0.45	0.45
Idiot's Delight	0.18	0.18	0.18
Tarpon Spring	0.24	0.2	0.26
Black Spring	0.28	0.28	0.28
Average	0.334	0.314	0.35

Appendix B - Golf Course Questionnaire

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

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

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

CONTACT INFORMATION

Name

Are you the course Superintendent?
○ YES
○ NO

Preferred Method of Contact
☐ Email
☐ Phone

Email Address

Phone Number

GOLF COURSE INFORMATION

Golf Course Name

What is the closest city or town?

Does your golf course follow the BMP manual?
○ YES ○ NO

What is the total area of the course?
○ Sq ft ○ Acre

GREENS (including practice greens)

Total Area of Greens ○ Sq ft ○ Acre

N Application Rate each Year per ○ 1000 sq ft ○ acre

N Application Rate each Application per ○ 1000 sq ft ○ acre

Number of Applications per Year

What is the type of grass planted?

TEES

Total Area of Tees ◯ Sq ft ◯ Acre

N Application Rate each Year per ◯ 1000 sq ft ◯ acre

N Application Rate each Application per ◯ 1000 sq ft ◯ acre

Number of Applications per Year

What is the type of grass planted?

FAIRWAYS **(including driving ranges)**

Total Area of Fairways ◯ Sq ft ◯ Acre

N Application Rate each Year per ◯ 1000 sq ft ◯ acre

N Application Rate each Application per ◯ 1000 sq ft ◯ acre

Number of Applications per Year

What is the type of grass planted?

ROUGH

Total Area of Rough ◯ Sq ft ◯ Acre

N Application Rate each Year per ◯ 1000 sq ft ◯ acre

N Application Rate each Application per ◯ 1000 sq ft ◯ acre

Number of Applications per Year

What is the type of grass planted?

OTHER AREAS

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

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

What types of fertilizer are utilized?

☐ Slow Release ☐ Ammonium Nitrate ☐ Urea based

☐ Other

Does your golf course have a:

☐ Rain Gauge ☐ Weather Station ☐ Neither

Are irrigation rates adjusted based on rainfall?

○ YES ○ NO

Please describe how grass clippings are treated.

REUSE WATER

Is reuse water utilized?

○ YES

○ NO, skip remainder of this section

What facility provides reuse water?

Do you know the average N concentration?

○ YES ○ NO

If yes, please list

Do you know the volume used per year?

○ YES ○ NO

If yes, please list

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

○ YES ○ NO

If yes, please describe how

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

Kirstin Eller: Kirstin.Eller@dep.state.fl.us
Brian Katz: Brian.Katz@dep.state.fl.us
Yesenia Escribano: Yesenia.Escribano@dep.state.fl.us

Ground Water Management Section
Golf Course Questionnaire
2600 Blair Stone Rd MS 3575
Tallahassee, FL 32399

Appendix C: Methods and Result Comparison with Jones et al. (1998)

In 1994, the Ambient Ground Water Quality Monitoring Program at the SWFWMD conducted a study to determine the sources of increasing nitrate concentrations in the springs of King's Bay; the study was later updated (Jones *et al.* 1998). 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 nitrate loading to ground water in the King's Bay contributing area.

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

Study Area

- The NSILT was used to evaluate the BMAP area, which encompasses 178,753 ac of Citrus County. For the purposes of this comparison, only data from high- and medium-recharge areas are included.
- The Jones *et al.* (1998) study area was estimated to equal 179,199 ac without any distinction between different recharge zones.
- The difference between the two study areas is very minor, equaling 446 ac. The NSILT boundary covers the land area farther west, while the SWFWMD boundary includes more land to the south.

Atmospheric Deposition

- NSILT used multiyear data from the TDEP model. There is an estimated nitrogen input to the land surface from atmospheric deposition of 938,620 lb-N/yr.
- The SWFWMD study (Jones *et al.* 1998) 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, the researchers estimated a total of 1,146 tons or 2,292,000 pounds of nitrogen in the study area from this source.

— The SWFWMD larger estimate by 1,353,380 lb-N/yr is related to the higher nitrogen concentrations in rainfall used in the study. Several factors may account for these differences, such as the period when rainfall was collected and differences in collection and analytical methods.

Septic Systems

— The NSILT relies on the modified estimate of septic systems by Hall and Clancy (2009). It is estimated that there are an average of 1.95 people contributing to each septic system in Citrus County. With an annual input of 9.92 lb-N/person, this equals an input of 19.37 lb-N/yr per system. There are an estimated 32,981 septic systems in the BMAP area, for a total input of 638,937 lb-N/yr.

— The Jones *et al.* (1998) estimation is based on an average of three people per septic system and an annual input of 53 lb-N/yr per system. The study estimated approximately 17,000 septic systems in the study area, with an annual input to the land surface of 916,000 lb-N/yr.

— There are two main differences between these methods: the number of septic systems and the annual input per system. The NSILT analysis included almost double the number of septic systems compared with Jones *et al.* (1998). This could be attributed to the more accurate counting methods utilized for the NSILT as well as increased population in the area. The annual input per system used for Jones *et al.* (1998) is more than double that of the NSILT, causing the Jones *et al.* (1998) estimate to be 277,063 lb-N/yr higher than the NSILT estimate.

Turf Fertilizers

— The NSILT relies on regional fertilizer application rates applied on the pervious land area associated with urban land uses. The estimated TN input is 1,498,754 lb-N/yr over the 18,036 ac assumed to be fertilized within the BMAP boundary.

— Jones *et al.* (1998) estimated 350,000 ac of low-, medium-, and high-density residential lands in the study area, of which 12,250 ac or 35% consisted of pervious land area capable of receiving fertilizer. An application rate of 2 lb-N/1,000 square feet (sq ft) was used for 60% of the land area. The remaining 40% was assumed not to receive fertilizer. This equals 638,000 lb-N/yr attributed to turfgrass fertilization.

- The higher NSILT estimate (a difference of 860,754 lb-N/yr) is due to two factors: increased land area and higher annual application rates. The land area used for the NSILT is larger by 5,786 ac, likely caused by population growth along the Springs Coast as well as the addition of other urban land uses aside from residential parcels.

Golf Course Fertilizer

- For the NSILT, there were nine golf courses covering 2,173 ac. Based on local surveys, the average annual application rate is 86.8 lb-N/ac, for a total input to the land surface of 188,589 lb-N/yr.

- Jones *et al.* (1998) included 11 golf courses with a total area of 1,865 ac. The application rate of 260 lb-N/ac was based on a study completed in Sarasota Bay. An estimated total of 486,000 lb-N/yr is applied on golf courses.

- The difference (297,411 lb-N/yr) between the two results is largely applicable to the application rates used in both studies. While the NSILT included a larger land area, the application of nitrogen was a third of the rate utilized by Jones *et al.* (1998).

WWTFs

- The NSILT used reported effluent data from the 29 permitted facilities in the BMAP area. These have a combined actual flow of 2.38 mgd, with an average nitrogen concentration of 5.91 mg/L. The estimated input is 39,102 lb-N/yr. The loadings from domestic WWTF residuals and septage were not included in the assessment because of these practices are used in small areas.

- Jones *et al.* (1998) evaluated WWTFs in three different categories: sewage effluent disposal, the land disposal of sewage sludge, and the land disposal of septage sludge. For the 42 WWTFs in the contributing area, the study used an annual average flow of 2.4 mgd and an average concentration of 40 mg/L. This equated to an input of 220,000 lb-N/yr for WWTFs and an additional nitrogen input of 66,000 lb from the additional sludge categories.

- There is a very large difference between the two studies because of the much higher effluent concentration utilized in the Jones *et al.* (1998) study as well as the addition of the sludge categories. Furthermore, since the first study was completed, considerable advances in waste treatment have been made and applied in this area that would contribute to the lower effluent concentration utilized in the NSILT.

Farm Fertilizer

- The NSILT uses property appraiser data, known crops grown in the area, and agricultural producer feedback, in addition to UF–IFAS recommended fertilizer application rates, to obtain nitrogen inputs from farm fertilizers. There are almost 18,501 ac of cropland and pastures in the BMAP area that contribute 420,441 lb-N/yr.

- Jones *et al.* (1998) utilized fertilizer sales data to estimate the input of nitrogen from agricultural fertilizers. The study estimated that 298,000 lb-N/yr are applied to 17,074 ac of cropland and pastureland.

- The difference of 122,441 lb-N/yr for the BMAP area can be attributed to a higher amount of crop acreage in the BMAP area compared with the SWFWMD study area, as well as more the detailed allocation of crop-specific application rates.

Livestock Waste

- The NSILT includes cattle as well as other livestock animals present within the BMAP boundary. Cattle populations are estimated based on stocking rates gathered from feedback from cattle farmers, resulting in an estimated population of 2,854. Additional livestock animal populations estimated from the 2012 CoA are assigned to the BMAP area based on the distribution of livestock lands (such as improved pastures). Daily waste factors are applied based on the nitrogen content for each animal. The total estimate input to the land surface equals 419,406 lb-N/yr.

- Jones *et al.* (1998) estimated a cattle population of 3,000 in the study area. The daily input factor is approximately 0.33 lb-N/1,000 lb of body weight, which equals a total input of 300,000 lb-N/yr.

- The difference of 119,406 lb-N/yr between the two studies is mainly due to the difference in estimated livestock populations over different areas. Additionally, the NSILT considers multiple livestock animals, while the Jones *et al.* (1998) study did not.

Stormwater

- The NSILT does not currently estimate the influence of stormwater-sourced nitrogen on ground water.
- Jones *et al.* (1998) estimated that 158,000 lb-N/yr runs off from golf courses, residential areas, commercial properties, and cropland that is transported via stormwater.

Comparison of TN Inputs

The TN inputs to the land surface estimated by Jones *et al.* (1998) were 5,672,000 lb-N/yr (based on 179,199 ac of land area, this results in an average of 32 lb-N/ac). The three sources that contribute the highest percentages of nitrogen to the land surface are atmospheric deposition (40%), septic systems (19%), and turf fertilizers (11%).

The NSILT estimates TN inputs of 3,958,010 lb-N/yr to the land surface (178,753 ac) in the King's Bay BMAP area, or an average of 20 lb-N/ac. The three sources that contribute the largest percentages of nitrogen inputs to the land surface are turf fertilizer (34%), atmospheric deposition (24%), and septic systems (16%). **Table C.1** compares the relative percentages estimated from both methods.

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

The SWFWMD study (Jones *et al.* 1998) provided an important baseline for comparison with the nitrogen inventory for the King's Bay BMAP. Current information on the nitrogen source inventory and nitrogen loads to ground water generated from the NSILT for the King's Bay BMAP will be used to determine where present-day nitrogen loading to ground water can be reduced to achieve the restoration of King's Bay and its springs.

Table C.1: Comparison of nitrogen input percentages calculated by NSILT and Jones et al. (1998) to the land surface

N Loading Category	NSILT (2015)	Jones *et al.* (1998)
Atmospheric Deposition	24%	40%
Septic Systems	16%	19%
WWTFs	1%	5%
Turf Fertilizers	34%	11%
Golf Course Fertilizers	5%	9%
Farm Fertilizers	11%	6%
Livestock Waste	10%	6%
Stormwater	0%	3%