NITROGEN SOURCE INVENTORY AND LOADING ESTIMATES FOR THE KINGS BAY SPRINGS BASIN MANAGEMENT ACTION PLAN AREA

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Update

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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. This September 2016 update includes changes to the septic system annual loading per person and associated attenuation, based on additional literature reviews. In addition, urban fertilizers were divided into two categories (urban turfgrass fertilizer and sports turfgrass fertilizer) and the methodology updated to facilitate the implementation of the Florida Springs and Aquifer Protection Act.

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

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Summary of Findings

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 93% of the total nitrogen (TN) entering the bay originates from spring discharge (Jones et al. 1998). In 2014, a total maximum daily load (TMDL) 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 (DEP) developed a Nitrogen Source Inventory and Loading Tool (NSILT) to provide information on the major sources of nitrogen (atmospheric deposition, wastewater treatment facilities [WWTFs], urban fertilizers, septic systems, livestock wastes, and agricultural fertilizers) in the groundwater contributing area covered by the basin management action plan (BMAP) (referred to as the Kings Bay BMAP) for the springs of Kings Bay. In addition, this tool is used to estimate nitrogen loads to groundwater from these sources in the spring contributing area. NSILT is an ArcGIS- and spreadsheet-based tool that provides spatial estimates of the relative contribution of nitrogen from major nitrogen sources, and accounts for the transport pathways and processes affecting the various forms of nitrogen as they move from the land surface through the soil and geologic strata overlying the UFA.

This report describes the methods, information, and data sources used in developing the NSILT to estimate nitrogen loads to groundwater in the Kings Bay BMAP area. The information is provided as a planning tool for the development and implementation of a BMAP that addresses the nitrate impairment in the springs of Kings Bay. The NSILT is being used in the BMAP development process to identify source categories and areas where nitrogen source reduction efforts from current land uses and activities could be focused to achieve the most beneficial effects on water quality for the springs of Kings Bay.

The total estimated annual nitrogen input to the land surface in the contributing area from all sources is 2.9 million pounds of nitrogen (lb-N). The nitrogen sources, in order of decreasing nitrogen inputs to the land surface, include atmospheric deposition (32 %), septic systems (20 %), farm fertilizers (14 %), livestock waste (14 %), urban turfgrass fertilizers (12 %), sports turfgrass fertilizers (7 %), and wastewater treatment facilities (1 %).

The NSILT results indicate a total annual load of 592,440 pounds of nitrogen to the UFA in the Kings Bay BMAP area, representing 20 % of the amount of nitrogen inputs to the land surface. Most of the nitrogen in a given year does not reach groundwater because of nitrogen attenuation processes and variations in the rate of aquifer recharge. In areas of the Kings Bay springshed where recharge rates are categorized as medium (3.01 to 10 inches per year [in/yr]) or high (greater than 10 in/yr), the UFA is more vulnerable to contamination than in areas where recharge rates are low (0 to 3 in/yr).

Groundwater discharge areas were not included in the calculations of nitrogen loads to the groundwater contributing area, as these areas do not contribute nitrogen to the aquifer. In these areas, direct runoff to Kings Bay would be a greater concern than loading from springs. To account for variations in recharge rates to the UFA, non-attenuated nitrogen inputs in high rate recharge areas are multiplied by a weighting factor of 0.9, while nitrogen inputs are multiplied by a weighting factor of 0.5 for medium rate recharge areas.

The highest nitrogen loads in the Kings Bay BMAP area were estimated to be from septic systems (42 %), followed by urban turfgrass fertilizer (15 %) and atmospheric deposition (13 %). Sources contributing smaller amounts of nitrogen include farm fertilizers (12 %), sport turfgrass fertilizer (8 %), livestock waste (5 %), and the land application of treated wastewater (4 %).

The NSILT results provide a baseline understanding of current nitrogen loads to groundwater from existing sources in the Kings Bay BMAP area that are likely to contribute the greatest loads of nitrogen to groundwater. This tool can also be used to evaluate the nitrogen load reduction benefits of various management actions and nitrogen reduction projects at locations within the 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 groundwater quality. Springs integrate groundwater vertically, spatially, and temporally from the Upper Floridan aquifer (UFA) (Bush and Johnston 1988; Katz 1992, 2004; Davis 1996). Rainfall that infiltrates into the subsurface and recharges the aquifer system contains nitrogen and other dissolved chemicals of concern originating from anthropogenic activities at or near the land surface. Groundwater with elevated nitrate concentrations flows toward 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 identify and quantify the major sources of nitrogen in groundwater contributing areas to springs, the Florida Department of Environmental Protection (DEP) developed the Nitrogen Source Inventory and Loading Tool (NSILT). This tool quantifies nitrogen inputs to the land surface based on the best available, current information on land uses, agricultural practices, urban fertilizer use, waste disposal methods, and atmospheric sources. The NSILT is also used to estimate nitrogen loads to groundwater in the contributing area by taking into account the attenuation of various forms of nitrogen from sources and recharge rates to the UFA. The NSILT results are used in the development and implementation of the basin management action plan (BMAP) for the springs of Kings Bay by helping to focus nitrogen source reduction efforts to achieve the greatest improvement in water quality.

1.1 Kings Bay Springs Group

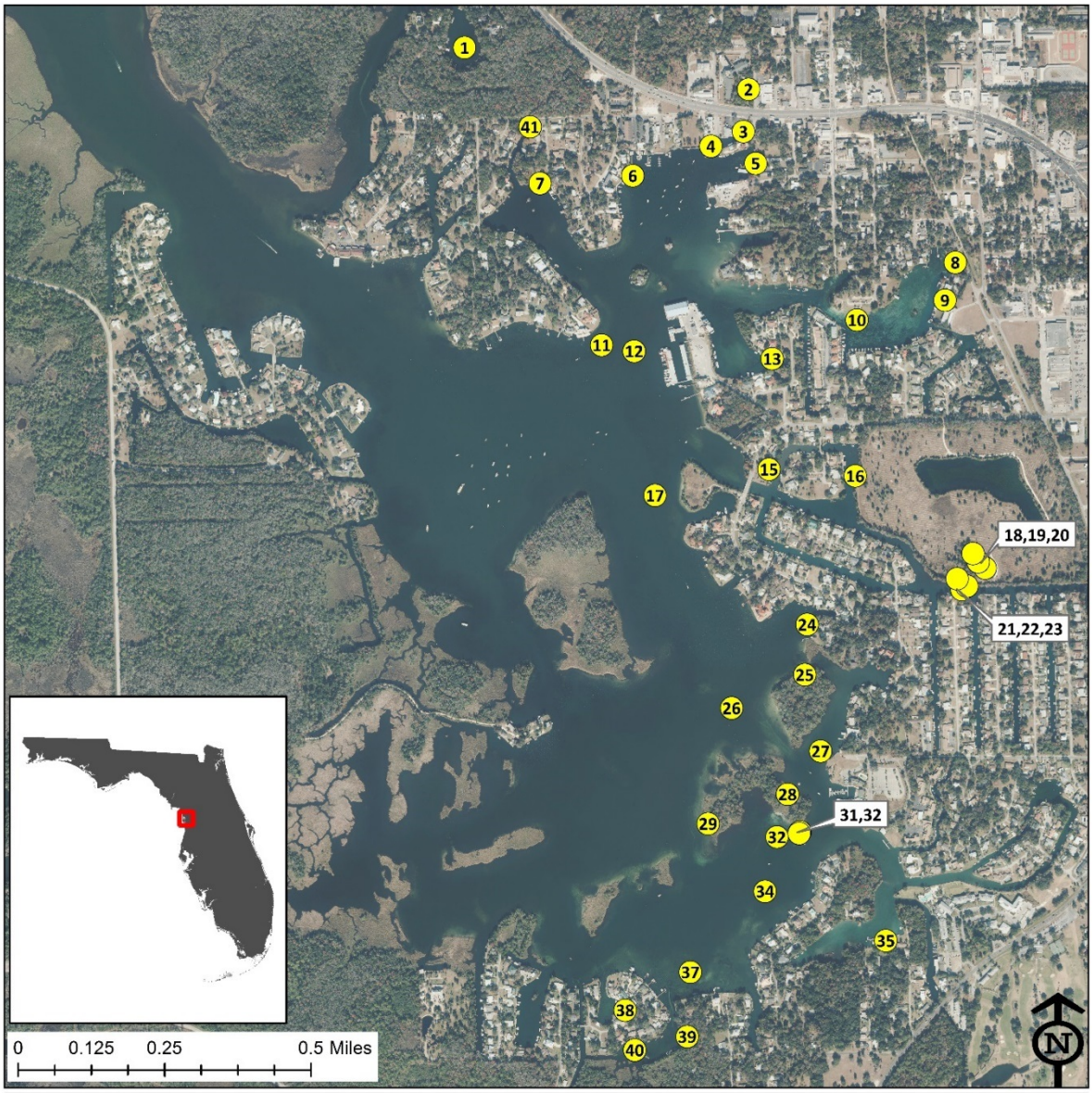
Kings Bay is a spring-fed, tidal bay on the Springs Coast region of southwest Florida. The latest count of springs contributing flow to Kings Bay is greater than 70, with approximately 37 providing significant discharge. **Figure 1** provides a map of these major springs, many of which are known by more than one name (see **Table A.2** for a list of aliases) (Vanasse Hangen Brustlin [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 (TMDL) was developed to establish a water quality restoration threshold of 0.28 milligrams per liter of total nitrogen (mg N/L) in the bay and 0.23 mg N/L of nitrate-nitrogen 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 provides 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.

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 groundwater 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.



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 flow to Kings Bay (VHB 2010)

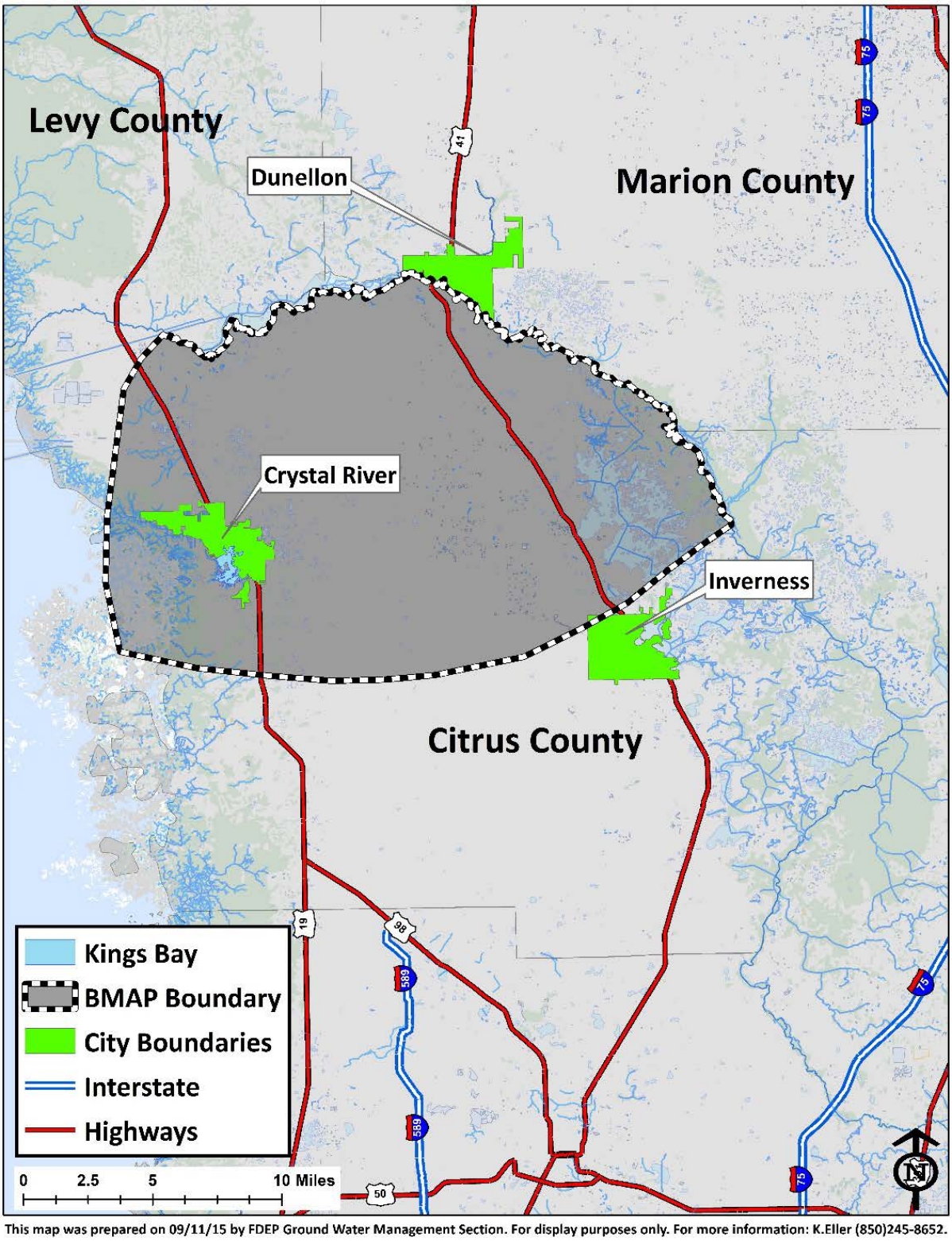


Figure 2: Map of the Kings Bay BMAP contributing area

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 groundwater contributing area for Kings Bay, the UFA is the predominant source of groundwater 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, groundwater in the UFA responds relatively quickly to changes in rainfall and recharge, and groundwater flows directly to springs where conduits are present. Groundwater discharging from springs originates from both nearby source areas and from more distant areas in the springshed. As a result, water flowing from springs includes a mixture of groundwater that has resided in the aquifer for varying amounts of time, ranging from days to several decades.

The predominant source of groundwater 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 U.S. 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 (3.01 to 10 in/yr), and high recharge (10.01 in/yr or greater) (**Figure 3**). The amount of annual recharge affects the transport of nitrogen to the aquifer. Therefore, DEP 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.

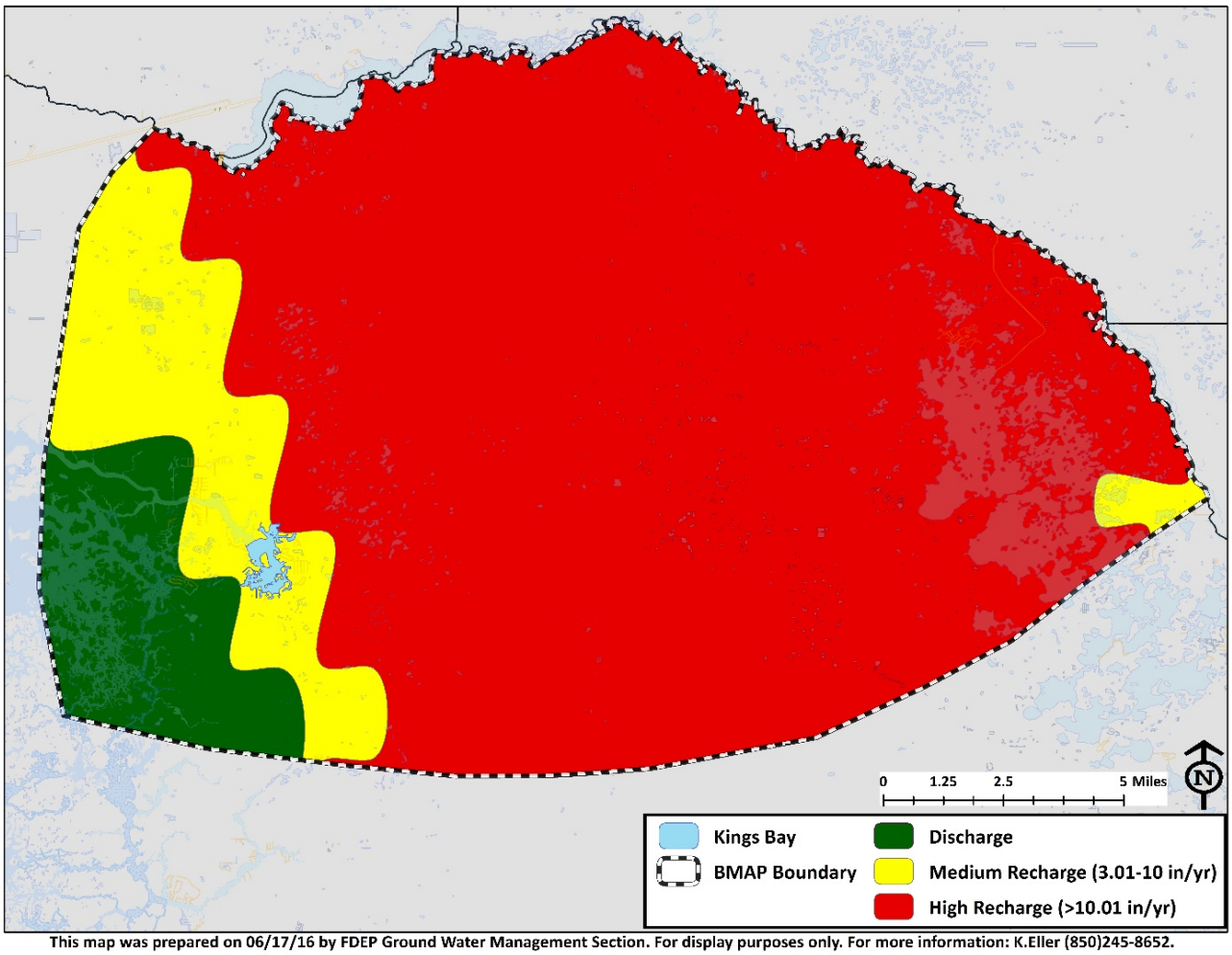


Figure 3: Recharge categories throughout the Kings Bay Springs BMAP area

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

For some nitrogen source categories, calculation of nitrogen inputs was achieved using assumptions and extrapolations, and as a result their estimated nitrogen inputs would be subject to further refinement if more detailed information becomes available. The approach and sources of information used to estimate the annual nitrogen input (in pounds per year [lb-N/yr]) to the land surface for each source category are discussed below.

2.1 Atmospheric Deposition

Atmospheric deposition is largely a diffuse, albeit continual, source of nitrogen. Nitrogen species and other chemical constituents are measured in wet and dry deposition at discrete locations around the U.S. In Florida, the Clean Air Status and Trends Network (CASTNET) has two stations that collect 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 (CMAQ) Modeling System—are combined in a multistep process with NTN wet deposition values to model total deposition in 16-kilometer (km) grid cells.

Multiple TDEP model runs are available, providing atmospheric data for individual and multiple years, with average values calculated for the multiyear models. The TDEP model run used for the NSILT includes data from 2011 to 2013. 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 and 123,373 lb-N/yr, respectively.

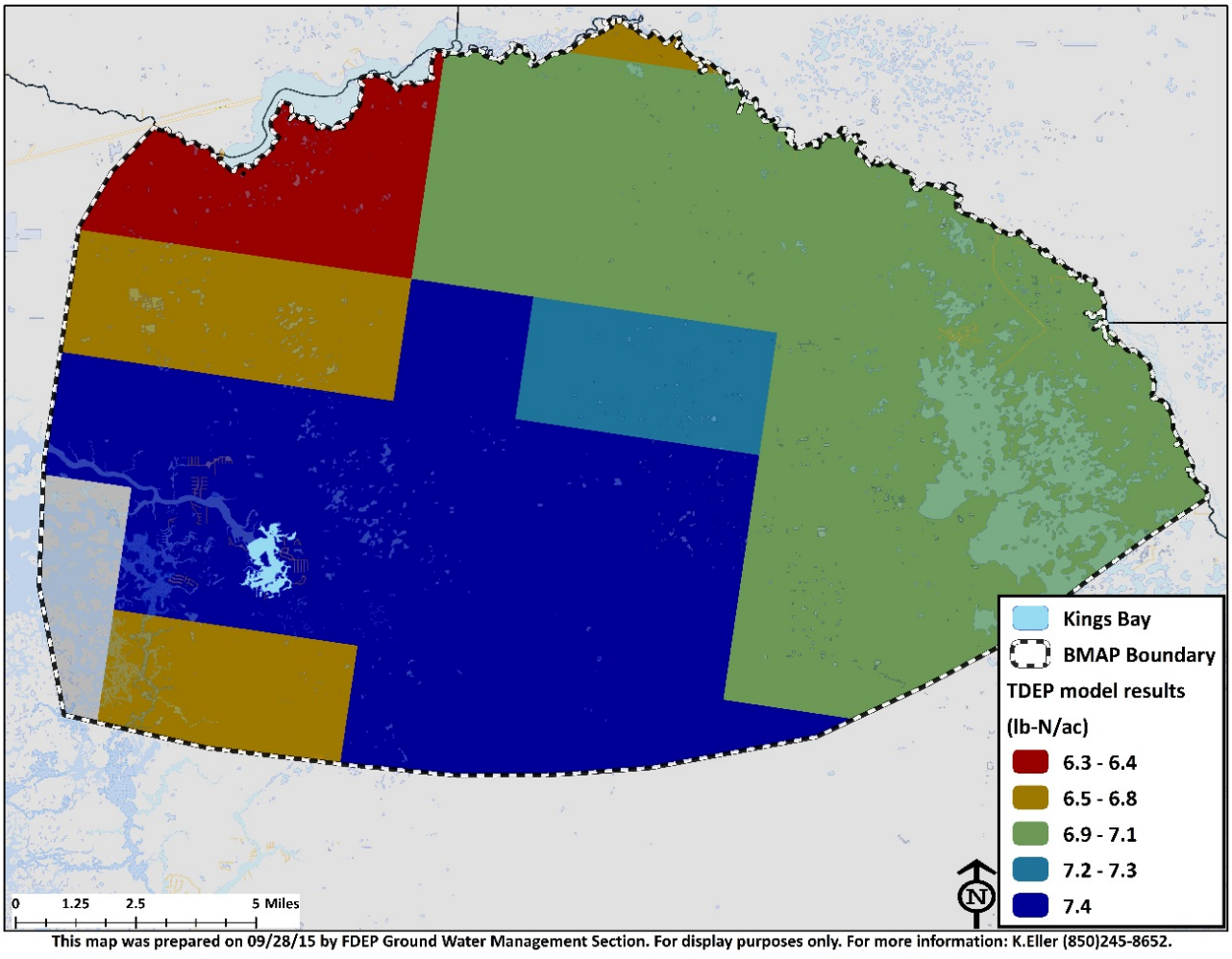


Figure 4: Atmospheric deposition model results used for the NSILT

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 DEP's Wastewater Facility Regulation (WAFR) database and used to calculate average annual input from WWTFs that discharge treated effluent in the BMAP area.

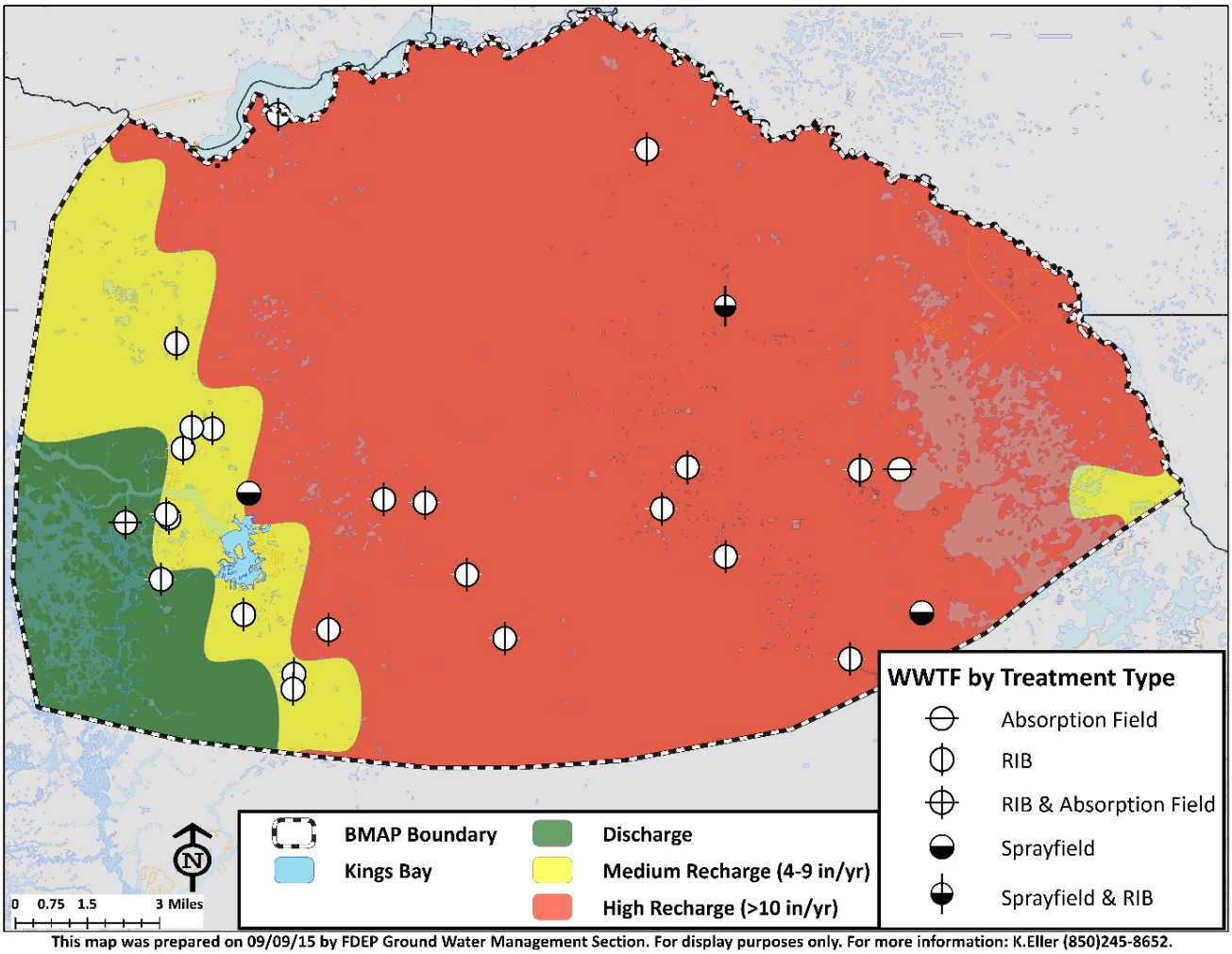


Figure 5: Distribution of WWTFs in the Kings Bay BMAP area

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, DEP 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 the data from 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 estimated TN concentration.

The WWTF data were compiled for each facility and include the most recent complete year of data. The years of data vary with the individual facilities. However, the majority of the data ranges from 2013 to 2014. Most of these facilities discharge all their treated wastewater to various land application sites, although 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 and other uses. These reductions in nitrogen loads from projects may not be reflected in the available WWTF data used in this assessment, but they 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 region 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 are included in **Table A.5** in **Appendix A**. In total, 30,393 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/yr 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 area, one facility was permitted for reuse distribution to a local golf course. Meadowcrest WWTF (FLA011845) is permitted for 2.0 mgd to be used 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, for an annual input of 8,708 lb-N/yr.

2.3 Septic Systems

On-site 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 groundwater (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, a 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 could be mapped.

The model may overestimate the number of septic systems. In some parts of Florida, the land use data used by Hall and Clancy (2009) projected future housing development. 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. As a result, the authors estimated a larger number of septic systems than what is actually in place.

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

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

Additionally, the proximity of sewer lines (provided by City of Crystal River Utilities and Citrus County Utilities) was evaluated. Any estimated septic tank from the model output that was located within 75 feet of a sewer was assumed to not be present because of the proximity to sewer service. This refined data layer was used to estimate the numbers of septic systems for the medium and high recharge rate areas in the BMAP area and is referred to as the "modified Hall and Clancy" dataset (**Figure 6**). This methodology compares favorably with the recently released OSTDS inventory of Citrus County by FDOH. The modified model output used for the NSILT included 30,091 septic systems in the high-recharge areas and 2,695 systems in the medium-recharge areas.

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 Citrus 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 or school), reducing the nitrogen input to the septic system. To estimate the effective number of people per household and the associated nitrogen input to septic systems, population age distribution information was obtained for Citrus County from the 2010 Census. In Citrus County, 48.1 % of the population are of school or working age

and, according to the Bureau of Labor Statistics (http://www.bls.gov/cps), spend 43.5 hours or 25.9 % of the week away from home and therefore are not using the septic system. This effectively reduces the number of people per household using septic systems in Citrus County by 12.5 %, resulting in an adjusted number of 1.95 people per household. For more information, see Appendix **Table A.6**, **Table A.7** and **Table A.8**.

The total population in the BMAP area served by septic systems was estimated by multiplying the estimated people per household (adjusted for actual use) by the number of septic systems. Several literature sources have reported a per capita contribution of 9.012 lb-N/yr, and this value was applied to the estimated number of people using septic tanks in different portions of the BMAP area (U.S. Environmental Protection Agency [EPA] 2002; Toor et al. 2011; Viers et al. 2012). In total, inputs from septic systems was estimated to be 47,431 lb-N/yr in medium recharge rate areas and 529,591 lb-N/yr in high recharge rate areas.

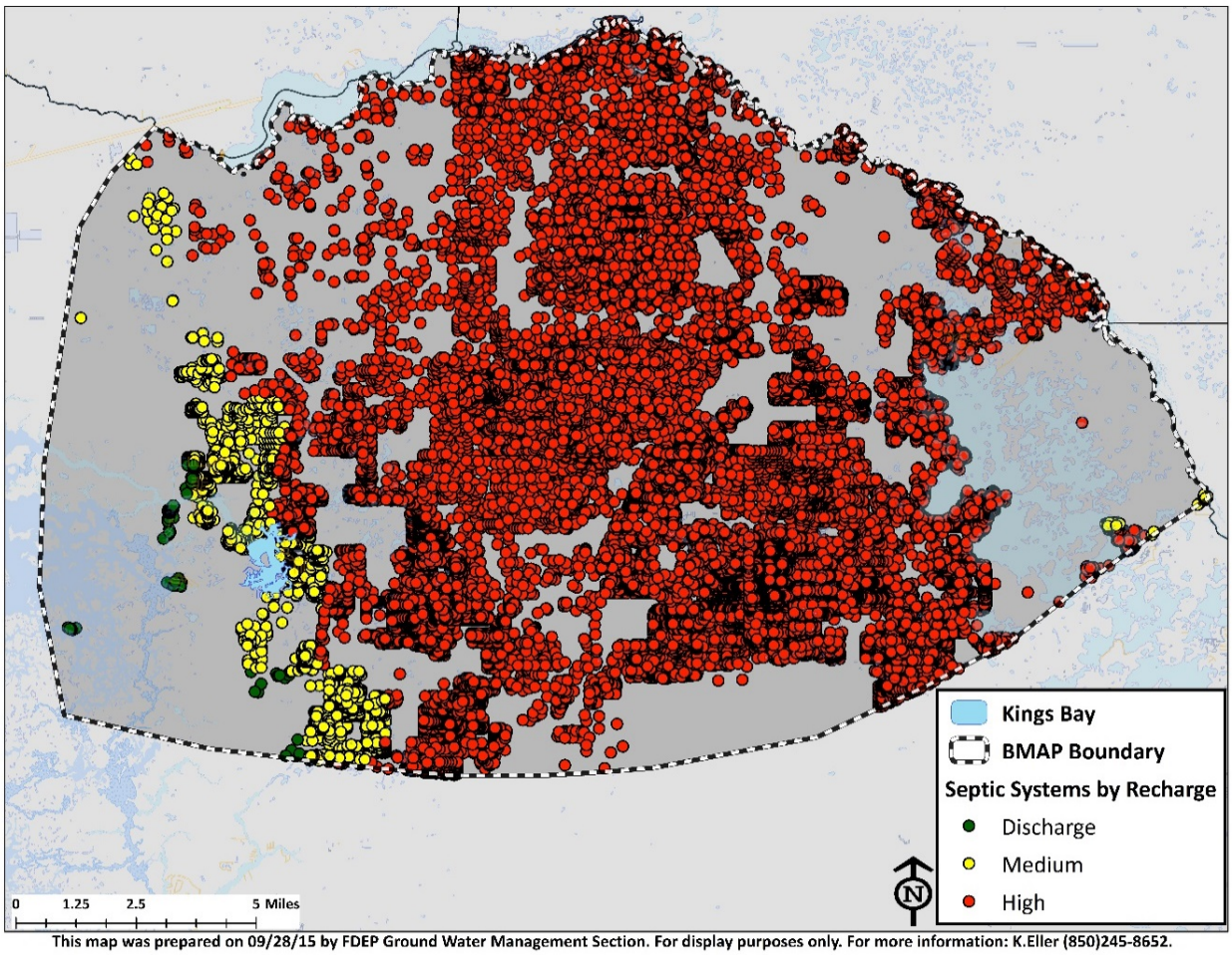


Figure 6: Distribution of septic systems throughout the Kings Bay Springs BMAP area

2.4 Urban Fertilizers

Fertilizers applied to the turfgrass typically found in residential and urban areas (including residential lawns and public green spaces) are referred to as “urban turfgrass” fertilizers (**Figure 7**). These are applied by either the homeowner or a hired lawn service company on residential properties, and on non-residential properties they may be applied by contractors or maintenance staff.

In 2008, a SWFWMD contractor conducted a telephone survey to solicit information about residential fertilizer use in Citrus County and southern Marion County. The results from this survey were used to estimate fertilizer application rates to all urban turfgrass in the BMAP area. According to the survey (Martin 2008), 68 % of the surveyed population applied fertilizer to their own lawns 3 times a year at variable rates that may range as high as 45.56 lb-N/ac (**Table 2)**. Additionally, 32 % of population surveyed hired lawn service companies. Lawn service companies typically apply fertilizer at rates consistent with the Green Industries Best Management Practices (BMP) Manual recommendation of 21.78 lb-N/ac twice a year (Martin 2008; DEP 2010; Downs et al. 2012). Fertilizer application on commercial and public green spaces was assumed to be performed by lawn service professionals or trained staff using application rates and frequencies similar to those recommended in the Green Industries BMP Manual.

2.4.1 Nonresidential Parcels

The acreage of nonresidential land areas to which fertilizer would be applied was estimated prior to calculating the nitrogen inputs from fertilizer application rates listed in **Table 2.** Parcel types assessed using the property appraiser 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 to each parcel contains information on the areas of impervious surfaces (i.e., structures, pavement, etc.), referred to as the "max lot coverage." For each parcel, the max lot coverage 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. **Appendix A**, **Table A.4** and **Table A.9**, provide details of the property appraiser data and max lot coverages, respectively. **Table 3** summarizes these data.

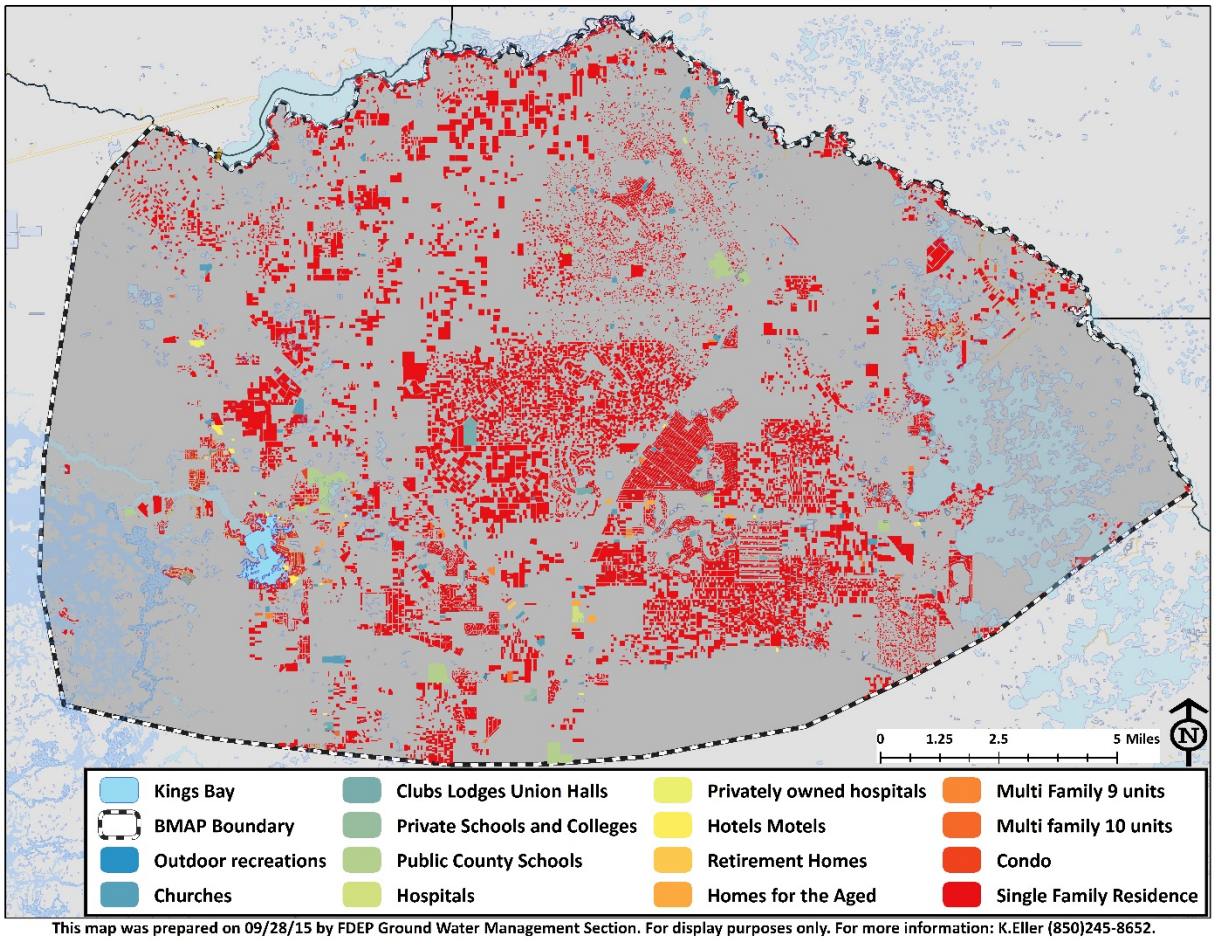


Figure 7: Urban noncommercial lands in the Kings Bay BMAP area according to county property appraiser data

Table 2: Estimated fertilizer application rates based on surveys completed in Citrus and Marion Counties

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

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	6,005
Public County Schools		92.64	4,035
Churches	54.41	184.36	10,401
Hotels/Motels	15.79	5.74	938
Private Schools and Colleges	0.13	4.07	183
Hospitals		13.49	588
Outdoor Recreation	1.86	7.05	388
TOTAL	**84.22**	**433.19**	**22,539**

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, two factors are taken into account: 1) the percentage of their property that a homeowner will fertilize and 2) the probability that a homeowner will use fertilizer.

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

The second factor taken into account is the probability of a homeowner fertilizing their property. Based on socioeconomic studies, property value can be generally correlated with landscape fertilization in a residential setting, with higher valued properties receiving more fertilizer (Kinzig et al. 2005; Law et al. 2004; Zhou et al. 2008; Cook et al. 2012). To apply this factor, the range of property values for single-family homes was evaluated for the 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 based on the literature.

Table 4: Distribution of property value 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 estimated input of nitrogen in fertilizer to the land surface on residential parcels. **Table 5** summarizes these data. **Appendix B** provides more detailed information on the methodology.

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

Parcel Type	Medium-Recharge Fertilizable Land Area (acres)	High-Recharge Fertilizable Land Area (acres)	Total Input (lb-N/yr)
Condo	4	10	1,070
Homes for the Aged	4	46	3,784
Multifamily 10 Units	16	55	5,351
Multifamily 9 Units	12	29	3,078
Retirement Homes		3	202
Single-Family Residence	856	12,695	1,020,956
Vacant Single-Family Residence	283	3,401	
TOTAL	**1,175**	**16,240**	**1,034,441**

2.5 Sports Turfgrass Fertilizers

Sports turfgrass areas fall into two main categories that were evaluated separately: golf courses and sporting facilities such as baseball, football, soccer and other fields where fertilizers are likely applied.

To estimate the nitrogen input attributed to golf courses, surveys completed by golf course superintendents were used to provide basic information about fertilizer practices. Of those surveyed, responses were provided for 44% of the golf courses, with detailed information provided about their fertilizer use (see **Appendix C** for the survey). The results indicate that the golf courses with information apply nitrogen fertilizer at a rate of 43.0 lb-N/ac/yr averaged over the entire golf course (including greens, tees, collars, fairways and rough).

For the remaining 56 % of the golf courses in the area, a statewide annual average application rate 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; DEP 2007). In total, the estimated input of nitrogen from all golf courses in the BMAP was 188,589 lb-N/yr. **Table 6** summarizes the estimated input to the land surface from each golf course in the BMAP area.

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

† = Facility receives reuse water in addition to applied fertilizer.
* = Provided 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

Sports facilities were assessed based on PA land use data. The parcel types likely to contain sports facilities were identified and evaluated based on aerial imagery. In total, 183 acres of land were associated with sports facilities in the high-recharge area. At the time of this analysis, no sports facilities were located in the medium-recharge area. It is assumed that turf areas at sports facilities are fertilized at rates applied by lawn service companies as described in **Section 2.4**. This results in an estimated input of 7,990 lb-N/yr at sports facilities. **Table 7** summarizes the sports turfgrass fertilizer applications.

Table 7: Summary of sports turfgrass fertilizer applications of nitrogen

Land Type	Input in High Recharge Areas (lb-N/yr)	Input in Medium Recharge Areas (Lb-N/yr)	TOTAL Input (lb-N/yr)
Golf Courses	160,679	27,911	**188,589**
Sports Facilities	7,990		**7,990**
TOTAL	**168,669**	**27,911**	**196,580**

2.6 Livestock Waste

Livestock operations occur in a small percentage of the Kings Bay BMAP area, with most of the land dedicated to cow-calf operations. Agricultural practices specific to this livestock management were obtained through meetings with agricultural producers and stakeholders. Typical cattle stocking rates in Citrus County are estimated as 1 cow per 6 to 8 acres of pasture (Public stakeholder discussion, Lecanto, FL, July 2014). The estimation of pasture acreage was based on property appraiser data and included improved, semi-improved, and native pastures. **Table 8** lists the estimated pasture acreage and the associated cattle populations in the BMAP area.

Table 8: Property appraiser 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 U.S. Department of Agriculture (USDA), which publishes a Census of Agriculture (CoA) every five years. This comprehensive report provides summary data on the agricultural practices and livestock populations for each state and county in the U.S. The 2012 CoA report was used to provide data on livestock populations for this assessment. However, since the CoA reports entire county data, assumptions of livestock populations in the BMAP area were made based on land use coverage.

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 percentages of county wide livestock area that occur in the BMAP area and the high and medium recharge areas in it.

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 9**). 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.10** lists total county populations from the CoA.

Nitrogen waste factors were assigned to each animal type (in lb-N/day per animal) and applied to the estimated livestock populations to calculate the nitrogen input to the land surface, as follows: cattle, 0.337; broiler chickens, 0.159; layer chickens, 0.003; goats, 0.035; hogs, 0.190; sheep, 0.198; turkeys, 0.006; and horses, 0.273 (Goolsby et al. 1999; Katz et al. 1999; Chelette et al. 2002; Ruddy et al. 2006; Meyer 2012; Sprague and Gronberg 2013). The estimated TN input to the land surface from livestock waste is listed in **Table 10** for the medium and high recharge rate parts of the BMAP area.

Table 9: WMD land use percentages and miscellaneous livestock population data

Land Category	Land Area (acres)	Land Use %	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 10: Estimated nitrogen applied (lb-N/yr) 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 Area	**350,998**	**7,550**	**727**	**4,313**	**5,082**	**7,538**	**22**	**43,176**	**419,406**

2.7 Farm 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. The 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 11** 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.

Table 11: Summary of crop types, assumed nitrogen application rates, and estimated inputs inthe 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

2.8 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 estimated total nitrogen input from all sources is 2.94 million lb-N/yr. Atmospheric deposition contributed 32 % of the TN input to the land surface in the BMAP area. Other sources, in order of decreasing contributions of nitrogen input to the land surface, included septic systems (20 %), farm fertilizers (14 %), livestock waste (11 %), urban turfgrass fertilizers (12 %), sports turfgrass fertilizer (7 %) and WWTF land application sites (1%).

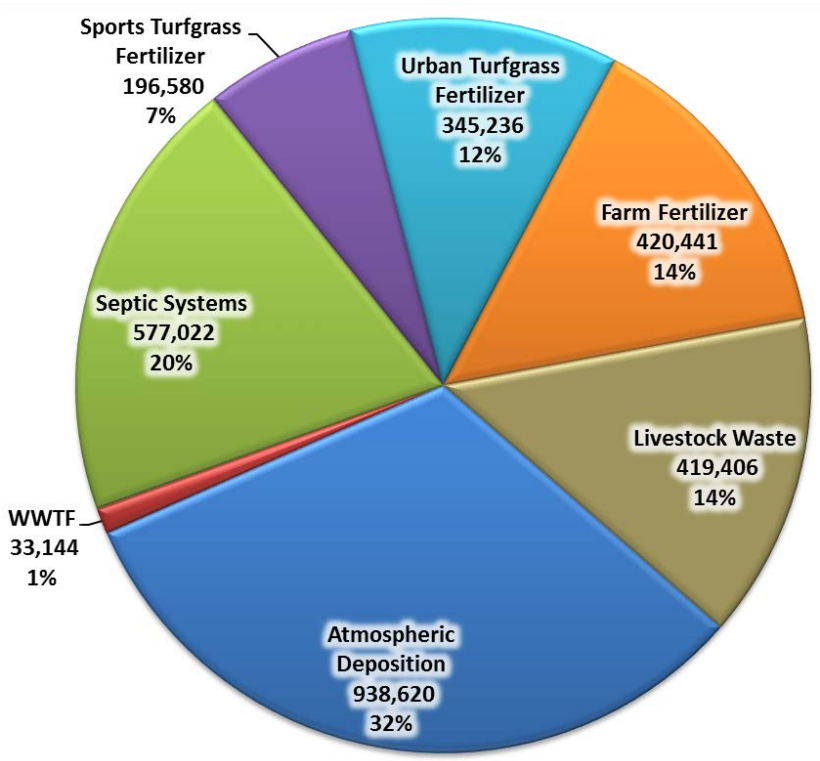


Figure 8: Relative estimated nitrogen inputs to the land surface in the Kings Bay Springs BMAP area from major anthropogenic source categories in lb-N/yr

3. Nitrogen Attenuation and Loading to Groundwater

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

To estimate the amount of nitrogen loading to the aquifer in the Kings Bay BMAP area area, DEP applied two nitrogen attenuation factors. The specific biochemical attenuation factor (BAF) is applied to each nitrogen source category to account for biochemical processes that remove or transform the different forms of nitrogen. The hydrogeological attenuation factor (HAF) accounts for spatial variations in hydrogeological properties that affect the rate of water infiltrating through geologic media to recharge the UFA. Both factors control the amount of nitrogen reaching the UFA annually and in the movement of groundwater to the springs of Kings Bay.

3.1 Biochemical Attenuation

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

Specific BAFs were used to account for the various processes that affect the movement of nitrogen from each source category in the subsurface and were obtained through an extensive literature review of relevant studies conducted in Florida as well as other areas with similar environmental characteristics. Additionally, research scientists in Florida (UF-IFAS, other universities, and USDA Agricultural Research Service [ARS]) as well as local stakeholders provided additional guidance. The biochemical attenuation factors, listed in **Table 12**, represent the average percentage of the nitrogen attenuated or removed by subsurface processes and not available to leach to groundwater.

As a first step in estimating loading to groundwater, the nitrogen inputs at the land surface from each category, discussed previously, are multiplied by their respective biochemical attenuation factors (**Table 12**). For example, atmospheric deposition has an average nitrogen attenuation of

90 % (mainly from uptake by vegetation). This means that 10 % of the atmospheric nitrogen input to the land surface has the potential to infiltrate to groundwater.

Table 12: BAFs applied to the nitrogen input calculations

* = Both sports and urban turfgrass.
** These percentages represent the average amount of nitrogen removed by the environment over varying soil characteristics.

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

3.2 Hydrogeological Attenuation

Nitrogen (usually in the form of nitrate) that is not attenuated by biochemical attenuation processes can leach to groundwater. Leaching to groundwater is a function of the properties of the soil and unsaturated zone, such as composition (particle size, organic matter content), texture, drainage, wetness, and thickness. The rate of groundwater recharge (from rainfall or irrigation water) ultimately controls how rapidly nitrogen moves from below the root zone to the UFA. The amount of water recharging the UFA each year also depends on the amount of rainfall, evapotranspiration, and runoff, in addition to subsurface hydrogeological properties.

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

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

Additional nitrogen attenuation factors related to recharge rates were arbitrarily assigned as follows: 90 % in high recharge rate areas (≥10 in/yr), and 50 % in medium recharge rate areas (3 to 10 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 % is assumed to reach the aquifer annually in medium rate recharge areas. These attenuation factors are based on the recharge characteristics specific to the hydrogeological conditions in the Kings Bay BMAP area.

3.3 Estimated Nitrogen Loads to Groundwater

Table 13, **Table 14**, and **Table 15** 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 592,440 lb-N load to the UFA in the BMAP area annually. This represents 20 % 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 42 % of the total load to groundwater, followed by urban turfgrass fertilizers (15%), atmospheric deposition (13%) and farm fertilizer (12%).

Figure 9 shows the distribution of annual loads of nitrogen to the UFA by source category. The NSILT results indicate that most of the nitrogen load to groundwater 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 human 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 groundwater for the medium and high recharge rate areas, including a breakdown for each source category. The majority of the nitrogen loading to groundwater in the BMAP area (93%) occurs in high recharge rate areas. For both the medium and high recharge rate areas, the dominant sources of nitrogen loading to groundwater are septic systems and urban fertilizers.

Table 13: Estimated inputs to the 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	Sports Turfgrass Fertilizer	Urban Turfgrass Fertilizer	Farm Fertilizer	Livestock Waste	Total
High	815,247	23,593	6,800	8,708	529,591	168,669	319,121	358,121	245,565	**2,475,979**
Medium	123,373	2,751			47,431	27,911	25,551	62,319	173,841	**463,178**
TOTAL	**938,620**	**26,344**	**6,800**	**8,708**	**577,022**	**196,580**	**345,236**	**420,441**	**419,406**	**2,939,157**

Table 14: 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	Sports Turfgrass Fertilizer	Urban Turfgrass Fertilizer	Farm Fertilizer	Livestock Waste	Total
BAF	***90 %***	***25 %***	***60 %***	***75 %***	***50 %***	***70 %***	***70 %***	***80 %***	***90 %***	
High	81,525	17,695	2,720	2,177	264,795	50,601	95,905	71,624	24,556	**611,599**
Medium	12,337	2,063			23,716	8,373	7,665	12,464	17,384	**84,003**
TOTAL	**93,862**	**19,758**	**2,720**	**2,177**	**288,511**	**58,974**	**103,571**	**84,088**	**41,941**	**695,601**

Table 15: Estimated load to groundwater 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	HAF	Atmospheric Deposition	WWTF§	Septic Systems	Sports Turfgrass Fertilizer	Urban Turfgrass Fertilizer	Farm Fertilizer	Livestock Waste	Total
High	90 %	73,372	20,333	238,316	45,541	86,315	64,462	22,101	**550,439**
Medium	50 %	6,169	1,032	11,858	4,187	3,833	6,232	8,692	**42,001**
TOTAL		**79,541**	**21,364**	**250,174**	**49,727**	**90,148**	**70,694**	**30,793**	**592,440**

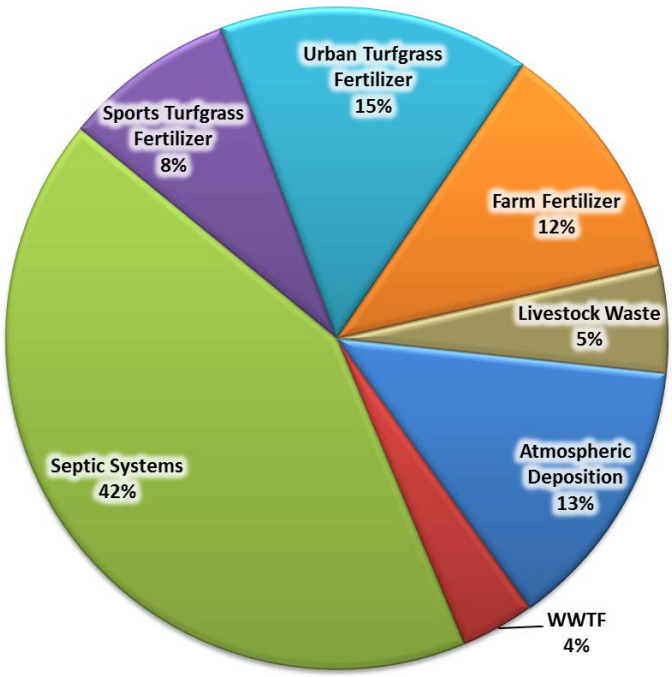


Figure 9: Relative contributions of nitrogen loading to groundwater based on source category in the Kings Bay BMAP area

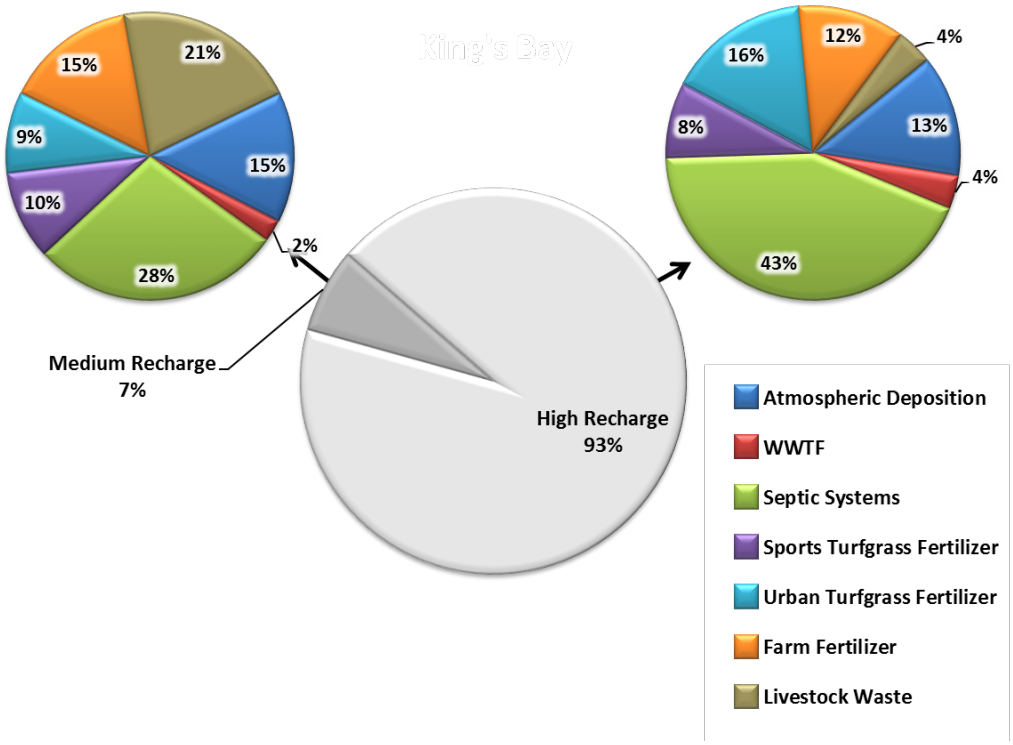


Figure 10: Estimated annual nitrogen loading to groundwater by recharge category

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

The pie charts in **Figure 10** only provide information about the relative estimated contribution of nitrogen loading to groundwater 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 groundwater 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.

Given the relatively large range in nitrogen attenuation for each source, DEP 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 16** lists the potential range in nitrogen attenuation for each source type.

Table 16: 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	50 %	75 %	85 %
Septic Tanks	40 %	50 %	75 %
Livestock Operations	80 %	90 %	95 %
Farm Fertilizers	50 %	80 %	90 %
Urban Fertilizers	50 %	70 %	85 %

Using the range of nitrogen attenuation factors in **Table 16**, DEP estimated the corresponding range of nitrogen loading to groundwater 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 groundwater greatly exceeds the target load estimated for the TMDL for the Kings Bay springs.

Based on the estimated discharge of the Kings Bay springs, which is 466 cubic feet per second (cfs), and the adopted nitrate-nitrogen TMDL for the springs of 0.23 mg/L, the target nitrogen

load for the Kings Bay BMAP area is 210,648 lb-N/yr (VHB 2010; Bridger 2014). Using the high-level nitrogen attenuation factors for each source, the minimum estimated load to groundwater in the BMAP area is 301,809 lb-N/yr, which is considerably higher than the TMDL target (**Figure 12**).

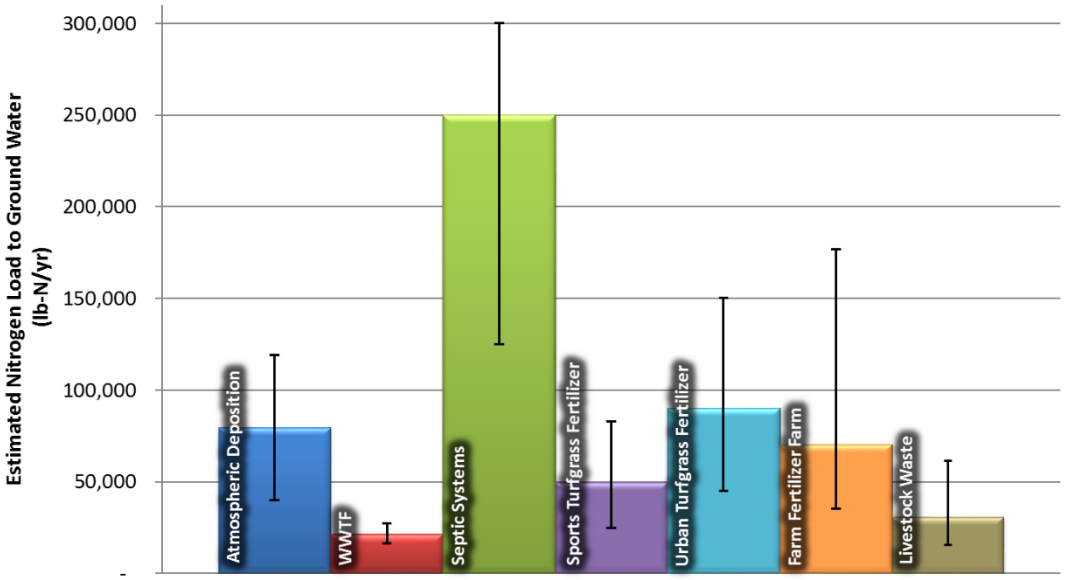


Figure 11: Influence of the range of attenuation factors on estimated nitrogen loads to groundwater from each source category in the Kings Bay BMAP area

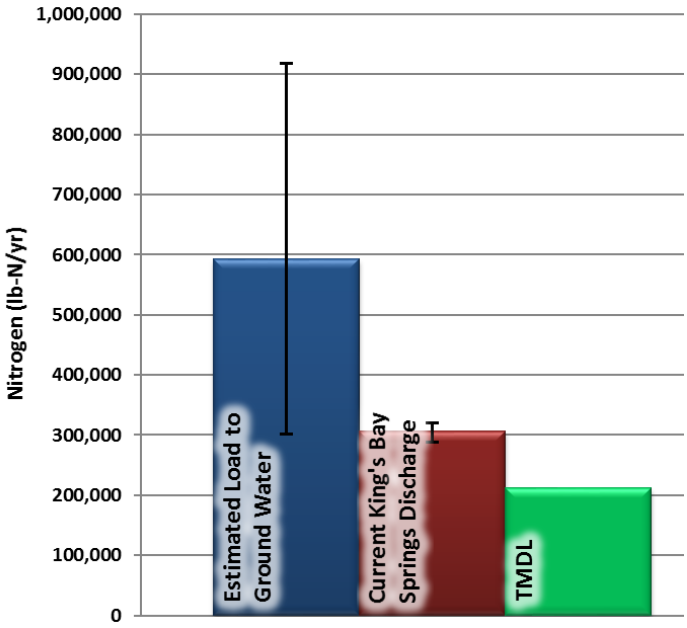


Figure 12: Estimated nitrogen load to groundwater compared with current nitrogen discharging from the springs of Kings Bay and TMDL goal

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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

Name	List of Aliases	2009 Average Discharge (cfs)
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
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	29,081	2,625	330
1	Single Family Residential	24,685	1,891	202
3	Multi Family 9 Units	61	24	
4	Condo	25	8	23
6	Retirement Homes	9		
8	Multi Family 10 Units	128	36	
30	Florist Greenhouses	0.4		
38	Golf Courses Driving Ranges	2,154	198	
39	Hotels Motels	58		
50	Improved Ag	3,726	2,537	
51	Cropland Soil Class 1	1,319	11	
52	Cropland Soil Class 2	7		
53	Cropland Soil Class 3	53		
60	Grazing Land	1,488	381	
61	Grazing Land	2,817	316	
62	Grazing Land	3,133	491	41
63	Grazing Land	1,928	13	
66	Orchard Groves Citrus	23		
67	Poultry Bees Fish Rabbits	31	13	
68	Dairies Feed Lots	25		
69	Ornamentals Misc Ag	148		
71	Churches	102		
72	Private Schools and Colleges	0		
74	Homes for the Aged	77	8	
77	Clubs Lodges Union Halls	29	22	
83	Public County Schools		21	
85	Hospitals			
97	Outdoor Recreation	3		
71	Churches	102		

Table A.5: WAFR data used to calculate annual average input for WWTFs

* TN data estimated based on available NO_3 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.6: 2010 Labor statistics data for Citrus County

Category	Citrus County
Total Labor Force	52,847
Employed Labor Force	45,594
Unemployed Labor Force	7,253

Table A.7: 2010 Census population data for Citrus County

Population Category	Citrus County
Under 18	22,394
18 to 64	73,801
65 or older	45,041
Total	141,236

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

Population Category	Equation	Citrus County
Non-working	= 18 to 64 population – employed labor force	28,207
Retired	= 65 or older	45,041
School	= under 18	22,394
Work	= employed labor force	45,594

Table A.9: 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 %	

Zoning Code	Zoning Description	% Maximum Lot Coverage	Exception
PSO	Professional Services/Office District	0.7 %	
PSO MH	Professional Services/Office District with Mobile Homes	0.7 %	
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.10: 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.11: 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. Estimating Fertilized Residential Acreages within the Springs Coast of Florida

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

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

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

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

large parcel owners will fertilize their entire property. A parcel with a pervious acreage greater than 1 can be identified using an if/then statement in the field calculator and assigning a pervious acreage of 1, while all remaining parcels maintain the previously calculated pervious acreages.

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

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

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

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

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

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

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

The final factor used to estimate the estimated fertilizable acreage is the probability that a homeowner will fertilize a property, which is based on property values (Kinzig et al. 2005; Zhou et al. 2008). According to several socioeconomic studies of fertilizer usage by homeowners, homeowners with high property values are more likely to fertilize their lawns than homeowners with low property values. Property appraiser data for single-family residential properties were used to assess the ranges of high, medium- and low property values for each Springs Coast county. The single-family residential parcels (DOR code = 1) were selected for each county using a definition query, and the data were exported from GIS to Excel. A histogram was completed on these data to determine the frequency of parcels within different assessed value

ranges. **Table B.4** and **Figure B.1** show the distribution of the number of single-family parcels for various ranges of property values in Citrus, Hernando, and Pasco Counties.

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

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

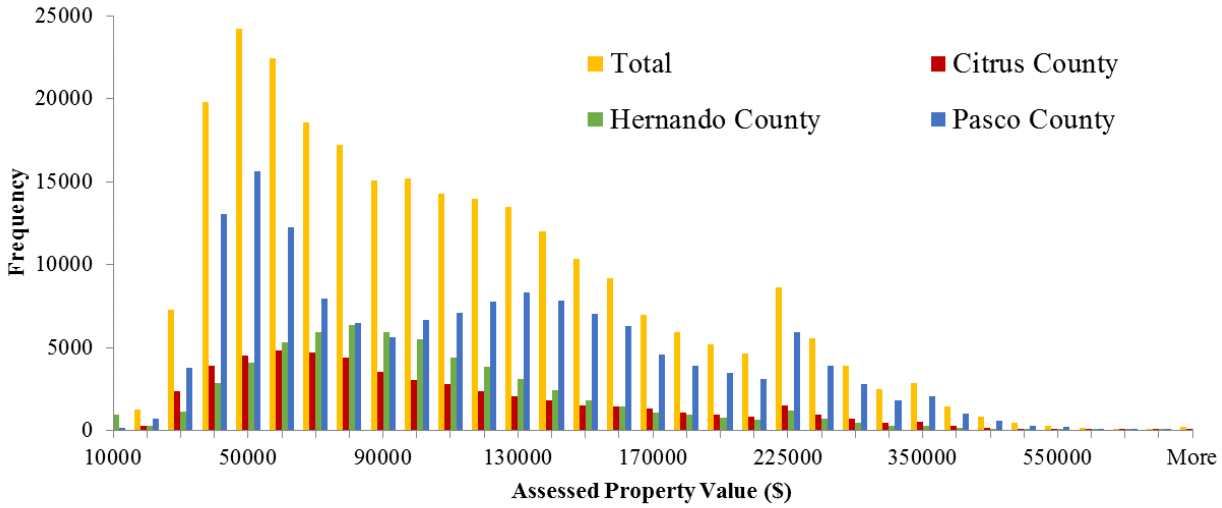

Figure B.1: Parcel frequency based on property value for single-family residential properties in the Springs Coast counties

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

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

Appendix C: Golf Course Questionnaire

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

This survey is designed to gather data on nitrogen (N) application rates. All information is optional, remains confidential and is not utilized for any regulatory purposes.
This form is available electronically, for an e-mail version please contact us at the addresses listed at the bottom.

CONTACT INFORMATION

Name

Are you the course Superintendent?
◯ 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 D: Comparison of the NSILT Methods and Results with Jones et al. (1998)

In 1994, the SWFWMD Ambient Ground Water Quality Monitoring Program conducted a study to determine the sources of increasing nitrate concentrations in the springs of Kings Bay; the study was later updated (Jones et al. 1998). The study objectives were to delineate the areas where nitrate was entering the aquifer system, identify the land uses contributing nitrate, and determine management actions to slow or reduce nitrate loading to groundwater in the King's Bay contributing area.

This appendix compares the differences in methods and estimated nitrogen inputs between the SWFWMD study and those from the DEP 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 is 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 equals 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

- The NSILT uses multiyear data from the TDEP model. The nitrogen input to the land surface from atmospheric deposition is 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 calculated a total of 1,146 tons or 2,292,000 pounds of nitrogen in the study area from this source.

- The SWFWMD number, which is larger 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). An average of 1.95 people contribute to each septic system in Citrus County. With an annual input of 9.012 lb-N/person, this equals an input of 19.37 lb-N/yr per system. There are 32,786 septic systems in the BMAP area, for a total input of 577,022 lb-N/yr.

- The Jones et al. (1998) calculation was based on an average of 3 people per septic system and an annual input of 53 lb-N/yr per system. The authors estimated 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 includes almost double the number of septic systems, compared with Jones et al. (1998). This could be attributed to the more accurate counting methods used 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) number to be 335,546 lb-N/yr higher than the NSILT estimate.

Urban Turf Fertilizers

- The NSILT relies on regional fertilizer application rates (ranging from 0 to 0.8 lb-N/1,000 sq ft) applied on the pervious land area associated with urban land uses. The TN input is 345,236 lb-N/yr over the 5,162 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 Jones et al. (1998) number (a difference of 292,764 lb-N/yr) is caused by two factors: increased land area and higher annual application rates. This is caused by the increased data availability both on urban land uses and application practices used for the NSILT.

Sports Turf Fertilizer

- For the NSILT, there are 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. Additional calculations for other sporting facilities equal 17,059 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. A total of 486,000 lb-N/yr is applied on golf courses.

- The difference (289,420 lb-N/yr) between the two results is largely applicable to the application rates used in both studies. While the NSILT includes a larger land area, the application of nitrogen was a third of the rate used by Jones et al. (1998).

WWTFs

- The NSILT uses 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 input is 39,102 lb-N/yr. The loadings from domestic WWTF residuals and septage are not included in the assessment because 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 combined 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 used 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 used 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. The 18,501 ac of cropland and pastures in the BMAP area contribute 420,441 lb-N/yr.

- Jones et al. (1998) used fertilizer sales data to calculate the input of nitrogen from agricultural fertilizers; 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 within the BMAP boundary. Cattle populations are calculated 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 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 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 groundwater.

- Jones et al. (1998) calculated 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 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 calculates TN inputs of 2,939,157 lb-N/yr to the land surface (178,753 ac) in the King's Bay BMAP area, or an average of 16 lb-N/ac. The three sources that contribute the largest percentages of nitrogen inputs to the land surface are atmospheric deposition (32 %), septic systems (20 %), and urban fertilizers (urban and sports trufgrass) (19 %). **Table C.1** compares the relative percentages computed 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 groundwater generated from the NSILT for the King's Bay BMAP will be used to determine where present-day nitrogen loading to groundwater can be reduced to achieve the restoration of King's Bay and its springs.

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

N Loading Category	NSILT (2015)	Jones et al. (1998)
Atmospheric Deposition	32 %	40 %
Septic Systems	20 %	19 %
WWTFs	1 %	5 %
Urban Turf Fertilizers	12 %	11 %
Sports Turf Fertilizers	7 %	9 %
Farm Fertilizers	14 %	6 %
Livestock Waste	14 %	6 %
Stormwater	0 %	3 %