FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION

Division of Environmental Assessment and Restoration, Water Quality Evaluation and TMDL Program

SOUTHWEST DISTRICT • SPRINGS COAST BASIN

FINAL TMDL REPORT

Nutrient TMDL for Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H)

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Florida Department of Environmental Protection, Bureau of Watershed Restoration

TMDL Program
http://www.dep.state.fl.us/water/tmdl/index.htm

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http://www.dep.state.fl.us/legal/Rules/shared/62-303/62-303.pdf

Florida STORET Program
http://www.dep.state.fl.us/water/storet/index.htm

2012 Integrated Report
http://www.dep.state.fl.us/water/docs/2012_integrated_report.pdf

Criteria for Surface Water Quality Classifications
http://www.dep.state.fl.us/legal/Rules/shared/62-302/62-302.pdf

Basin Status Report and Water Quality Assessment Report: Springs Coast
http://www.dep.state.fl.us/water/basin411/springscoast/status.htm

Florida's Springs
http://www.floridasprings.org/

U.S. Environmental Protection Agency, National STORET Program

Region 4: TMDLs in Florida
http://www.epa.gov/region4/water/tmdl/florida/

National STORET Program
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Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Load for nutrients, which were determined to contribute to the degraded condition of Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. These waterbodies are located in the Crystal River/Kings Bay Planning Unit of the Springs Coast Basin (**Figure 1.1**). They were verified by the Florida Department of Environmental Protection as impaired by nutrients (algal mats) and were included on the Verified List of impaired waters for the Springs Coast Basin that was adopted by Secretarial Order in February 2012. The TMDL establishes the allowable threshold of nutrients (specifically nitrate) in Kings Bay, Hunter Spring (also locally known as Hunters Spring), House Spring, Idiot's Delight Spring, Tarpon Spring (also known as Tarpon Hole Spring), and Black Spring that can be used as a restoration target. Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring support a complex aquatic ecosystem and together are important cultural and economic resources for the state. This report will be used as the basis for discussions during the development of the Basin Management Action Plan for addressing elevated nitrate concentrations.

For assessment purposes, the Department has divided the waters of the state into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. Kings Bay is WBID 1341 (**Figure 1.2**). Hunter Spring is WBID 1341C, House Spring is WBID 1341D, Idiot's Delight Spring is WBID 1341F, Tarpon Spring is WBID 1341G, and Black Spring is WBID 1341H. **Figures 1.3** and **1.4** show the impaired WBIDs and the locations of the springs within them.

1.2 Identification of Waterbody

1.2.1 Crystal River/Kings Bay (WBID 1341)

Crystal River/Kings Bay is a tidally influenced, spring-fed system located approximately 75 miles north of Tampa in Citrus County, Florida, and adjacent to the city of Crystal River (**Figure 1.2**). The Crystal River/Kings Bay spring complex includes more than 70 springs, which account for 99% of the fresh water entering 600-acre Kings Bay (Wetland Solutions Inc. 2013). Collectively, Kings Bay's numerous springs and countless seeps form the sixth largest spring system in Florida, by discharge (Southwest Florida Water Management District [SWFWMD] 2011). The tidally influenced bay is the headwater of the Crystal River, which forms at the northwest corner of the bay.

While other spring systems within the state are tidally influenced, the large Kings Bay embayment makes this system unique. On average the bay ranges in depth from 3 to 10 feet. Shallow depths allow warming and greater sunlight penetration, resulting in an increased photozone and accelerated plant growth (Livingston 2001). Water circulation in Kings Bay has been monitored through dye studies and modeled, and two distinct water circulation regimes within the bay have been identified. Water in the northern part of the bay flows and flushes more rapidly than water in the main portion of the bay to the south, and this northern portion has a more direct connection to the Crystal River. Researchers have also found that these two flow regimes have differences in specific conductance (a measurement of salinity), with the northern area and the springs within it having lower specific conductance than the larger bay area to the south and the springs in that area.

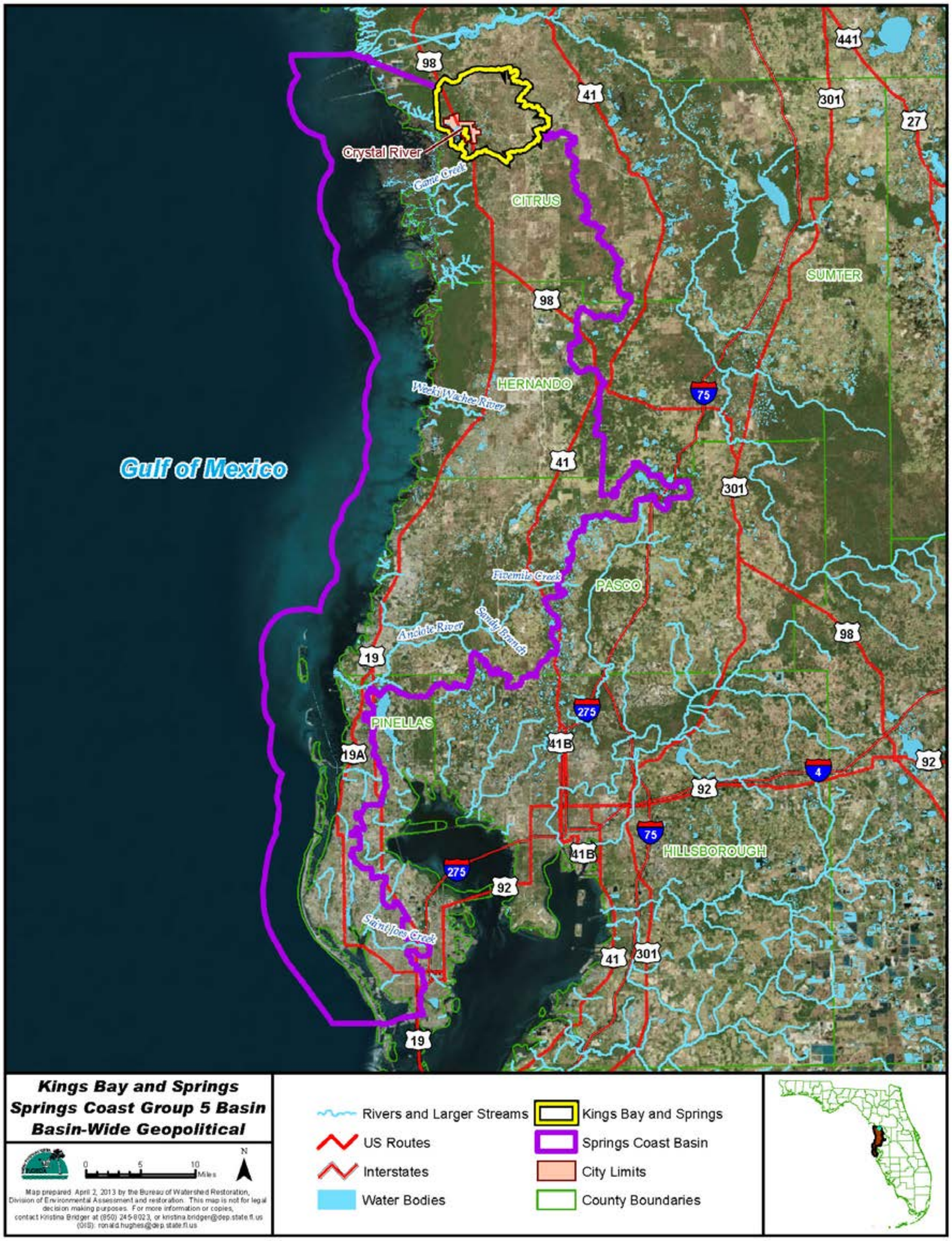

Figure 1.1. Location of the Kings Bay Watershed (WBID 1341) in the Springs Coast Basin with Major Hydrologic and Geopolitical Features in the Area

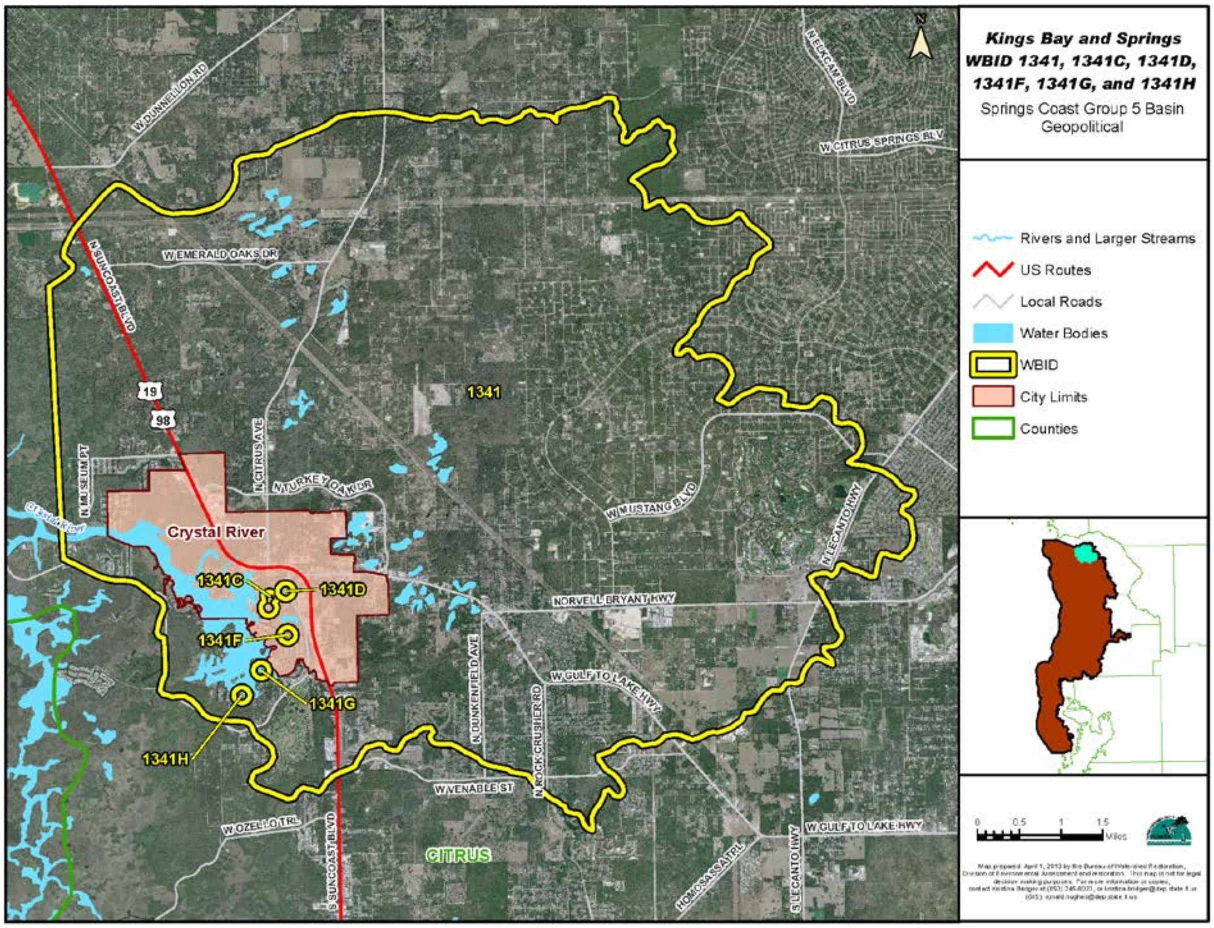

Figure 1.2. Location of the Kings Bay Watershed (WBID 1341) in Citrus County with Major Hydrologic and Geopolitical Features in the Area

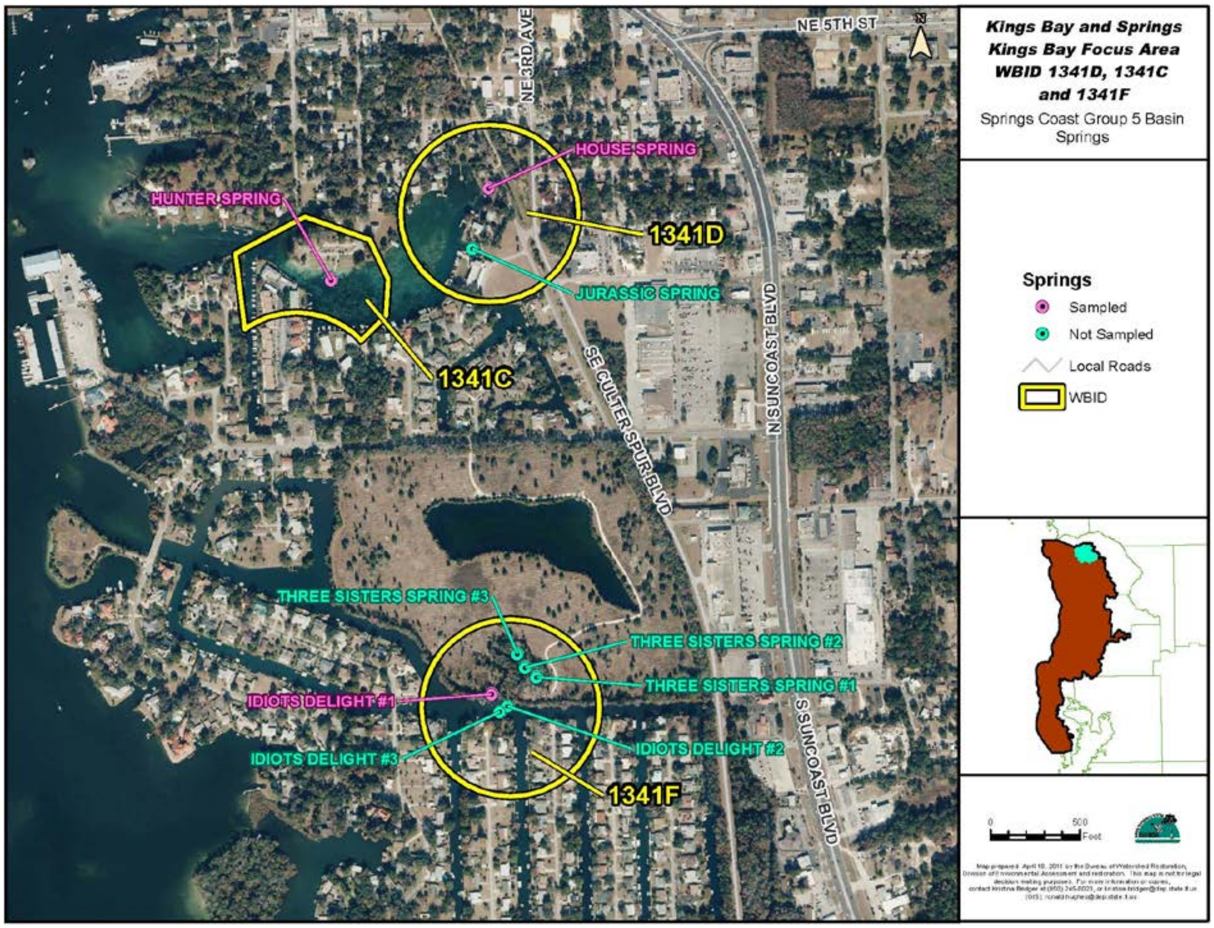

Figure 1.3. Sampled Springs (in Red) and Unsampled Springs (in Turquoise) for Hunter Spring (WBID 1341C), House Spring (WBID 1341D), and Idiot's Delight Spring (WBID 1341F)

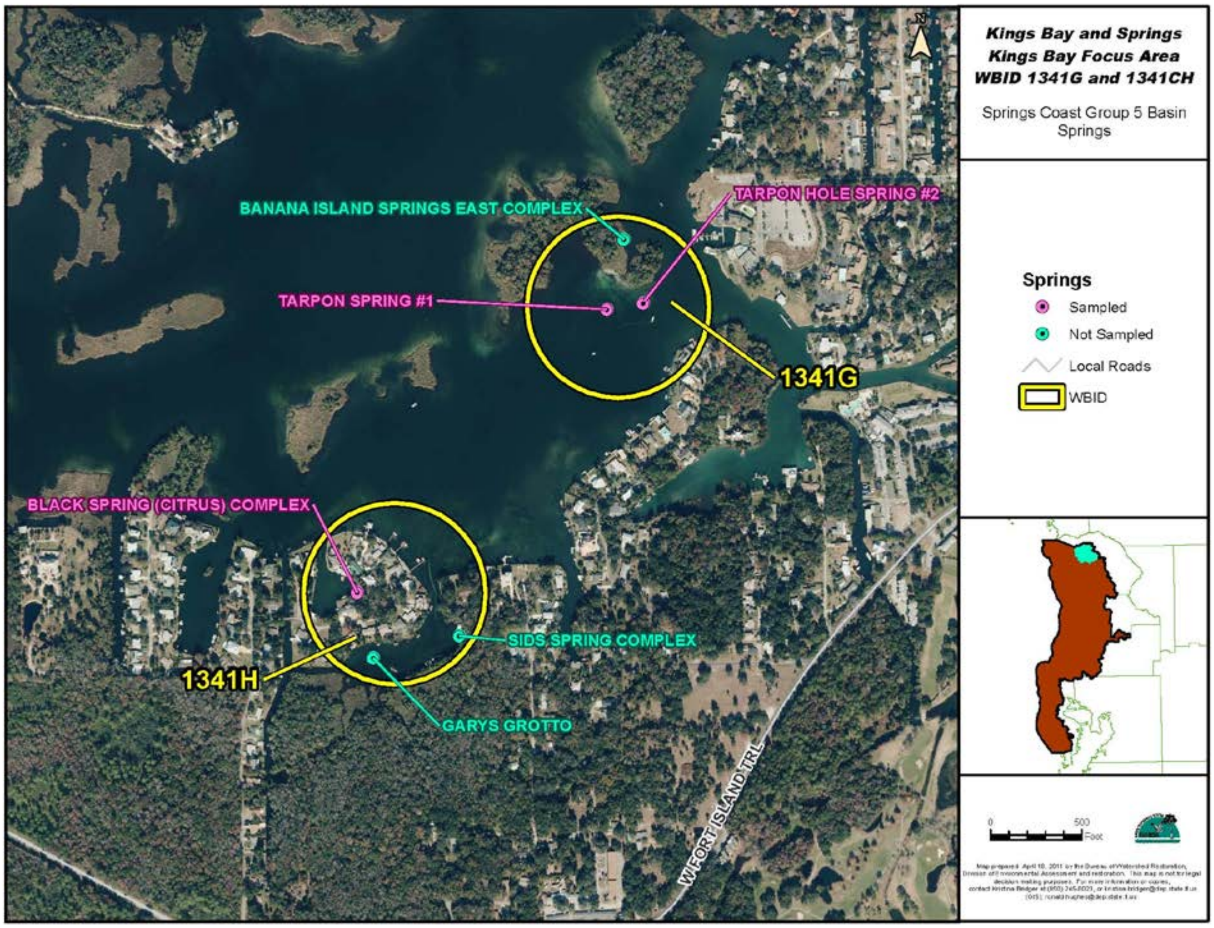

Figure 1.4. Sampled Springs (in Red) and Unsampled Springs (in Turquoise) for Tarpon Spring (WBID 1341G) and Black Spring (WBID 1341H)

1.2.2 Hunter Spring (WBID 1341C)

Hunter Spring, also known as American Legion Spring is located in the northeast portion of Kings Bay in Hunters Cove (**Figure 1.3**). The spring is surrounded by a recreational park to the north and a residential area to the east and south. The spring vent is located within a designated swimming area about 40 feet offshore of the park. The spring is tidally influenced. The average discharge rate for Hunter Spring measured by a SWFWMD contractor in 2009 (Vanasse Hangen Brustlin [VHB] 2010) was 31.02 cubic feet per second (cfs).

1.2.3 House Spring (WBID 1341D)

House Spring is located at the head of the easternmost end of Hunter Cove within a seawalled enclosure (**Figure 1.3**) used as a swimming area by nearby residents. This multiple vent spring area is approximately 4 feet deep at the center of the swimming enclosure. Numerous other sand boils were also observed within this area. According to VHB (2010) the average discharge rate measured for House Spring was 5.23 cfs.

1.2.4 Idiot's Delight Spring (WBID 1341F)

Idiot's Delight Spring is located on the east side of Kings Bay (**Figure 1.3**). This spring complex is located within the Paradise Isles and Palm Island subdivision canal system. The spring consists of a group of 3 vertical shafts at least 20 feet in depth, the largest of which is documented to be 5 feet in diameter. The spring lies adjacent to the shoreline and west of the Three Sisters Springs run. Water depths in this area are approximately 4 feet. The spring is tidally influenced. According to VHB (2010) the average discharge rate for Idiot's Delight Spring was 4.84 cfs.

1.2.5 Tarpon Spring (WBID 1341G)

Tarpon Spring, also known as Tarpon Hole Spring and King Spring, is located just south of Banana Island in the southern portion of Kings Bay (**Figure 1.4**). The largest of the 30 springs that make up the headwaters of the Crystal River, Tarpon Spring is a popular scuba-diving location that is easily accessible by boat. This spring vent system is the middle vent of the 3 large vent systems in this area. It consists of multiple holes and fractures. The fractures are generally in a roughly circular formation and appear to represent a large undercut shelf/cavern that collapsed sometime in the past. Water depths measured at the edge of the spring formation were approximately 4 to 5 feet, while depths at the deepest center were approximately 15 to 20 feet. According to VHB (2010) the average discharge rate for Tarpon Spring was 42.83 cfs, but its discharge is influenced by tidal stage.

1.2.6 Black Spring (WBID 1341H)

Black Spring (Citrus) Complex is located near the end of a canal in a residential neighborhood at the southern margin of Kings Bay (**Figure 1.4**). The spring lies in 4 feet of water and may produce a boil at the surface of the canal. The spring is one of several vents in the area and is tidally influenced. According to VHB (2010) the average discharge rate for Black Spring was 5.89 cfs.

1.3 Crystal River/Kings Bay Contributing Area

For the purposes of the TMDL discussion, the estimated contributing area for water discharged by the springs and surface runoff to the bay is shown in **Figure 1.5**. In evaluating the potential sources of nutrients impacting Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, the Department considered the contributing area to be a combination of the surface water drainage basin and the springshed of the Kings Bay Springs

Group. Developed by the U.S. Geological Survey (USGS) and the Department, the surface water drainage basin is based on the Level 8 Hydrologic Unit Codes (HUCs). A springshed is the area of land that contributes water to a spring or group of springs, mainly via ground water flow. The estimated Kings Bay contributing area encompasses an area of approximately 261 square miles (mi^2). This area includes 233 mi^2 in Citrus County and 28 mi^2 in Marion County, Florida.

The springshed is also essentially the recharge area. Ground water discharging from the Kings Bay springs originates within this recharge area (SWFWMD 2000). In the recharge area, the rainfall infiltrates the soils and overlaying sediments to the upper Floridan aquifer, and this ground water flows seaward toward the springs (SWFWMD 1998). The generalized springshed for the Kings Bay Springs Group used in this report was developed by the SWFWMD using USGS potentiometric surface contour maps for the upper Floridan aquifer. This springshed delineation provides a reasonable representation of the area contributing to the springs, but it is limited by the resolution of the potentiometric surface map, the climatic conditions that existed when the map was created, and the assumption of uniform drainage within the mapped area.

1.4 Climate

The climate in Citrus County, specifically areas surrounding Crystal River/Kings Bay, is subtropical and humid, with annual rainfall averaging approximately 52 inches—although rainfall amounts can vary greatly from year to year (Southeast Regional Climate Center [SERCC] 2013). Rainfall occurs in the area as a result of 3 types of weather systems: frontal, convective, and tropical cyclonic (SWFWMD 2000). Based on data over a 30-year period (1971–2000), the average summer temperature is 82.1ºF., and the average winter temperature is 58.5ºF. (SERCC 2013). The overriding climatological influence affecting the area is the Gulf of Mexico (SWFWMD 2000).

1.5 Soils (SWFWMD 2000)

The soils of Crystal River area generally fall into two categories: hydric soils characterized by a high water table and wetland vegetation, and nonhydric soils characterized by fine sandy soils with a lower water table.

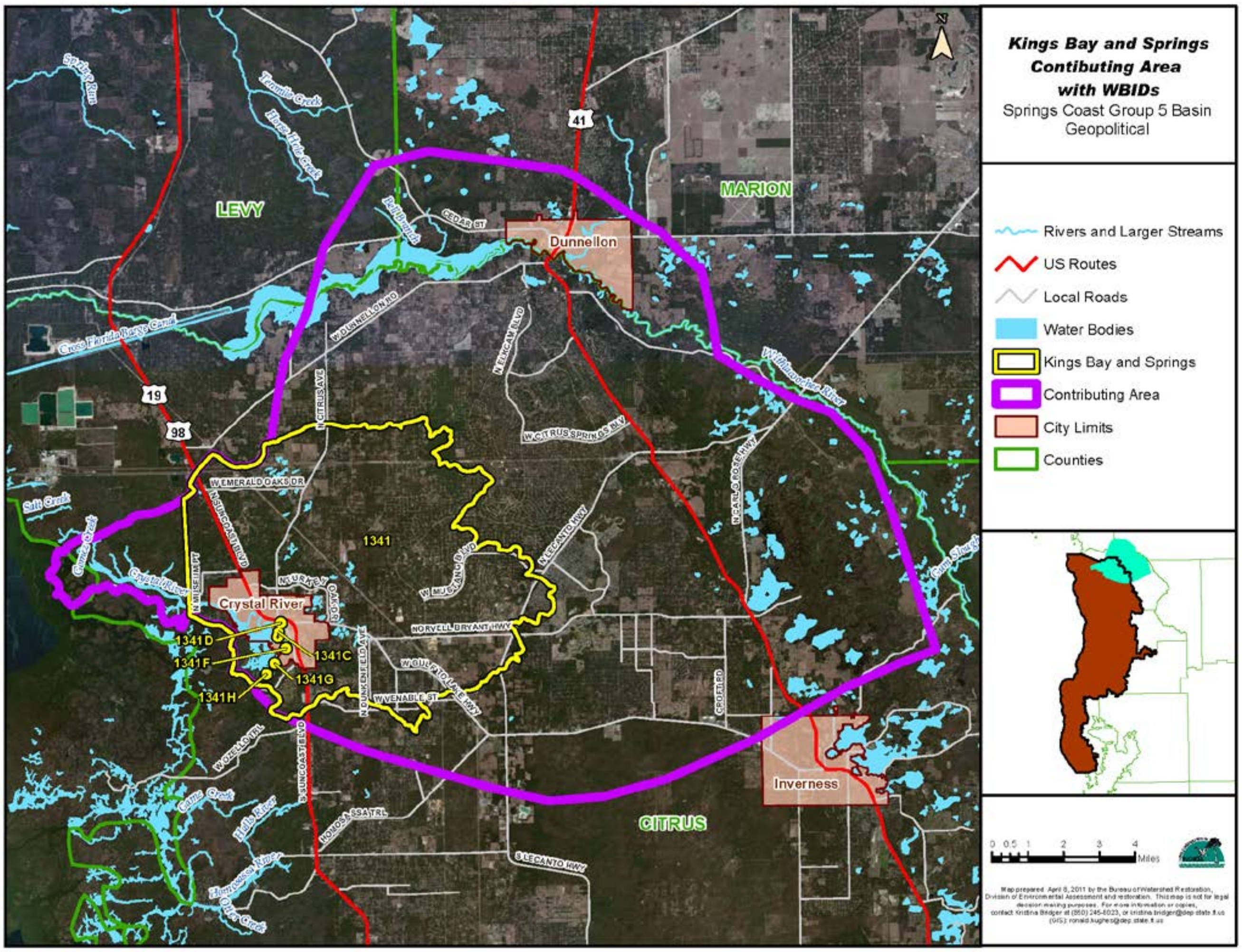

Figure 1.5. Estimated Contributing Area for the Following Verified Impaired WBIDs: Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H)

1.6 Physiographic Features (SWFWMD 2000)

Four major physiographic subdivisions exist in Citrus County and the contributing area for Kings Bay. The main surface drainage features within the recharge area are the Withlacoochee River, which forms the eastern and northern borders of the county, and the Crystal River.

The Tsala Apopka Plain lies between the Brooksville Ridge and the Withlacoochee River. It includes a large number of interconnected lakes divided by peninsulas and islands. Silicic deposits cover the limestone surface. Elevations range from 35 to 75 feet above the National Geodetic Vertical Datum (NGVD). The soils are generally sandy and weakly cemented with organic matter. This lack of surface drainage features is characteristic of karst areas because much of the drainage is internal. In karst areas, landforms are created by the erosion and dissolution of near-surface limestone. These include the Coastal Swamps, the Gulf Coastal Lowlands, the Brooksville Ridge, and the Tsala Apopka Plain (White 1970). The physiographic areas are primarily a function of the topographic relief and underlying sediments.

The Brooksville Ridge trends north-south and occupies the central part of Citrus County. It ranges from approximately 17 miles in width at the Hernando County line to about 5 miles in width at the Marion County line. Elevations along the ridge range from 70 to about 250 feet above NGVD. The margins of the ridge are deep, sandy soils. The soils of the ridge interior are a mixture of poorly to well-drained sandy-clayey soils. The entire Brooksville Ridge area overlies a clayey unit that varies between 10 and 30 feet in thickness but allows good hydraulic connection to the underlying upper Floridan aquifer system via karst features and fractures. The ridge has an irregular surface due to karst activity (sinkhole formation), and elevations may vary by more than 100 feet (30 meters) over short distances.

The Coastal Lowlands area lies between the Coastal Swamp and the Brooksville Ridge, and ranges from about 2 to 8 miles in width. Elevations range from sea level to about 100 feet above NGVD. The topography consists of relatively flat plains to rolling hills. The hills consist of sand dunes modified by karst development. In this subdivision, limestone is typically overlain by a thin layer of sand.

The Coastal Swamp parallels the coast and extends inland 2 to 5 miles. Characteristics include both tidal marshes and coastal swamps. Within the Coastal Swamp system, elevations are typically less than 10 feet, and poorly drained organic soils directly overlie the limestone of the upper Floridan aquifer.

1.7 Karst Features (SWFWMD 2000)

In an area of karst topography, the underlying geology controls the landforms and surface water features. In general, the topographic features and internal drainage in karst regions are caused by the underground erosion and subsidence of near-surface carbonate rocks. Within the rock, slightly acidic rainwater causes the limestone to slowly dissolve, and further dissolution along zones of jointed or fractured rock and sedimentary bedding planes causes the development of interconnected openings known as conduits. Ground water migrates through these zones and conduits, and springs occur where the hydraulic head or water level in the aquifer coincides with natural openings in the land surface.

In the vicinity of Kings Bay, the limestone of the Upper Floridan aquifer is at or very near (within 10 to 20 feet) land surface. According to Vernon (1951), limestone is as a rule jointed vertically and bedded horizontally. Openings along these joints and beds provide easy avenues for the travel of water. These joints often form along structural fractures in the rock. Ground water may flow rapidly through conduits and passages within the limestone, or slowly through minute pore spaces within the rock matrix (SWFWMD 2001).

The Amy H. Remley Foundation and the University of Georgia (2013) have identified possible fracture traces that may be associated with springs in Kings Bay. Their study analyzed indicators of potential preferential ground water flow by considering surface expressions of underlying geological conditions (lineaments [linear karst features] and modern sinkholes) in the limestone surface of the upper Floridan aquifer that coincide with the United States' Southeastern Coastal Plain. Established methods for georectification, including control-point identification and spatial matching of scanned maps and remotely sensed images, were applied to the previously mapped Vernon (1951) and Florida Department of Transportation (FDOT) (1973) lineaments. These techniques were applied in the karst areas of Citrus and Levy Counties. Geographic information system (GIS) geospatial analyses of lineament distribution and modern sinkhole locations from the state database showed a dense network of lineaments with associated springs and sinkholes throughout the area (**Figure 1.6**). The red lines running southeast to northwest are lineaments from Vernon (1951). The yellow-green lines are possible fracture traces identified by the Amy H. Remley Foundation and the University of Georgia (2013).

1.8 Geology (SWFWMD 2000)

The geology of Citrus County is relatively simple but has a very important influence on both the quality and quantity of water discharging into Kings Bay. Thick sequences of limestone occur beneath the county and the contributing area for Kings Bay. Where limestone is near the land surface it is covered by a thin layer of sediment consisting primarily of quartz sand. These sands are primarily marine deposits and coastal dunes. Dunes are prevalent in the Coastal Lowlands and along the sides of the Brooksville Ridge in central Citrus County. Thicker sediments occur across the Brooksville Ridge and consist mostly of quartz sand and clay of the Miocene to Oligocene Hawthorn Group. The uppermost limestone unit of the Kings Bay contributing area is the Ocala Limestone of Late Eocene age. The Middle Eocene age Avon Park Formation underlies the Ocala Limestone throughout most of the entire contributing area. However, the Avon Park Formation is exposed in restricted portions of southeastern Levy and northwestern Citrus Counties where the overlying units have been removed by erosion (SWFWMD 2001). The Ocala Limestone and Avon Park Formation comprise the upper Floridan aquifer in the region (SWFWMD 2001).

1.9 Ground Water Hydrology

1.9.1 Surficial Aquifer (SWFWMD 2000)

The surficial aquifer consists of sand, silty sand, and clay deposits that are contiguous with the land surface. The lower limit of the aquifer coincides with the top of laterally extensive and vertically persistent low-permeability beds of the Hawthorn Group sediments. These beds consist of sand, silty sand, and waxy-green clay, and are mainly restricted to the Brooksville Ridge province. Because of a lack of an extensive confining layer, most of the county does not have a surficial aquifer.

1.9.2 Floridan Aquifer System (SWFWMD 2000)

Two major hydrostratigraphic horizons make up the Floridan aquifer system. In the Kings Bay area, the upper Floridan generally contains fresh water (except in some areas along the coast), and the lower Floridan is saline. The upper Floridan aquifer is the principal source of water for domestic, agricultural, and industrial activities in the region. It is also the source of water discharging from the Kings Bay springs. In north and central Citrus County, the Avon Park Formation and the Ocala Limestone contain the freshwater-bearing part of the upper Floridan aquifer. In general the upper Floridan aquifer is unconfined in the Kings Bay contributing area. However, clay layers in the Brooksville Ridge are sufficiently thick to cause local, semiconfined conditions to exist. A limited surficial aquifer may be present in these areas, but there are probably enough breaches in the clay layer to allow water to percolate from the sand into the underlying limestone.

In karst areas, ground water in the upper Floridan aquifer can come from localized recharge near Kings Bay, or can flow preferentially within solution features and conduits from distant recharge areas. The water discharged from springs can thus be derived from multiple source areas and could have resided from days to decades in the aquifer matrix.

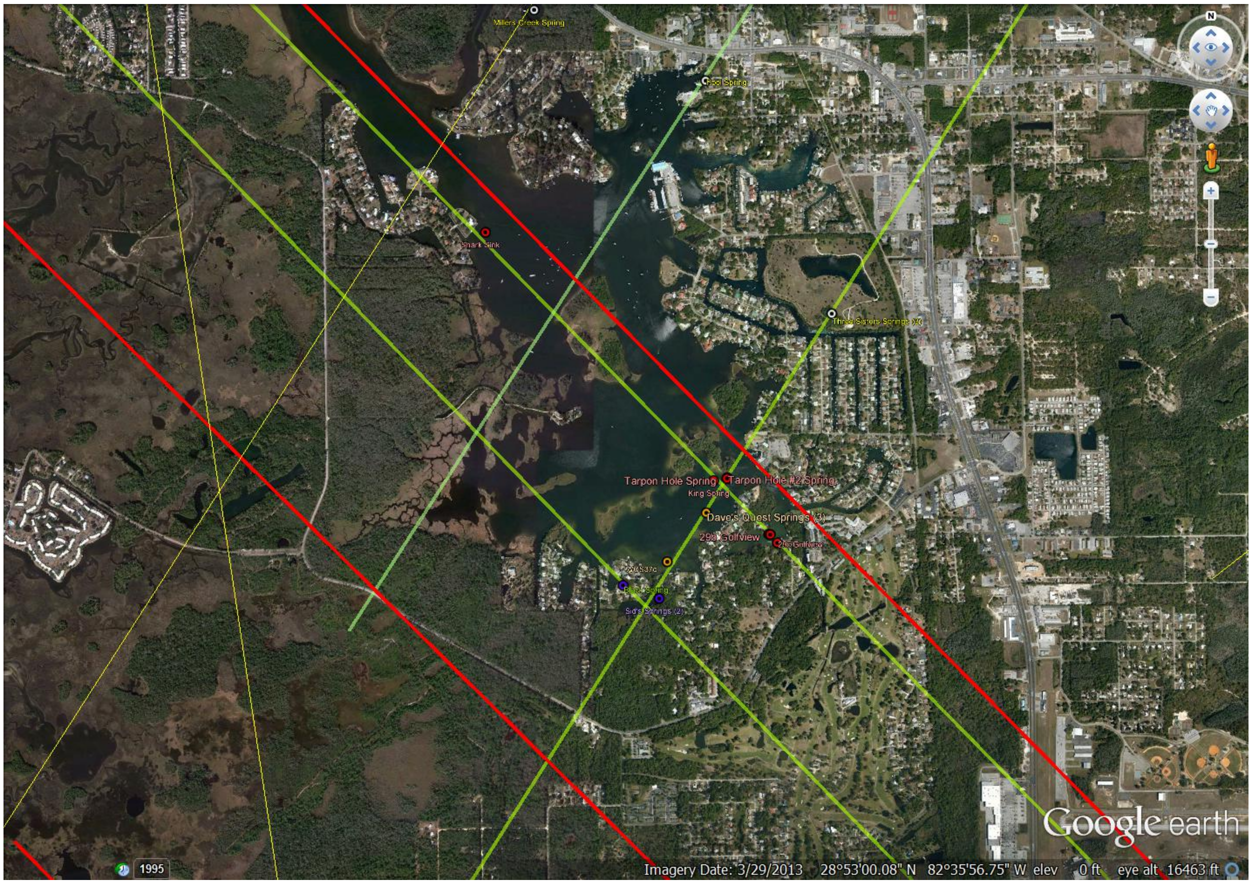

Figure 1.6. Lineament Features Located in Kings Bay (Source: Amy H. Remley Foundation and University of Georgia 2013)

1.10 Florida Aquifer Vulnerability Assessment (FAVA)

Figure 1.7 shows the vulnerability of the Floridan aquifer in the area contributing to Crystal River/Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. This map is based on the FAVA model developed by the Florida Geological Survey using conditions such as soil characteristics, depth to ground water, recharge rate, and the prevalence of sinkhole features (Arthur *et al.* 2007). The map shows that the Floridan aquifer in entire contributing area for Kings Bay is more vulnerable to contamination from surface sources than other areas in the state.

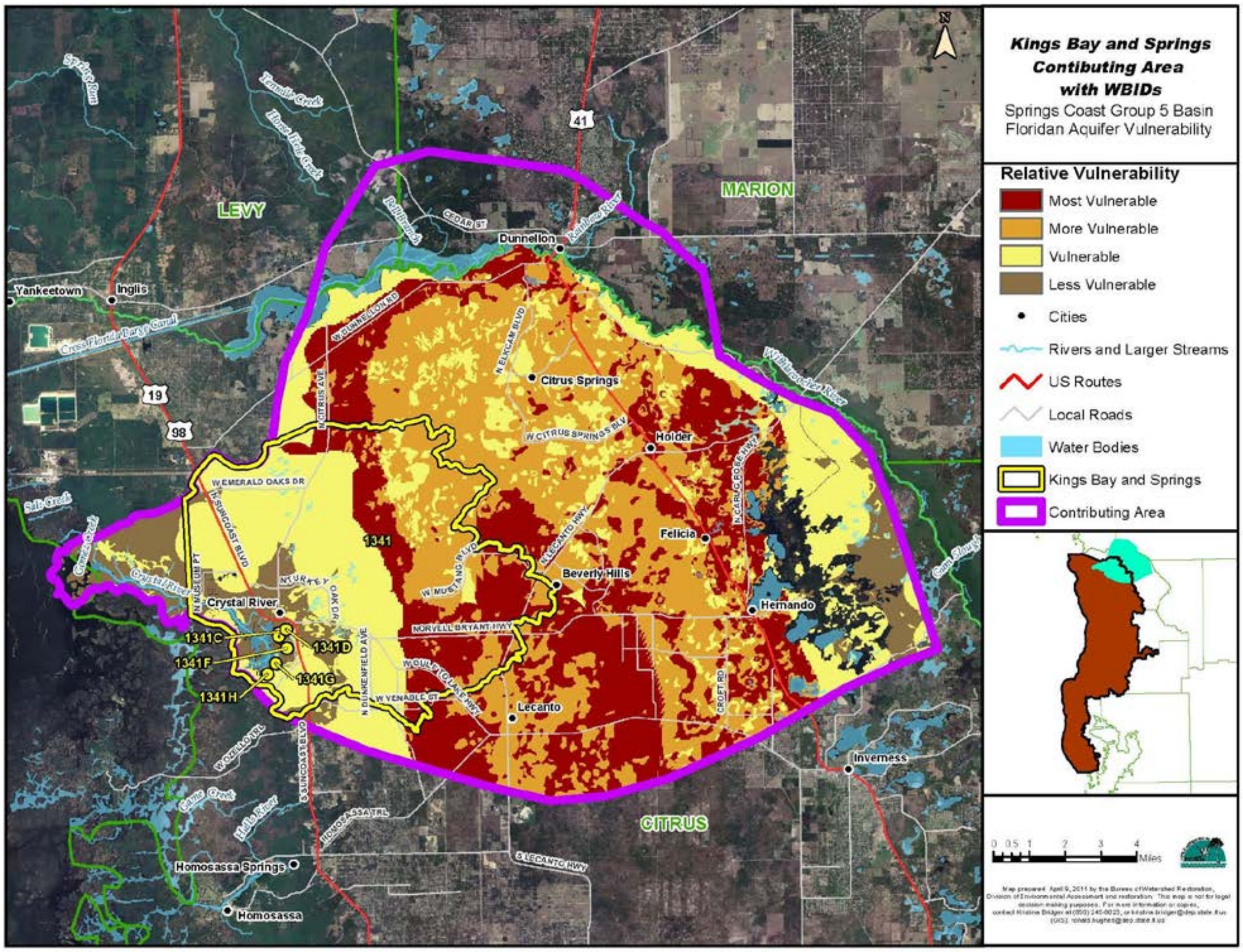

Figure 1.7. Floridan Aquifer Vulnerability in the Portion of the Kings Bay Contributing Area within Florida

1.11 Background

This report was developed as part of the Department's watershed management approach for restoring and protecting state waters and addressing TMDL Program requirements. The watershed approach, which is implemented using a cyclical management process that rotates through the state's 52 river basins over a 5-year cycle, provides a framework for implementing the TMDL Program–related requirements of the 1972 federal Clean Water Act and the 1999 Florida Watershed Restoration Act (FWRA) (Chapter 99-223, Laws of Florida).

A TMDL represents the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards, including its applicable water quality criteria and its designated uses. TMDLs are developed for waterbodies that are verified as not meeting their water quality standards. They provide important water quality restoration goals that will guide restoration activities.

This TMDL Report will be followed by the development and implementation of a Basin Management Action Plan to reduce the amount of nutrients that contribute to the algal mats causing the impairment of Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. Under Florida's Watershed Restoration Program, a BMAP is the primary method for implementing a TMDL in Florida. It is a watershed restoration plan developed in conjunction with local stakeholders and the Department. The restoration of thee waterbodies in the Springs Coast Basin will depend heavily on the active participation of stakeholders in the contributing area, including Citrus County, the city of Crystal River, other local governments, landowners, businesses, local interest groups, and private citizens. The SWFWMD, FDOT, and Florida Department of Agriculture and Consumer Services (FDACS) will also play important roles in the implementation of restoration activities.

Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring are economically valuable to the state and local communities. With more than 70 documented springs within the 600-acre bay, and a mean water temperature range of 66°F. to 76°F., Kings Bay forms the largest natural warm-water refuge for the endangered West Indian manatee (SWFWMD 2011).

Although Kings Bay is best known for manatees, it is also home to many other species. The Florida Fish and Wildlife Conservation Commission (FWC) observed 21 species of amphibians, 47 species of reptiles, 191 species of birds, and 22 species of mammals, including 26 state or federally listed species (Joiner *et al.* 1992). Joiner *et al.* (1992) also noted the importance of marsh and hydric hammock habitats to wildlife in the Crystal River/Kings Bay area. These habitats help support numerous bird species and some animals depend on these habitats during a portion or all of their life cycles. As a result of its diverse habitats and wildlife species, Crystal River/Kings Bay is a popular ecotourism destination where manatee and wildlife viewing, diving, snorkeling, fishing, and recreational boating are popular activities.

The diversity of Florida's wildlife attracts tourists and creates jobs (Florida Department of Economic Opportunity [FDEO] 2012). Ecotourism is a major reason that tourists visit the City of Crystal River and surrounding communities, and these areas are economically dependent on ecotourism. The loss of habitats such as swamps, marshes, and estuaries can have both economic and quality-of-life implications for the community. Since recreational activities occur on and in the water, water quality is the most important aspect of ecotourism in these areas (City of Crystal River–Waterfronts Partnership Advisory Board [CCR–WPAB] 2004).

Chapter 2: DESCRIPTION OF WATER QUALITY PROBLEM

2.1 Statutory Requirements and Rulemaking History

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency (EPA) a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment of listed waters on a schedule. The Department has developed such lists, commonly referred to as 303(d) lists, since 1992. The list of impaired waters in each basin, referred to as the Verified List, is also required by the FWRA (Subsection 403.067[4], Florida Statutes [F.S.]), and the state's 303(d) list is amended annually to include basin updates.

However, the FWRA (Section 403.067, F.S.) stated that all previous Florida 303(d) lists were for planning purposes only and directed the Department to develop, and adopt by rule, a new science-based methodology to identify impaired waters. After a long rulemaking process, the Environmental Regulation Commission adopted the new methodology as Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The IWR was modified in 2006 and 2007.

2.2 Information on Verified Impairment

Section 62-303.450, F.A.C., includes the methodology for listing nutrient-impaired surface waters based on documentation that supports the determination of an imbalance of flora or fauna attributable to nutrients. In 2011, the Department used available water quality data in the IWR database, data from the Department and SWFWMD spring monitoring activities, photographic evidence, and other available information to document the nutrient enrichment in Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. The SWFWMD collected the bulk of the water quality data for Kings Bay and the springs. Photographic evidence of algal smothering was collected by Department staff, and other evidence of algal distribution was obtained from reports produced by the SWFWMD and Jacoby *et al.* (2007 and 2011).

Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H) were listed as impaired for nutrients (algal mats) at the end of the Cycle 2 verified period (January 1, 2004, to June 30, 2011). The information documented by Harrington (2011) supplemented the determination of impairment. **Table 2.1** lists the Cycle 2 verified impaired waterbodies in the Crystal River Planning Unit located in the Springs Coast Basin.

To ensure that the nutrient TMDL was developed based on current conditions in the bay and that recent trends in the bay's water quality were adequately captured, monitoring data collected from January 1, 2004, to June 30, 2011, were used to develop the TMDL. **Tables 2.3a** and **2.3b; Tables 2.4a**, **2.4b**, and **2.4c; Tables 2.5a** and **2.5b; Tables 2.7a** and **2.7b; Tables 2.8a, 2.8b,** and **8.c;** and **Tables 2.9a** and **2.9b** summarize the nitrate and orthophosphate monitoring results for the Cycle 2 verified period for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring.

Table 2.1. Verified Impaired Waterbodies in the Crystal River Planning Unit

WBID	Waterbody Segment	Waterbody Type	Parameters Assessed Using the IWR	Concentration or Criterion or Threshold Not Met	Assessment Status
1341	Crystal River/ Kings Bay	Estuary	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired
1341C	Hunter Spring	Spring	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired
1341D	House Spring	Spring	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired
1341F	Idiot's Delight Spring	Spring	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired
1341G	Tarpon Spring	Spring	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired
1341H	Black Spring (Crescent Drive Spring)	Spring	Nutrients (algal mats)	Balanced natural population of flora and fauna	Impaired

2.3 Nutrient Enrichment

Nutrient enrichment causes the impairment of many surface waters, including springs and estuaries. The two major nutrient groups monitored are nitrogen (N) and phosphorus (P). These are essential nutrients to plant life, including algae. For aquatic vegetation and algae to grow, both nutrients have to be present. In fact, one can be present in excess, but if the other is absent, the overgrowth of vegetation or algae is unlikely to occur. It is widely accepted that primary production in an estuarine waterbody is controlled by nutrients, sunlight, tidal flow, temperature, and, depending on the species, salinity.

The results of ongoing research on many Florida springs have led to significant progress in understanding the threshold concentrations of nitrogen or phosphorus that cause the overgrowth of submersed aquatic vegetation (SAV) and nuisance macroalgae (Stevenson *et al.* 2007). Macroalgae may also sequester nutrients from ground water seepage, which may not be apparent from surface water or spring monitoring data. The nutrient inputs contributing to the algal growth in Kings Bay may not be exclusively related to spring discharge, as the bay also receives nutrients via stormwater and shallow ground water inflows from nearby sources. In addition nutrients can also diffuse from the sediments back into the water column, which provides a focused source of bio-available nutrients for the benthic macroalgal mats. Legacy nutrients found within the sediments from historical WWTP discharges could also be a nutrient source in the bay.

2.4 Ecological Issues in Kings Bay

The amount and type of aquatic vegetation is linked to water quality and clarity. Submersed aquatic plant communities support wildlife species, stabilize sediments, prevent erosion, and remove contaminants from the water column and sediments (SWFWMD 2004). Historical anecdotal evidence suggests that beds of native tape grass (*Vallisneria americana*) once dominated the vegetative community of Kings Bay (SWFWMD 2004). Over the years, the tape grass beds gave way to the invasive plants *Hydrilla verticillata* (circa 1960) and *Myriophyllum spicatum* (circa 1960). For many years *Hydrilla* was the dominant plant.

These plants in turn were succeeded by algae, such as the blue-green algae *Lyngbya* sp. (circa 1980), which has undergone uninhibited growth in portions of the bay in recent years. Nuisance species have a competitive advantage over native species because of their ability to grow and reproduce faster. The overgrowth of these nuisance species has corresponded with increased nutrient concentrations in the springs and bay.

2.4.1 *Lyngbya* sp. and Algal Mats (SWFWMD 2000)

Lyngbya sp. has become a major nuisance in the eastern part of Kings Bay and the dominant form of aquatic vegetation in much of the bay (**Figures 2.1** through **2.4** and **2.6**). This species has developed as mats on the bay's bottom. Trapped gases often form in and beneath these algal mats, causing them to break free of the substrate and float to the surface. Once floating, wind and water currents can move the mats can move to other areas of the bay, impeding navigation and impairing recreational use of the waterbody. The mats can be several acres in size (University of Florida–Institute of Food and Agricultural Sciences [UF–IFAS] 2009). *Lyngbya* sp. also has the potential to trap sediments, causing the development and accumulation of muck. Upon decomposition the algal cells release a compound (geosmin) with a strong musty odor, this further impairs the aesthetic value of the waterbody (Romie 1990). The *Lyngbya* sp. biomass in Crystal River/Kings Bay was observed to be especially high in the Cedar Cove and Hunter Spring areas, where it is well established and has formed thick mats. Lyngbya sp. can thrive in very low light levels and it is likely phosphorus limited when nitrogen levels are less than 0.05 mg/L.

2.4.2 *Chaetomorpha sp.*

The SWFWMD and the Amy H. Remley Foundation have observed and documented *Chaetomorpha* sp. algal blooms in Kings Bay (**Figure 2.5**). Around 2003, in the southern portion of Kings Bay, the dominant algal blooms shifted from *Lyngbya* sp. to *Chaetomorpha* sp., possibly due to increased water salinity in this area. *Chaetomorpha* is a unique variety of green algae that is native to the Gulf of Mexico, Atlantic, and Caribbean. It is found in nutrient-rich areas such as bird islands, lagoons, and protected shallow waters (Gulf Coast Ecosystems [GCE] 2010). It features a thick, tangled mass of filaments that resembles fishing line (GCE 2010). *Chaetomorpha sp.* is very hardy because it grows in the intertidal zone, which is often completely exposed at low tide. It will not attach to rocks or substrates. In nutrient-rich environments, it has a competitive advantage over other native species because it is a fast grower and is not palatable to fish or invertebrates. *Chaetomorpha sp.* is also known as green hair or horse hair algae.

2.4.3 Phytoplankton

Phytoplankton are small photosynthesizing organisms that occur in the water column in sunlit areas. The production of chlorophyll by these organisms can turn the water column green and impede light penetration. Phytoplankton can block sunlight from reaching aquatic life at the bottom and absorb the light so that there is less reaching the benthic zone. While the production of chlorophyll is naturally occurring, elevated levels can have adverse effects on designated beneficial uses and cause impairment. Phytoplankton algae populations and their chlorophyll production vary greatly with depth because the algae must stay within the top portion of the waterbody where sunlight is available to photosynthesize and stay alive. Elevated chlorophyll levels, which occur in association with elevated nutrients, have contributed to an ecological imbalance in Kings Bay, particularly in the Hunter Spring area (**Figure 2.3**). Some algae produce toxins, which during an algal bloom can become harmful at high concentrations. The reduction of nutrients (nitrogen and phosphorus) in the water column will reduce chlorophyll concentrations as well as filamentous algal mats.

2.4.4 *Hydrilla verticillata* and *Myriophyllum spicatum*

The invasive plants *H. verticillata* and *M. spicatum were* first found in Kings Bay in 1960 (SWFWMD 2004). *M. spicatum* is also known as Eurasian water milfoil. The nutrient TMDL proposed in this document addresses excessive algal mat formation and is not specifically designed to eliminate *H. verticillata* or *M. spicatum*, but achieving the nutrient reductions is expected to reduce their competitive advantage over more desirable native aquatic plants. While *H. verticillata* and *M. spicatum* can impair recreational uses, they also serve as a food source for the endangered West Indian manatee (Department 1993).

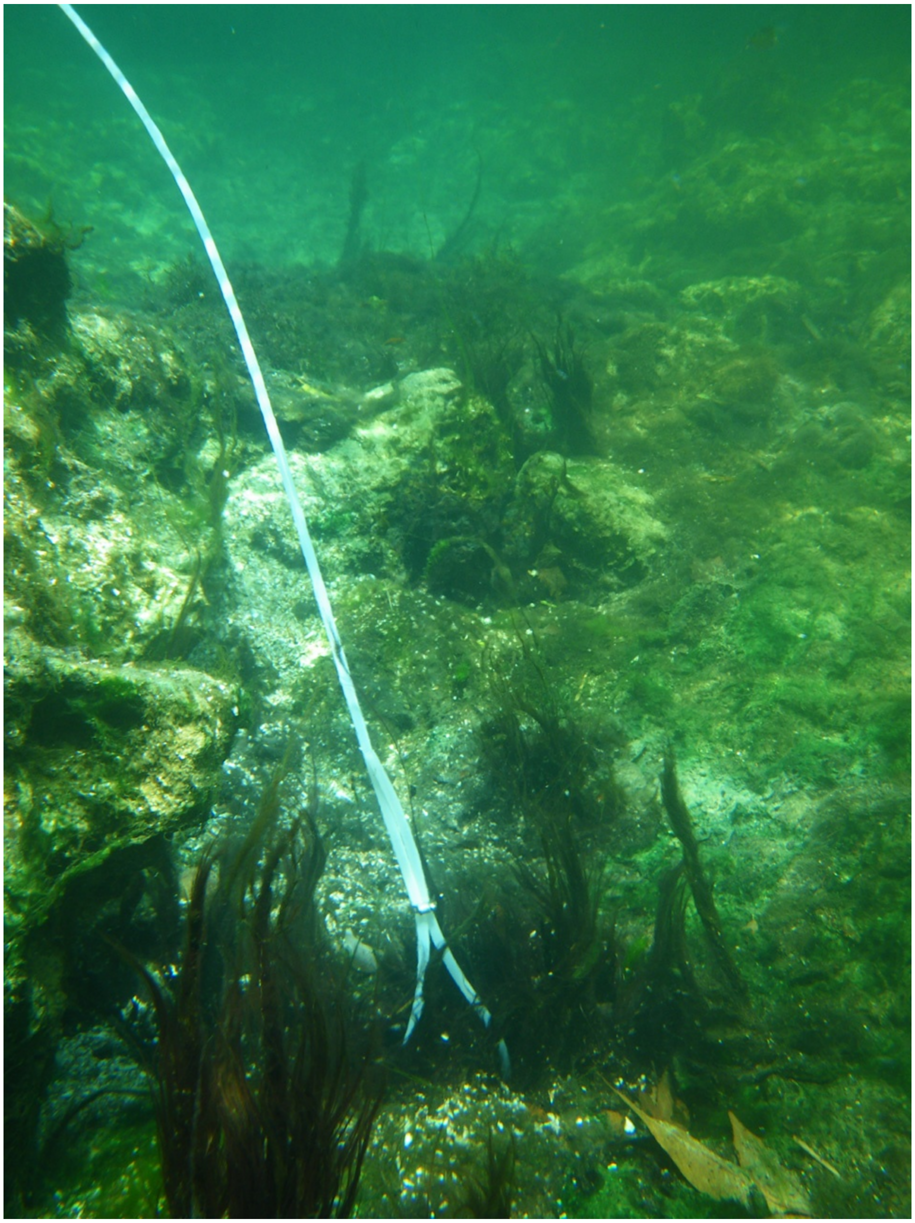

Figure 2.1. Vents with Waving Algae at Idiot's Delight Spring (WBID 1341F) in September 2010 (Source: G. Maddox, Department)

Figure 2.2. Floating *Lyngbya* sp. Mats at Hunter Spring (WBID 1341C) in November 2009 (Source: L. Hester)

Figure 2.3. Aerial Photo of Algal Coverage and Chlorophyll in the Water Column at Hunter Spring (WBID 1341C) in June 2010 (Source: H. Means, Department)

Figure 2.4. Aerial Photo of Algal Coverage at Tarpon Spring (WBID 1341G) (Source: Florida Geological Survey)

Figure 2.5. *Chaetomorpha* sp. Algal Bloom in Kings Bay (WBID 1341) (Source: SWFWMD)

Figure 2.6. Growing Algal Towers in Kings Bay (WBID 1341) in May 2010 (Source: G. Maddox, Department)

2.5 Monitoring Sites and Sampling

Historical water quality data for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring are limited, but they do provide a glimpse of nutrient concentration trends during the period of record. Water quality data have been collected from various locations in the bay and at the springs. Various entities have stored this data in Florida's Storage and Retrieval (STORET) database and the USGS National Water Information System (NWIS) database.

The SWFWMD collected most of the water quality data for these waters (**Figure 2.7**). The Kings Bay stations were sampled monthly. Hunter Spring and Tarpon Spring, also known as Tarpon Hole Spring, were sampled four times a year (January, April, July, and October). Idiot's Delight Spring, House Spring, and Black Spring were sampled on an annual basis in July. This schedule is the part of the SWFWMD routine springs sampling. Many of the smaller springs are sampled annually every July and the larger springs are sampled four times a year.

The water quality data used in this TMDL evaluation were from the Cycle 2 verified period (January 1, 2004, to June 30, 2011) plus recent data (2011–12), and are the result of sampling done by the SWFWMD, USGS, and Department. **Figures 2.8, 2.9,** and **2.10** display the locations of the current and past ambient water quality sampling stations and biological stations monitored by the SWFWMD, USGS, and Department.

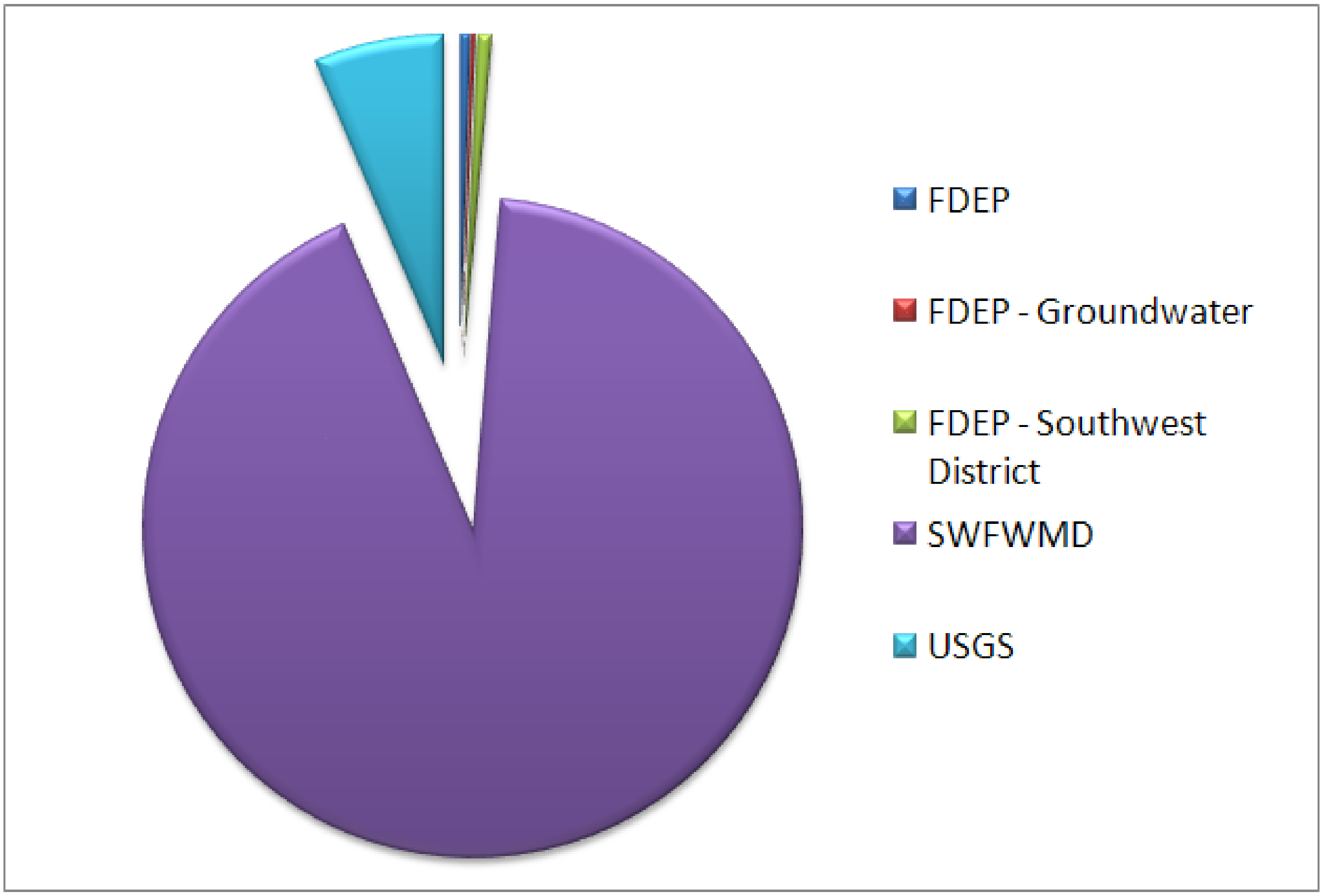

Figure 2.7. Water Quality and Biological Data Providers within the Kings Bay Contributing Area

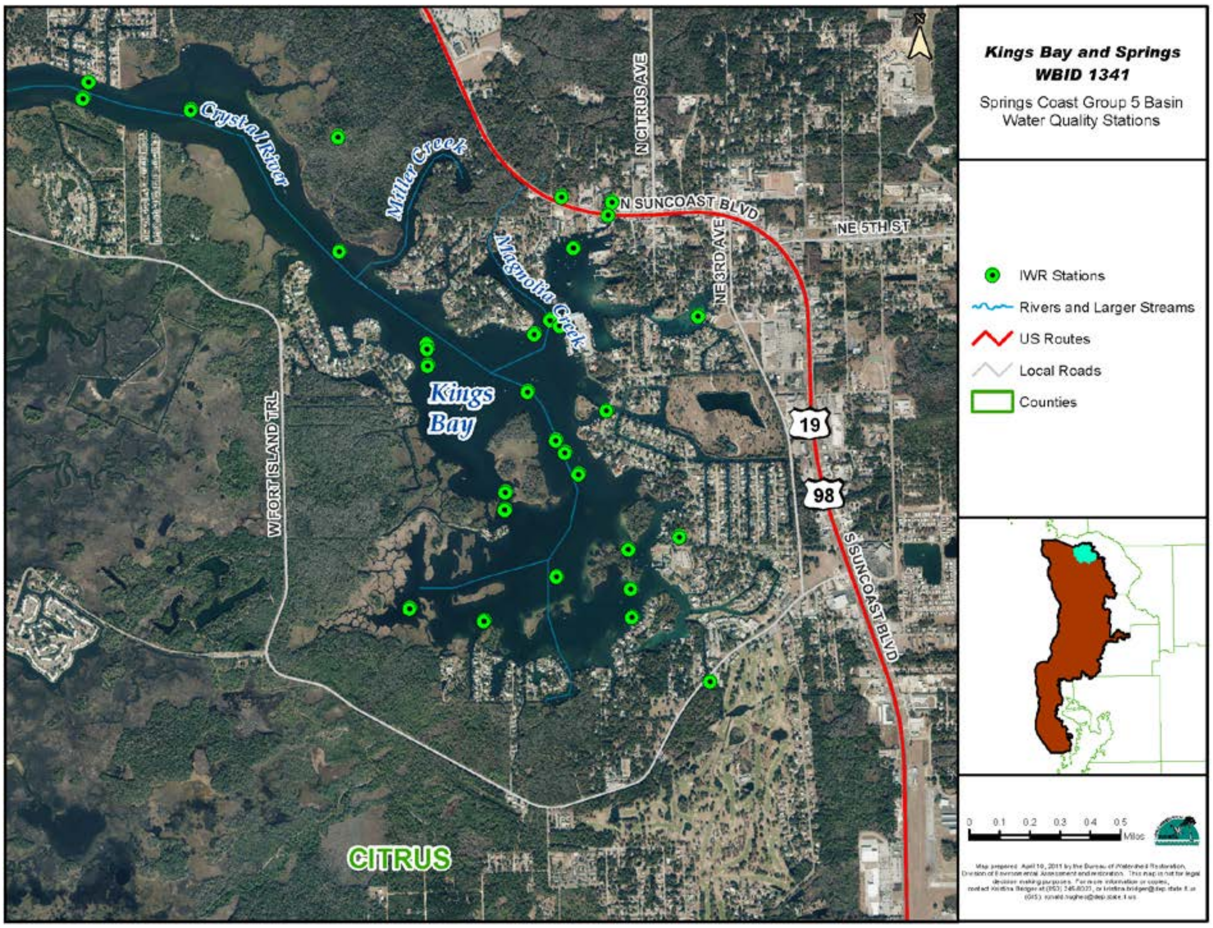

Figure 2.8. Location of Water Quality Stations for Kings Bay (WBID 1341)

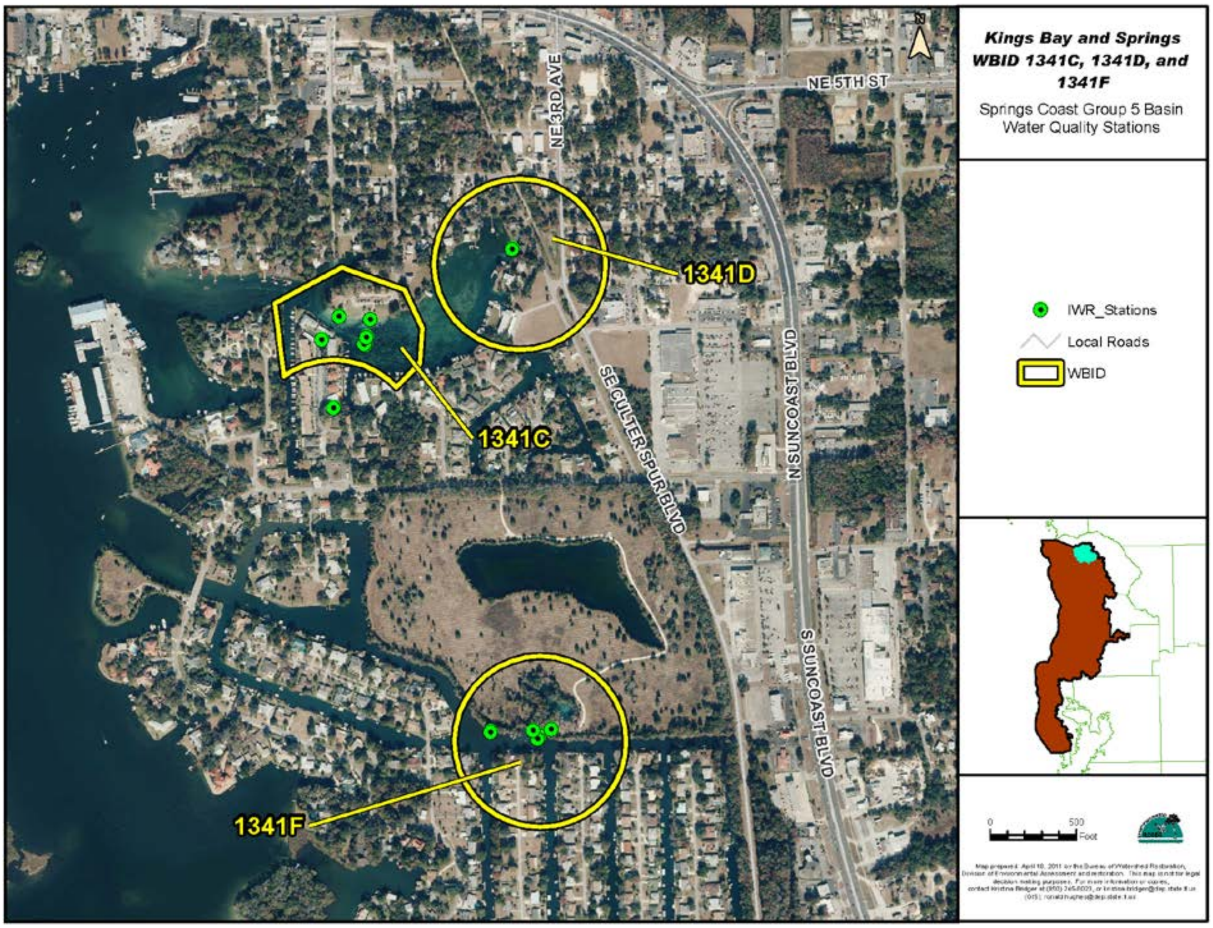

Figure 2.9. Location of Water Quality Stations for Hunter Spring (WBID 1341C), House Spring (WBID 1341D) and Idiot's Delight Spring (WBID 1341F)

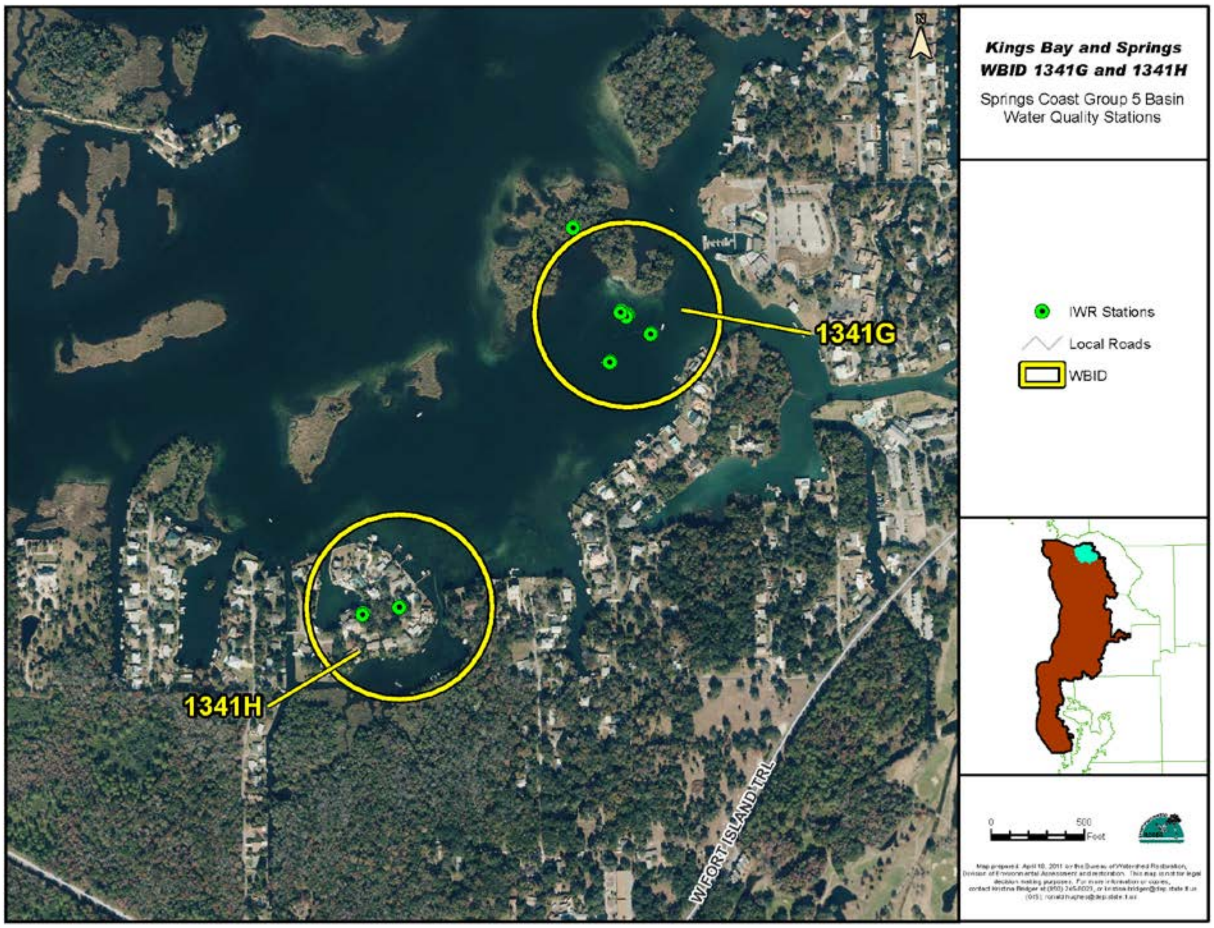

Figure 2.10. Location of Water Quality Stations for Tarpon Spring (WBID 1341G) and Black Spring (WBID 1341H)

2.6 Monitoring Results

2.6.1 Nitrogen

Nitrogen is found in several forms and is ubiquitous in the environment. Seemingly low nitrogen concentrations can actually cause a significant shift in the balance of spring ecological communities, leading to the degradation of biological systems due to the overgrowth of algae and sometimes aquatic plants (Harrington *et al.* 2010).

Nitrate (NO_3) is a mobile and conservative form of nitrogen that occurs in the highest concentrations in ground water and springs. The remaining nitrogen content in spring discharge is low. For the Kings Bay spring vents, based on the long-term annual average (2004–12), the majority of TN consisted of nitrate (**Table 2.2**). Nitrite-nitrogen (NO_2), an intermediate form of nitrogen, is almost entirely converted to nitrate in the nitrogen cycle. While nitrate and nitrite are frequently analyzed and reported together as one concentration (nitrate + nitrite-nitrogen), the nitrite contribution is insignificant. Historically, nitrogen was only a minor constituent of spring water, and typical nitrate concentrations in Florida springs were lower than 0.2 milligrams per liter (mg/L) until the early 1970s. In recent years, elevated concentrations of nitrate have been found in many springs. Nitrate is also the most available form of nitrogen for uptake by plants and algae.

In water, TN is made up of both inorganic and organic fractions. Inorganic nitrogen components include ammonium, nitrate, and nitrite. In Kings Bay, based on the long-term annual average (2004–12) from multiple stations, nitrate constitutes 36% of the TN (**Table 2.2**). Therefore, the remaining nitrogen content (organic nitrogen and ammonium) in the bay is approximately 64%. Various sources of organic nitrogen exist within the bay, including stormwater runoff, microbial cycling, and aquatic vegetation nutrient cycling. For Kings Bay (WBID 1341) the TN and nitrate data from water quality sampling stations for the entire period of record (1974 – 2012) were analyzed to detect temporal trends. A non-parametric test for trend is obtained using the Mann-Kendall statistical test, which examines if there is a general increase or decrease in total nitrogen and nitrate concentrations over time (Schwarz 2013). The statistical test revealed an increasing temporal trend in the bay for nitrate from 1980 through 2012 (N [results] = 609, Kendall tau = 0.08, Prob = 0.005) and a decreasing temporal trend in the bay for TN from 1974 through 2012 (N [results] = 754, Kendall tau = -0.08, Prob = 0.002). Between 1974 through 2012 a significant source of nitrogen was removed from Kings Bay. In 1992 the City of Crystal River Wastewater Treatment Plant (WWTP) stopped discharging effluent directly into the bay. The removal of the wastewater effluent has decreased TN concentrations from 1992 levels; however, further reductions in total nitrogen are needed to reduce the growth rate of filamentous algae. **Tables 2.3a and 2.3b** summarize the TN and nitrate results, and **Figure 2.11** displays the annual TN and nitrate concentrations in Kings Bay.

For each spring WBID, nitrate data from water quality sampling stations for the entire period of record (1990 – 2012) were also analyzed to detect temporal trends using the Mann-Kendall statistical test. The statistical test revealed increasing temporal trends for nitrate in Hunter Spring (N [results] = 99, Kendall tau = 0.61, Prob = 0.0001), House Spring (N [results] = 7, Kendall tau = 0.84, Prob = 0.012), and Tarpon Spring (N [results] = 114, Kendall tau = 0.43, Prob = 0.0001). A slight increasing trend was detected for Black Spring (N [results] = 26, Kendall tau = 0.16, Prob = 0.27) and Idiot's Delight Spring (N [results] = 33, Kendall tau = 0.22, Prob = 0.07), but it was not significant. **Tables 2.4a, 2.4b,** and **2.4c** and **Tables 2.5a** and **2.5b** summarize the nitrate results, and **Figures 2.11** through **2.16** display the annual nitrate concentrations for Hunter Spring, House Spring, Tarpon Spring, Black Spring and Idiot's Delight Spring.

Due to the increasing temporal trend in nitrate, it is considered the target nutrient for Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. It is also the main form of nitrogen in the spring water. However, the nitrate in Kings Bay only constitutes 34% of the TN. Therefore, TN is considered the target nutrient for Kings Bay (WBID 1341). **Chapter 5** includes a discussion of the nutrient impairment and the setting of the water quality target concentrations for nitrogen.

Table 2.2. Percent Nitrate of TN Based on Long-Term Annual Average for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, 2004–12 (in mg/L)

LTA = Long-term average (2004–12)

Spring Vent (WBID)	Waterbody Type	LTA_NO3	LTA_TN	Difference	% NO3 of TN
Kings Bay (WBID 1341)	Bay	0.1	0.28	0.18	36%
Hunter Spring (WBID 1341C)	Spring	0.49	0.55	0.06	89%
House Spring (WBID 1341D)	Spring	0.47	0.47	0	100%
Idiot's Delight Spring (WBID 1341F)	Spring	0.21	0.25	0.04	84%
Tarpon Spring (WBID 1341G)	Spring	0.21	0.32	0.11	66%
Black Spring (WBID 1341H)	Spring	0.24	0.34	0.09	71%

Table 2.3a. Summary Data for Nitrate-Nitrite in Kings Bay (WBID 1341), 1974–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1974	-	-	-	-
1975	-	-	-	-
1976	-	-	-	-
1977	-	-	-	-
1979	-	-	-	-
1980	1	0.02	0.020	0.02
1981	1	0.03	0.030	0.03
1984	12	0.02	0.003	0.05
1985	6	0.02	0.002	0.05
1989	-	-	-	-
1990	137	0.06	0.010	0.75
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	80	0.09	0.003	0.32
2005	51	0.06	0.003	0.18
2006	71	0.07	0.003	0.31
2007	72	0.08	0.003	0.34
2008	72	0.09	0.003	0.35
2009	72	0.07	0.000	0.37
2010	63	0.13	0.003	0.58
2011	48	0.11	0.003	0.42
2012	48	0.09	0.003	0.46

Table 2.3b. Summary Data for TN in Kings Bay (WBID 1341), 1974–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1974	3	1.65	0.27	2.84
1975	1	0.10	0.10	0.10
1976	1	0.44	0.44	0.44
1977	1	0.40	0.40	0.40
1979	-	-	-	-
1980	1	0.33	0.33	0.33
1981	-	-	-	-
1984	12	0.30	0.19	0.64
1985	6	0.32	0.25	0.46
1989	-	-	-	-
1990	137	0.38	0.25	0.61
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	2	0.30	0.21	0.38
1997	12	0.21	0.11	0.35
1998	12	0.23	0.16	0.35
1999	12	0.24	0.11	0.47
2000	12	0.30	0.18	0.64
2001	12	0.37	0.20	0.79
2002	12	0.27	0.11	0.40
2003	11	0.27	0.08	0.42
2004	92	0.31	0.16	0.66
2005	48	0.25	0.12	0.49
2006	84	0.27	0.12	1.26
2007	84	0.32	0.17	0.53
2008	84	0.36	0.19	1.02
2009	84	0.35	0.04	1.11
2010	60	0.21	0.07	0.50
2011	48	0.23	0.09	0.53
2012	48	0.20	0.09	0.51

Table 2.4a. Summary Data for Nitrate in Hunter Spring (WBID 1341C, 1990–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1990	4	0.18	0.17	0.19
1991	4	0.25	0.22	0.28
1992	-	-	-	-
1993	-	-	-	-
1994	1	0.29	0.29	0.29
1995	4	0.31	0.28	0.35
1996	-	-	-	-
1997	2	0.31	0.30	0.31
1998	1	0.35	0.35	0.35
1999	4	0.33	0.29	0.36
2000	4	0.34	0.22	0.41
2001	6	0.38	0.36	0.40
2002	4	0.41	0.37	0.47
2003	4	0.36	0.34	0.39
2004	4	0.39	0.39	0.40
2005	5	0.40	0.38	0.43
2006	5	0.41	0.40	0.42
2007	7	0.43	0.23	0.49
2008	8	0.51	0.47	0.57
2009	8	0.52	0.46	0.58
2010	18	0.43	0.17	0.59
2011	4	0.60	0.55	0.63
2012	4	0.64	0.62	0.66

Table 2.4b. Summary Data for Nitrate in House Spring (1341D), 1990–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1990	4	0.21	0.18	0.22
1991	4	0.27	0.24	0.30
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	-	-	-	-
2005	-	-	-	-
2006	-	-	-	-
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	1	0.45	0.45	0.45
2011	1	0.47	0.47	0.47
2012	1	0.49	0.49	0.49

Table 2.4c. Summary Data for Nitrate in Idiot's Delight Spring (WBID 1341F), 1990–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1990	4	0.15	0.13	0.17
1991	3	0.16	0.13	0.18
1992	1	0.14	0.14	0.14
1993	1	0.21	0.21	0.21
1994	1	0.16	0.16	0.16
1995	4	0.18	0.16	0.23
1996	-	-	-	-
1997	2	0.17	0.15	0.19
1998	1	0.19	0.19	0.19
1999	1	0.28	0.28	0.28
2000	2	0.19	0.18	0.21
2001	1	0.20	0.20	0.20
2002	1	0.18	0.18	0.18
2003	2	0.20	0.18	0.21
2004	1	0.31	0.31	0.31
2005	1	0.25	0.25	0.25
2006	1	0.22	0.22	0.22
2007	1	0.19	0.19	0.19
2008	1	0.18	0.18	0.18
2009	1	0.18	0.18	0.18
2010	4	0.21	0.19	0.22
2011	1	0.19	0.19	0.19
2012	1	0.17	0.17	0.17

Table 2.5a. Summary Data for Nitrate in Tarpon Spring (WBID 1341G), 1990–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1990	4	0.13	0.11	0.16
1991	8	0.16	0.14	0.18
1992	-	-	-	-
1993	1	0.19	0.19	0.19
1994	1	0.17	0.17	0.17
1995	4	0.15	0.14	0.17
1996	3	0.16	0.15	0.17
1997	4	0.16	0.14	0.17
1998	4	0.16	0.15	0.17
1999	4	0.15	0.13	0.16
2000	3	0.20	0.18	0.22
2001	6	0.18	0.17	0.20
2002	3	0.20	0.19	0.21
2003	4	0.18	0.16	0.20
2004	4	0.16	0.09	0.19
2005	5	0.18	0.16	0.19
2006	5	0.18	0.15	0.20
2007	8	0.21	0.17	0.23
2008	9	0.22	0.14	0.25
2009	8	0.24	0.20	0.26
2010	23	0.18	0.02	0.38
2011	4	0.25	0.24	0.26
2012	2	0.29	0.28	0.29

Table 2.5b. Summary Data for Nitrate in Black Spring (WBID 1341H), 1990 – 2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1990	4	0.20	0.17	0.22
1991	4	0.23	0.15	0.28
1992	-	-	-	-
1993	1	0.27	0.27	0.27
1994	1	0.88	0.88	0.88
1995	1	0.21	0.21	0.21
1996	-	-	-	-
1997	3	0.23	0.21	0.24
1998	1	0.23	0.23	0.23
1999	1	0.21	0.21	0.21
2000	1	0.14	0.14	0.14
2001	1	0.26	0.26	0.26
2002	1	0.27	0.27	0.27
2003	1	0.27	0.27	0.27
2004	1	0.24	0.24	0.24
2005	1	0.23	0.23	0.23
2006	1	0.27	0.27	0.27
2007	1	0.20	0.20	0.20
2008	1	0.07	0.07	0.07
2009	1	0.28	0.28	0.28
2010	1	0.31	0.31	0.31
2011	1	0.29	0.29	0.29
2012	1	0.31	0.31	0.31

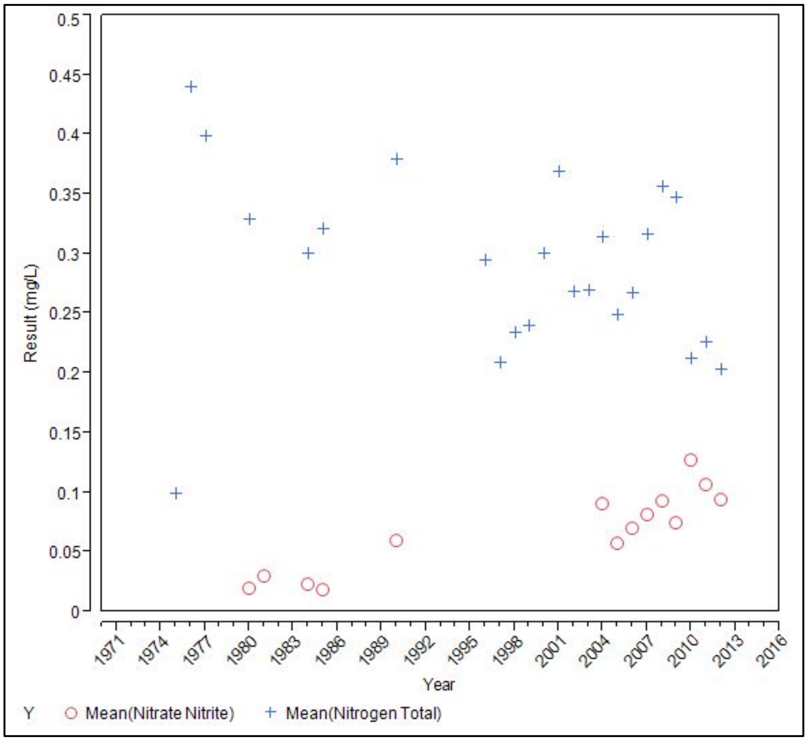

Figure 2.11. Annual TN and Nitrate Concentrations in Kings Bay (WBID 1341) During the Period of Record (Annual Means by Year)

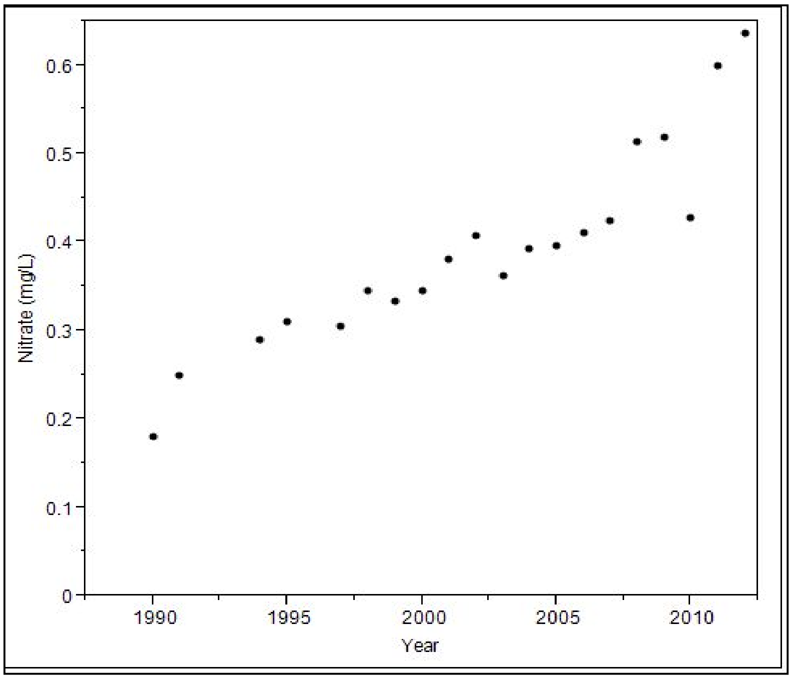

Figure 2.12. Annual Nitrate Concentrations in Hunter Spring (WBID 1341C) During the Period of Record (Annual Means by Year)

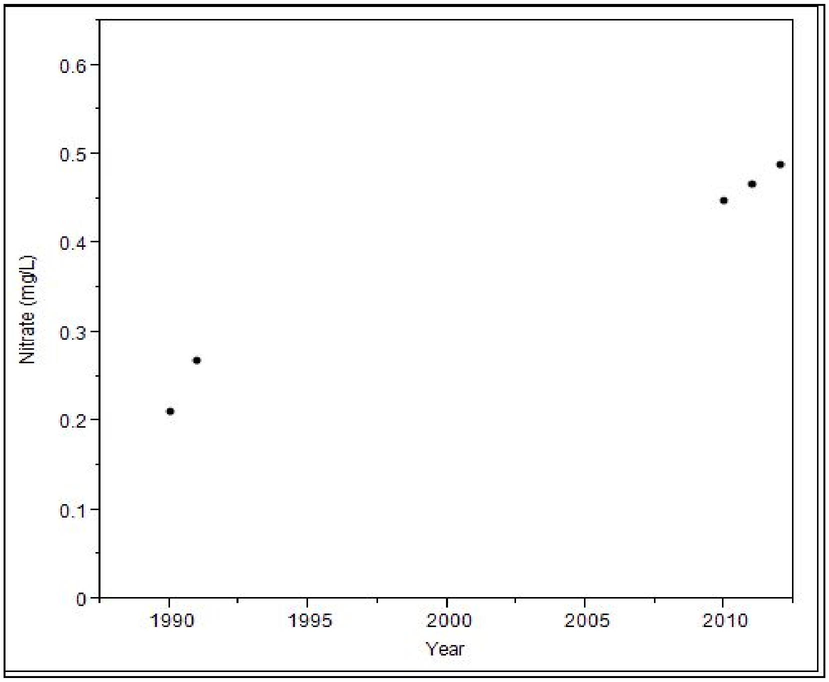

Figure 2.13. Annual Nitrate Concentration in House Spring (WBID 1341D) During the Period of Record (Annual Means by Year)

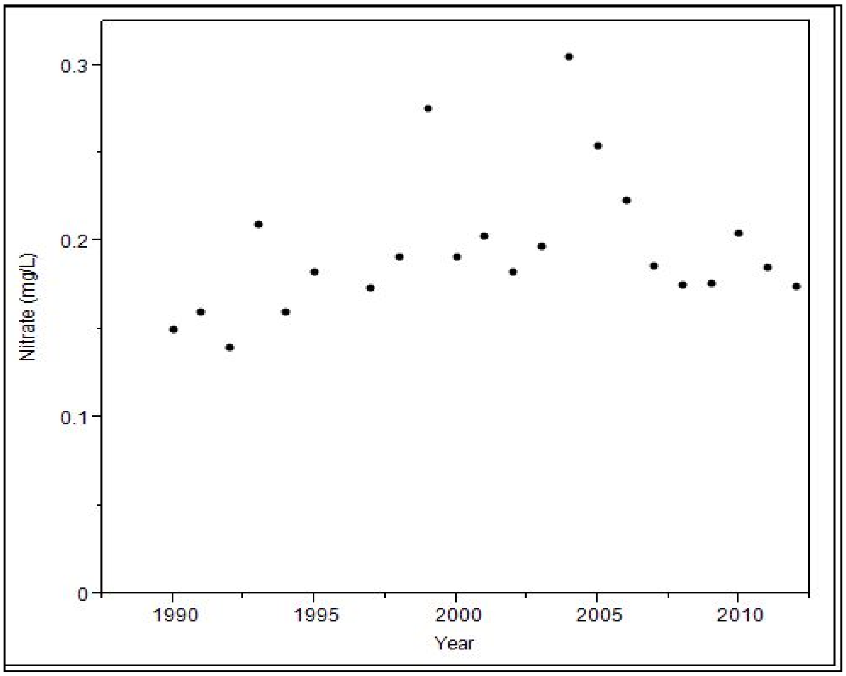

Figure 2.14. Annual Nitrate Concentration in Idiot's Delight Spring (WBID 1341F) During the Period of Record (Annual Means by Year)

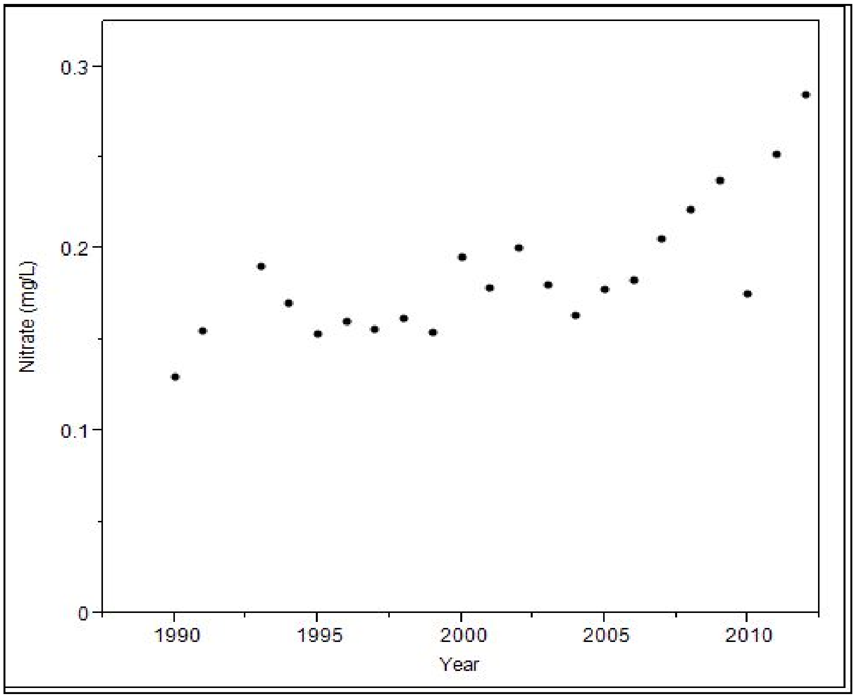

Figure 2.15. Annual Nitrate Concentration in Tarpon Spring (WBID 1341G) During the Period of Record (Annual Means by Year)

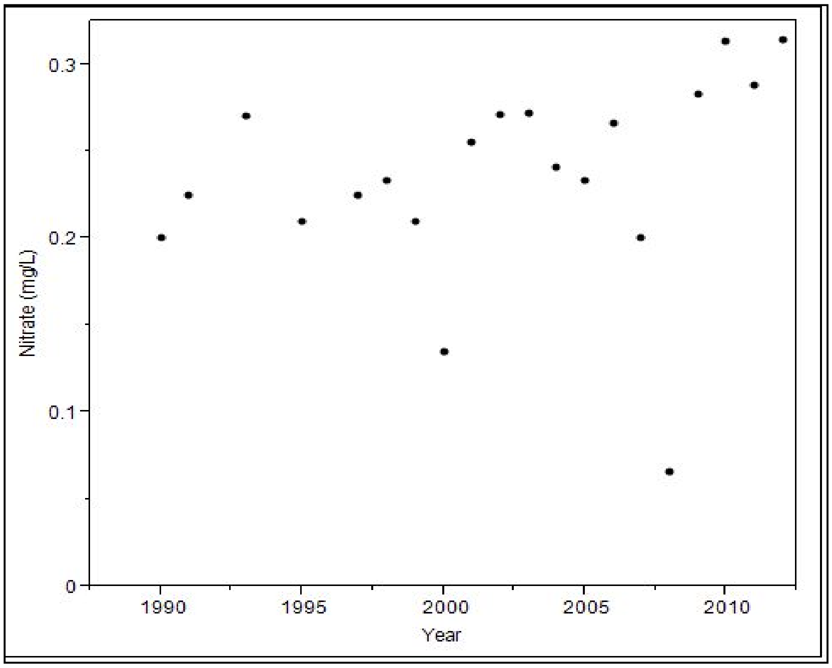

Figure 2.16. Annual Nitrate Concentration in Black Spring (WBID 1341H) During the Period of Record (Annual Means by Year)

2.6.2. Phosphorus

Phosphorus is naturally abundant in the geologic material in much of Florida and is often present in significant concentrations in both surface water and ground water. Total phosphorus (TP) includes both orthophosphate (PO_4) and organic forms of phosphorus.

In Kings Bay, based on the long-term annual average from multiple stations (2004–12), orthophosphate constitutes 41% of the TP (**Table 2.6**). Therefore, the organic phosphorus content in the bay is approximately 59%. There are various sources of organic phosphorus within the bay, including tidal mixing with adjacent wetlands, stormwater runoff, sediment recycling within bay sediments, and aquatic vegetation nutrient cycling. For Kings Bay (WBID 1341) TP and orthophosphate data from water quality sampling stations for the entire period of record (1974 – 2012) were analyzed to detect temporal trends. A non-parametric test for trend is obtained using the Mann-Kendall statistical test, which examines if there is a general increase or decrease in total phosphorus and orthophosphate concentrations over time (Schwarz 2013). The statistical test revealed a slight increasing temporal trend in the bay for TP (N [results] = 750, Kendall tau = 0.16, Prob = 0.0001) and a slight decreasing temporal trend in the bay for orthophosphate (N [results] = 617, Kendall tau = -0.08, Prob = 0.002). **Tables 2.7a** and **2.7b** summarize the TP and orthophosphate data for Kings Bay, and **Figure 2.17** shows the annual TP and orthophosphate concentrations in the bay.

The most common form of phosphorus in geologic material is orthophosphate because it is relatively insoluble in alkaline, carbonate-rich aquifers (SWFWMD 1998). If orthophosphate is present in spring discharge, local ground water inputs from nearby sources are often indicated (Upchurch and Lawrence 1984). Most of the phosphorus in the spring vent samples is in the form of orthophosphate based on a long-term annual average (**Table 2.6**). The organic phosphorus content is low in spring discharge. For each spring WBID, orthophosphate data from water quality sampling stations for the entire period of record (1989 – 2012) were also analyzed to detect temporal trends using the Mann-Kendall statistical test. Based on the statistical test no temporal trends were detected for orthophosphate in Hunter Spring (N [results] = 90, Kendall tau = -0.06, Prob = 0.40), House Spring (N [results] = 11, Kendall tau = 0.42, Prob = 0.10), Black Spring (N [results] = 30, Kendall tau = -0.17, Prob = 0.21), Idiot's Delight Spring (N [results] = 34, Kendall tau = -0.07, Prob = 0.58),and Tarpon Spring (N [results] = 110, Kendall tau = -0.07, Prob = 0.28). The orthophosphate data range for Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring has not significantly differed from 1989 to 2012. **Tables 2.8a, 2.8b,** and **2.8c** and **Tables 2.9a** and **2.9b** summarize the orthophosphate data, and **Figures 2.18** through **2.22** show the annual orthophosphate concentrations for Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring.

The Department has selected a conservative approach for phosphorus. Based on the statistical test, TP is slightly increasing in Kings Bay (WBID 1341). The phosphorus content in Kings Bay is made up of both orthophosphate and organic phosphorus. Therefore, TP is considered the target nutrient for Kings Bay (WBID 1341). For each spring WBID, orthophosphate is considered the target nutrient for Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H) because Stevenson et al (2007) found that for Lyngbya sp. orthophosphate is limiting when nitrate concentrations are greater than 0.05 mg/L. **Chapter 5** includes a discussion of the nutrient impairments and the setting of the water quality target concentrations.

Table 2.6. Percent Orthophosphate in TP Based on Long-Term Annual Average for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, 2004–12 (in mg/L)

LTA = Long-term average (2004–12)

Spring Vent (WBID)	Waterbody Type	LTA_OPO4	LTA_TP	Difference	% OPO4 of TP
Kings Bay (WBID 1341)	Bay	0.013	0.032	0.019	41%
Hunter Spring (WBID 1341C)	Spring	0.024	0.029	0.005	83%
House Spring (WBID 1341D)	Spring	0.023	0.024	0.001	96%
Idiot's Delight Spring (WBID 1341F)	Spring	0.026	0.027	0.001	96%
Tarpon Spring (WBID 1341G)	Spring	0.027	0.034	0.007	79%
Black Spring (WBID 1341H)	Spring	0.017	0.024	0.007	71%

Table 2.7a. Summary Data for Orthophosphate in Kings Bay (WBID 1341), 1974–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1974	3	0.023	0.020	0.030
1975	1	0.010	0.010	0.010
1976	1	0.020	0.020	0.020
1977	1	0.025	0.025	0.025
1979	-	-	-	-
1980	-	-	-	-
1981	-	-	-	-
1984	12	0.021	0.013	0.031
1985	6	0.020	0.012	0.027
1989	2	0.056	0.042	0.070
1990	6	0.059	0.035	0.084
1991	1	0.029	0.029	0.029
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	80	0.018	0.011	0.020
2005	48	0.015	0.010	0.027
2006	72	0.013	0.005	0.029
2007	72	0.011	0.005	0.027
2008	72	0.012	0.005	0.033
2009	72	0.010	0.004	0.029
2010	60	0.012	0.005	0.048
2011	48	0.011	0.005	0.028
2012	48	0.011	0.004	0.032

Table 2.7b. Summary Data for TP in Kings Bay (WBID 1341), 1974–2012 (in mg/L)

\- = No data available

Year	N	Mean	Minimum	Maximum
1974	3	0.027	0.020	0.040
1975	1	0.040	0.040	0.040
1976	1	0.020	0.020	0.020
1977	1	0.090	0.090	0.090
1979	1	0.050	0.050	0.050
1980	1	0.090	0.090	0.090
1981	1	0.120	0.120	0.120
1984	10	0.057	0.020	0.090
1985	6	0.072	0.050	0.090
1989	2	0.034	0.010	0.058
1990	5	0.109	0.045	0.220
1991	1	0.030	0.030	0.030
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	2	0.030	0.027	0.033
1997	12	0.027	0.016	0.044
1998	12	0.029	0.021	0.042
1999	12	0.023	0.013	0.030
2000	12	0.034	0.021	0.075
2001	12	0.045	0.025	0.115
2002	12	0.032	0.022	0.050
2003	11	0.031	0.010	0.075
2004	93	0.027	0.017	0.057
2005	47	0.024	0.012	0.048
2006	84	0.027	0.013	0.048
2007	84	0.032	0.010	0.052
2008	84	0.034	0.020	0.100
2009	84	0.036	0.012	0.067
2010	48	0.035	0.016	0.059
2011	48	0.034	0.018	0.086
2012	48	0.037	0.019	0.060

Table 2.8a. Summary Data for Orthophosphate in Hunter Spring (WBID 1341C), 1989–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1989	3	0.016	0.000	0.029
1990	1	0.024	0.024	0.024
1991	4	0.028	0.020	0.030
1992	-	-	-	-
1993	-	-	-	-
1994	1	0.020	0.020	0.020
1995	4	0.025	0.010	0.040
1996	-	-	-	-
1997	2	0.020	0.013	0.027
1998	1	0.023	0.023	0.023
1999	4	0.024	0.016	0.027
2000	4	0.026	0.021	0.032
2001	6	0.027	0.021	0.031
2002	4	0.025	0.023	0.027
2003	4	0.027	0.026	0.028
2004	4	0.025	0.023	0.026
2005	4	0.025	0.021	0.030
2006	5	0.022	0.017	0.025
2007	8	0.025	0.021	0.032
2008	8	0.022	0.015	0.026
2009	8	0.023	0.005	0.034
2010	5	0.027	0.024	0.035
2011	4	0.024	0.022	0.025
2012	4	0.024	0.023	0.025

Table 2.8b. Summary Data for Orthophosphate in House Spring (1341D), 1989–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1989	3	0.023	0.010	0.044
1990	1	0.022	0.022	0.022
1991	4	0.020	0.020	0.020
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	-	-	-	-
2005	-	-	-	-
2006	-	-	-	-
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	1	0.021	0.021	0.021
2011	1	0.023	0.023	0.023
2012	1	0.025	0.025	0.025

Table 2.8c. Summary Data for Orthophosphate in Idiot’s Delight Spring (WBID 1341F), 1989–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1989	3	0.017	0.000	0.033
1990	1	0.027	0.027	0.027
1991	3	0.030	0.030	0.030
1992	1	0.030	0.030	0.030
1993	1	0.030	0.030	0.030
1994	1	0.020	0.020	0.020
1995	4	0.031	0.020	0.050
1996	-	-	-	-
1997	2	0.024	0.013	0.035
1998	1	0.028	0.028	0.028
1999	1	0.030	0.030	0.030
2000	2	0.024	0.022	0.025
2001	1	0.028	0.028	0.028
2002	1	0.020	0.020	0.020
2003	2	0.020	0.020	0.020
2004	1	0.030	0.030	0.030
2005	1	0.024	0.024	0.024
2006	1	0.025	0.025	0.025
2007	1	0.025	0.025	0.025
2008	1	0.025	0.025	0.025
2009	1	0.026	0.026	0.026
2010	1	0.024	0.024	0.024
2011	1	0.027	0.027	0.027
2012	1	0.027	0.027	0.027

Table 2.9a. Summary Data for Orthophosphate in Tarpon Spring (WBID 1341G), 1989–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1989	4	0.024	0.020	0.028
1990	1	0.027	0.027	0.027
1991	8	0.030	0.030	0.030
1992	-	-	-	-
1993	1	0.020	0.020	0.020
1994	1	0.020	0.020	0.020
1995	4	0.033	0.020	0.050
1996	3	0.028	0.013	0.044
1997	4	0.025	0.022	0.028
1998	4	0.025	0.017	0.029
1999	4	0.029	0.023	0.032
2000	4	0.027	0.015	0.038
2001	6	0.030	0.023	0.037
2002	4	0.031	0.027	0.035
2003	4	0.029	0.025	0.034
2004	4	0.028	0.014	0.035
2005	5	0.031	0.028	0.033
2006	5	0.027	0.024	0.030
2007	8	0.026	0.010	0.032
2008	9	0.025	0.017	0.030
2009	8	0.026	0.005	0.034
2010	11	0.023	0.016	0.028
2011	4	0.026	0.024	0.028
2012	2	0.028	0.026	0.030

Table 2.9b. Summary Data for Orthophosphate in Black Spring (WBID 1341H), 1989–2012 (in mg/L)

- = No data available

Year	N	Mean	Minimum	Maximum
1989	3	0.016	0.010	0.020
1990	1	0.023	0.023	0.023
1991	4	0.023	0.020	0.030
1992	-	-	-	-
1993	1	0.020	0.020	0.020
1994	1	0.080	0.080	0.080
1995	1	0.040	0.040	0.040
1996	-	-	-	-
1997	3	0.018	0.013	0.026
1998	1	0.021	0.021	0.021
1999	1	0.027	0.027	0.027
2000	1	0.026	0.026	0.026
2001	1	0.028	0.028	0.028
2002	1	0.017	0.017	0.017
2003	1	0.013	0.013	0.013
2004	1	0.026	0.026	0.026
2005	1	0.019	0.019	0.019
2006	1	0.019	0.019	0.019
2007	1	0.017	0.017	0.017
2008	1	0.005	0.005	0.005
2009	1	0.018	0.018	0.018
2010	1	0.017	0.017	0.017
2011	1	0.018	0.018	0.018
2012	1	0.018	0.018	0.018

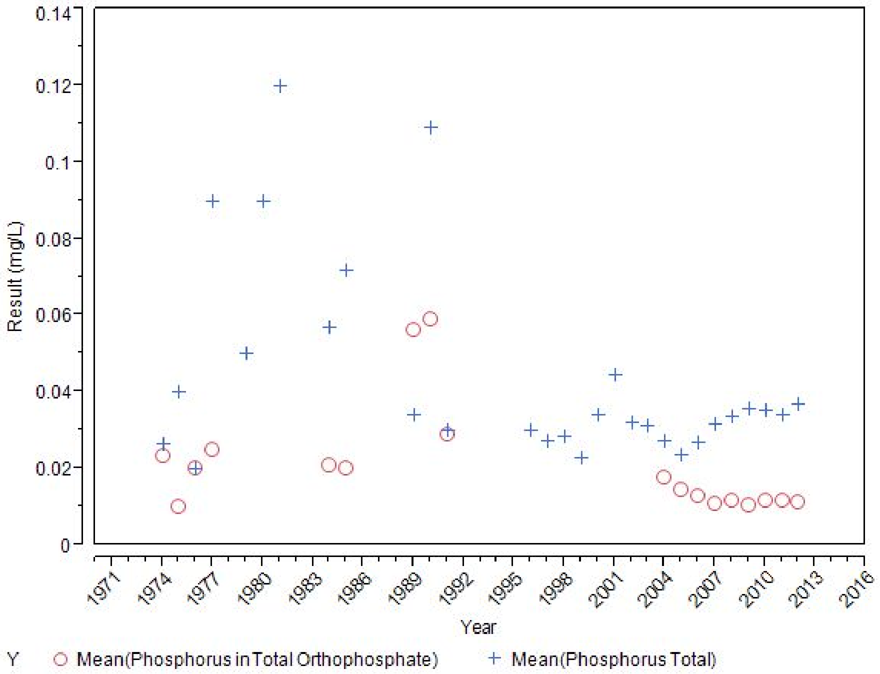

Figure 2.17. Annual TP and Orthophosphate Concentrations in Kings Bay (WBID 1341) During the Period of Record (Annual Means by Year)

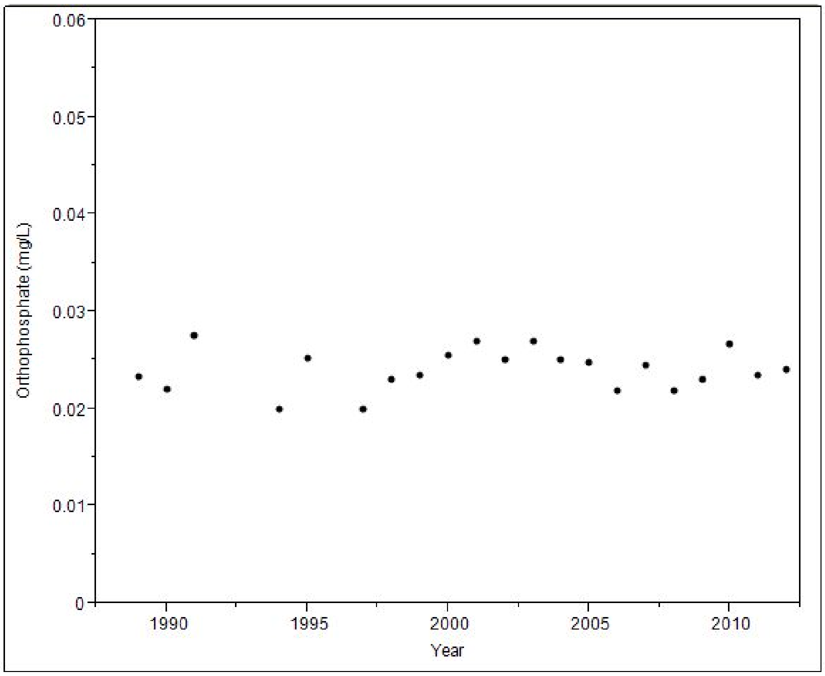

Figure 2.18. Annual Orthophosphate Concentrations in Hunter Spring (WBID 1341C) During the Period of Record (Annual Means by Year)

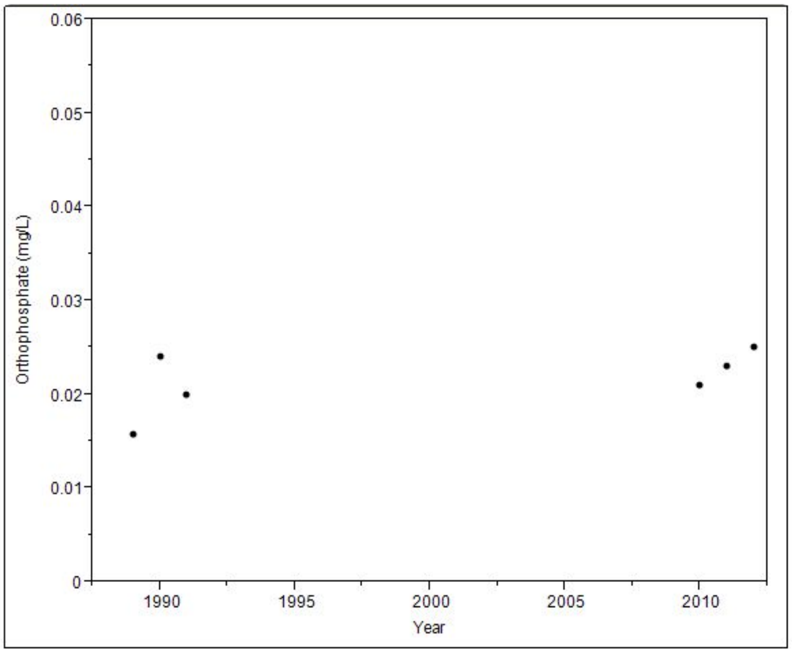

Figure 2.19. Annual Orthophosphate Concentrations in House Spring (WBID 1341D) During the Period of Record (Annual Means by Year)

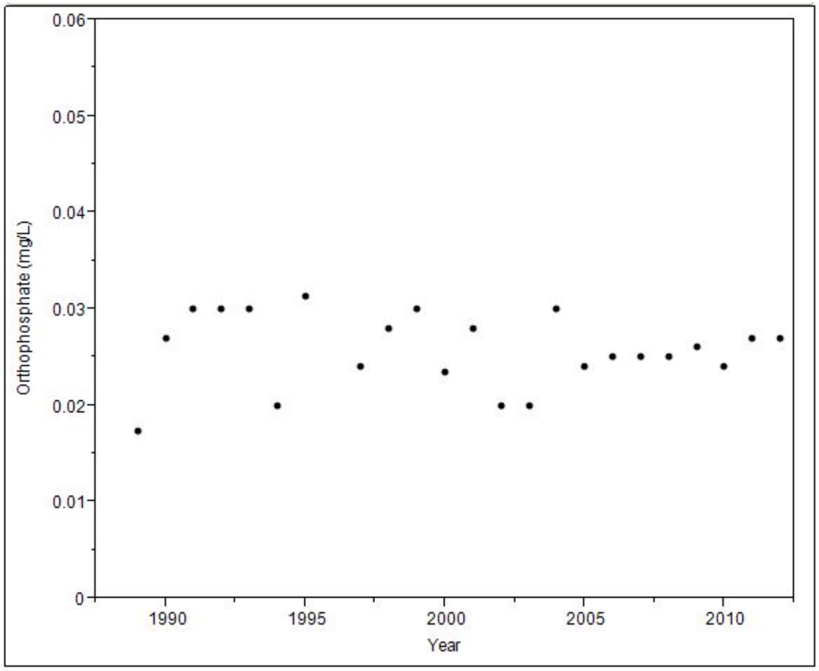

Figure 2.20. Annual Orthophosphate Concentrations in Idiot's Delight Spring (WBID 1341F) During the Period of Record (Annual Means by Year)

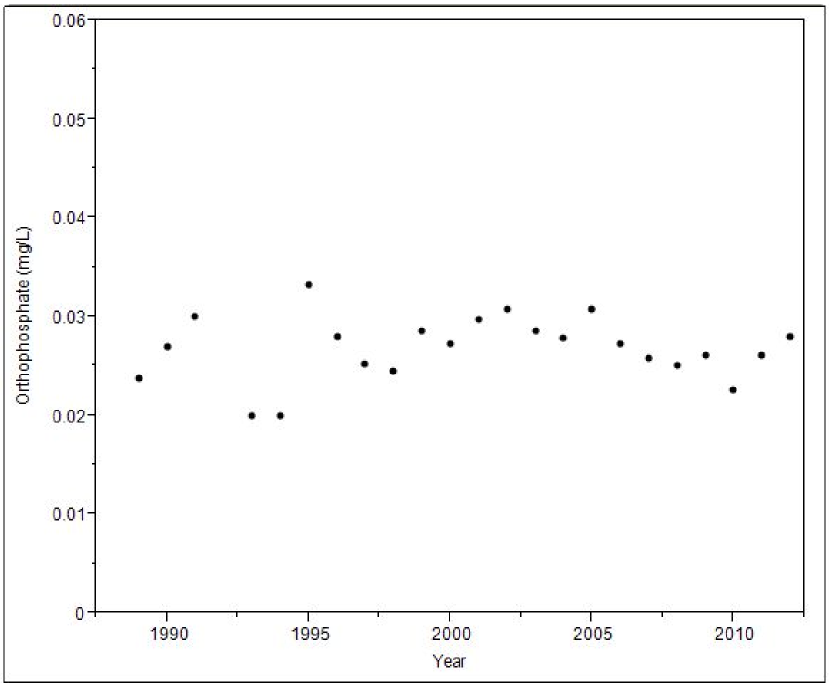

Figure 2.21. Annual Orthophosphate Concentrations in Tarpon Spring (WBID 1341G) During the Period of Record (Annual Means by Year)

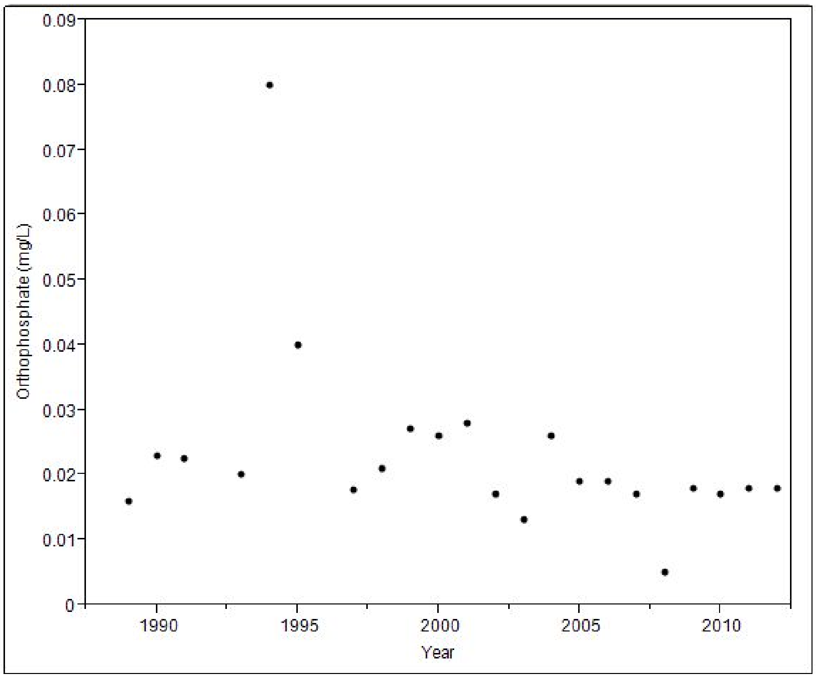

Figure 2.22. Annual Orthophosphate Concentrations in Black Spring (WBID 1341H) During the Period of Record (Annual Means by Year)

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

Florida's surface waters are protected for five designated use classifications, as follows:

Class I	**Potable water supplies**
Class II	**Shellfish propagation or harvesting**
Class III	**Recreation, propagation, and maintenance of a healthy, well-balanced population of fish and wildlife**
Class IV	**Agricultural water supplies**
Class V	**Navigation, utility, and industrial use (there are no state waters currently in this class)**

Kings Bay (WBID 1341), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H) are Class III marine waterbodies. Hunter Spring (WBID 1341C), House Spring (WBID 1341D), and Idiot's Delight Spring (WBID 1341F) are Class III freshwater waterbodies. Class III waterbodies have a designated use of recreation, propagation, and the maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criterion applicable to the impairment addressed by this TMDL is nutrients, which in excess have been demonstrated to adversely affect flora or fauna.

3.2 Applicable Water Quality Standards

3.2.1 Nutrients

The narrative nutrient water quality criterion for the protection of Class III waters, as established by Rule 62-303.450(2), F.A.C. (IWR), states that nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna. This imbalance includes algal mats or blooms that are present in sufficient quantities to pose a nuisance or hinder the reproduction of a threatened or endangered species, as stated in Subsections 62-303.353(3) and 62-303.354(2), F. A. C. Accordingly, the IWR (Subsection 62-303.450[5], F.A.C.) specifically allows the use of alternative, site-specific thresholds that more accurately reflect conditions beyond which an imbalance in flora or fauna occurs in the waterbody.

These TMDL target concentrations for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring will be submitted to EPA for approval as site specific (Hierarchy 1) interpretations of the narrative nutrient criteria for these water bodies as stated in Rule 62-302.531, F.A.C.

For Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, the excessive growth of algae is a significant problem. Filamentous algae growth causes a variety of conditions that result in ecological imbalances— including, but not limited to, habitat smothering, nutrition and habitat for pathogenic bacteria, the production of toxins that may affect biota, the reduction of oxygen levels, and an increase in diurnal swings of the dissolved oxygen (DO) regime in the bay. Algal mats can produce human health problems, foul beaches, inhibit navigation, and reduce the aesthetic value of the springs and bay.

3.2.2 Outstanding Florida Water Designation

The Outstanding Florida Water (OFW) criterion in Section 62-302.700, F.A.C., requires no degradation of water quality for Special Waters. On February 1, 1983, the Environmental Regulation Commission approved the petition designating the Crystal River and Kings Bay as an OFW.

3.2.3 Numeric Nutrient Criterion for Spring Vents

The Department's numeric nutrient criterion (NNC) of 0.35 mg/L nitrate for spring vents was adopted in Rule 62-302, F.A.C., by the Environmental Regulations Commission on December 8, 2011. Following legal challenges and federal rulemaking actions on November 30, 2012 the EPA approved the Department's NNC for spring vents. The NNC for springs is 0.35 mg/L nitrate-nitrite as an annual geometric mean, not be exceeded more than once in any 3 calendar year period. The complete technical support document on how the Department calculated the NNC is available at: http://www.dep.state.fl.us/water/wqssp/nutrients/docs/tsd-nnc-lakes-springs-streams.pdf.

Paragraph 62-302.530(47)(b), F.A.C., states that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." This narrative criteria is still applicable statewide, but the Department's hierarchical approach gives preference to the numeric nutrient value of 0.35 mg/L nitrate-nitrite for springs based on quantifiable stressor-response relationships between nutrients and biological response. In addition, if there are sufficient site-specific data for a particular spring, a site-specific alternative criterion can be set. The Department found sufficient algal growth response data to support a different site-specific criterion for these impaired waters. **Chapter 5** discusses the nitrogen and phosphorus impairment and the setting of the TMDL target concentrations.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of nutrients in the contributing area. Sources are broadly classified as either "point sources" or "nonpoint sources." Historically, the term "point sources" has meant discharges to surface waters that typically have a continuous flow via a discernible, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) discharging directly to surface waters are examples of traditional point sources. In contrast, the term "nonpoint sources" was used to describe intermittent, rainfall-driven, diffuse sources of pollution associated with human activities and those sources that do not directly discharge to the impaired surface water, including runoff and ground water migration from urban land uses, wastewater treatment sites, stormwater drainage areas, agriculture, silviculture, mining, discharges from septic systems, and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of surface water pollution as point sources subject to regulation under the EPA's National Pollutant Discharge Elimination System (NPDES) Program. These nonpoint sources included certain urban stormwater discharges to surface water, such as those from local government master drainage systems, construction sites over five acres, and a wide variety of industries that receive NPDES permits (see **Appendix A** for background information on the federal and state stormwater programs).

To be consistent with Clean Water Act definitions, the term "point source" will be used to describe traditional point sources (such as domestic and industrial wastewater discharges to surface water) and stormwater system discharges to surface water that require an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see **Section 6.1**). However, the methodology used to estimate nonpoint source loads does not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of Nutrients in the Kings Bay Contributing Area

4.2.1 Chemical and Isotopic Tracers to Evaluate Nitrogen Sources

On two occasions, in 2011 and 2013, a team of samplers from the Department's Ground Water Management Section (GWMS) collected water quality samples from springs in the Kings Bay Springs Group for chemical analysis to assess the sources of nitrate. The focus of this investigation was to use chemical and isotopic tracers to evaluate the contribution of nitrate from domestic wastewater sources.

Twelve of the springs in the Kings Bay Springs Group were sampled, and 11 of these provided useful information. These springs were selected because they were known to contain significant levels of nitrate and were closest to potential nitrate sources (**Figure 4.1**). The samples were analyzed for nutrients, several organic chemicals used as tracers for domestic wastewater, and stable isotopes used to differentiate between inorganic and organic sources of nitrate.

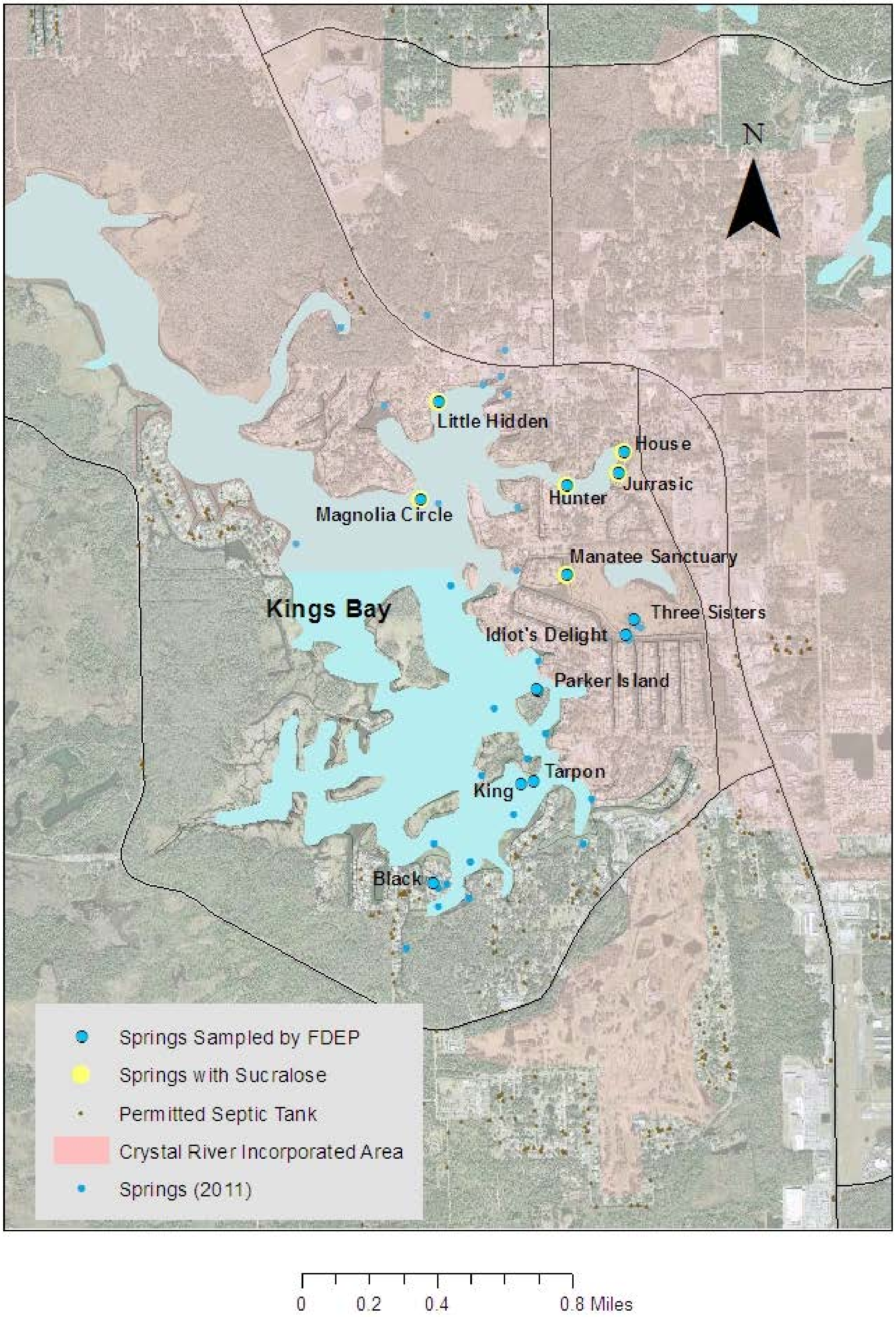

Figure 4.1. Locations of Selected Springs Included in the Kings Bay Group Nitrate Source Identification Sampling (October 2011)

The analytical parameters included nitrate; orthophosphate, galaxolide, tonalide, sucralose, and isotopes of nitrogen and oxygen (δ15N and δ18O in nitrate). Galaxolide, tonalide, and sucralose have been used in many studies as tracers of domestic wastewater influence in receiving surface waters. In addition, the analysis of δ15N and δ18O in nitrate are used to provide information about the nitrate sources and the relative amount of denitrification (the biological breakdown of nitrate in the environment) to which the sample has been subjected. **Table 4.1** summarizes the results of this sampling effort. Nitrate concentrations in the spring samples ranged from 0.06 to 0.65 mg/L.

Table 4.1. Water Quality Results from the October 2011 Sampling of Selected Kings Bay Group Springs

Notes:
µg/L = Micrograms per liter
U - Material was analyzed but not detected. The reported value is the method detection limit for the sample analyzed.
Q - Sample held beyond normal holding time.
I - The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
N - Presumed evidence of presence of material.
T - Value reported is less than the criterion of detection.
S - Value suspect because of low NO2NO3 concentration.
NS - Not sampled.
\- = Empty cell/no data
***** Not representative of spring vent based on historical results.

Spring	Date	NO2NO3 (mg/L)	Galaxolide (µg/L)	Tonalide (µg/L)	Sucralose (µg/L)	δ15N (‰)	δ18O (‰)
Catfish	10/26/11	0.30	0.0036 U	0.012 U	0.0075 TN	5.38	3.39
Catfish	2/27/13	0.15	-	-	0.010U	7.32	5.66
House	10/25/11	0.50	0.0037 U	0.0012 U	0.026 I	6.19	4.95
House	1/9/13	0.49	-	-	0.010U	5.45	3.44
Hunter	10/25/11	0.65	0.0035 U	0.0012 U	0.12	7.61	5.76
Hunter	1/9/13	0.54	NS	NS	0.041I	7.61	5.76
Idiot's Delight	10/26/11	0.20	0.0036 U	0.0012 U	0.010 U	5.62	4.42
Idiot's Delight	1/9/13	0.22	-	-	-	4.42	3.45
Jurassic	10/25/11	0.54	0.0037 U	0.0012 U	0.081	7.11	5.22
Jurassic	2/27/13	0.54	NS	NS	0.023I	5.59	1.86
Little Hidden	10/25/11	0.20	0.0035 U	0.0012 U	0.0099 U	6.19	5.04
Magnolia Circle	10/25/11	0.06*	0.0036 U	0.0012 U	0.018 I	9.11 S	8.81 S
Manatee Sanctuary	10/26/11	0.14	0.0037 U	0.0012 U	0.012 IN	6.21	5.40
Parker Island	10/26/11	0.21	0.037 U	0.0012 U	0.0098 U	5.27	2.81
Tarpon	10/26/11	0.27	0.0037 U	0.0012 U	0.010 U	5.37	4.48
King	1/9/13	0.21	NS	NS	0.010U	6.41	4.38
Three Sisters #1	10/26/11	0.20	0.0038 U	0.0013 U	0.010 U	5.37	5.35
Black Spring	2/27/13	0.30	NS	NS	0.010U	5.96	4.47

Sucralose is an artificial sweetener and has been found to be a very resilient tracer of domestic wastewater influence on receiving waters. The positive detection or presumed presence of sucralose was found by the laboratory in six of the springs. Detections of sucralose are indicative of domestic wastewater sources such as wastewater application sites or septic tanks.

The springs with quantifiable concentrations of sucralose also had the highest nitrate concentrations (Hunter Spring and Jurassic Spring). The sucralose concentrations in Hunter Spring and Jurassic Spring were 0.12 and 0.081µg/L, respectively. **Figure 4.2** shows the spatial relationship of the springs with positive or presumed sucralose detections to potential nearby sources of domestic wastewater, which include domestic wastewater application sites and septic tanks.

The isotope results for all but one of these springs can be used for data interpretation. The sample at Magnolia Circle Spring was not taken from the spring vent and included dilution from the bay, which significantly decreases the confidence in the isotope results. Over the years, researchers have associated isotopic ratios in ground water with a variety of sources. From those data, general δ15N ranges have been assigned for the types of sources. The three main nitrogen source categories are inorganic (from fertilizer), organic (from animal waste or domestic wastewater), and soil (which includes nitrogen from any source that is assimilated by the soil and accumulated in soil organic matter). The Department does not consider soil nitrogen to be a significant factor affecting these springs because most of the soils in the contributing area are low in organic content and would not tend to contain nitrogen.

Figure 4.3 shows the plotted δ15N and 18ONO3 values for the spring samples compared with the general ranges for inorganic and organic sources provided by Roadcap *et al.* (2002). Most of the springs fall between the inorganic and organic source categories, which could be due to a mixture of inorganic and organic nitrate sources, isotope enrichment caused by denitrification, or a combination of the two. Samples from Hunter, Catfish, and Jurassic Springs had ratios closest to the domestic wastewater/animal waste category (**Table 4.1**), consistent with the detections of sucralose.

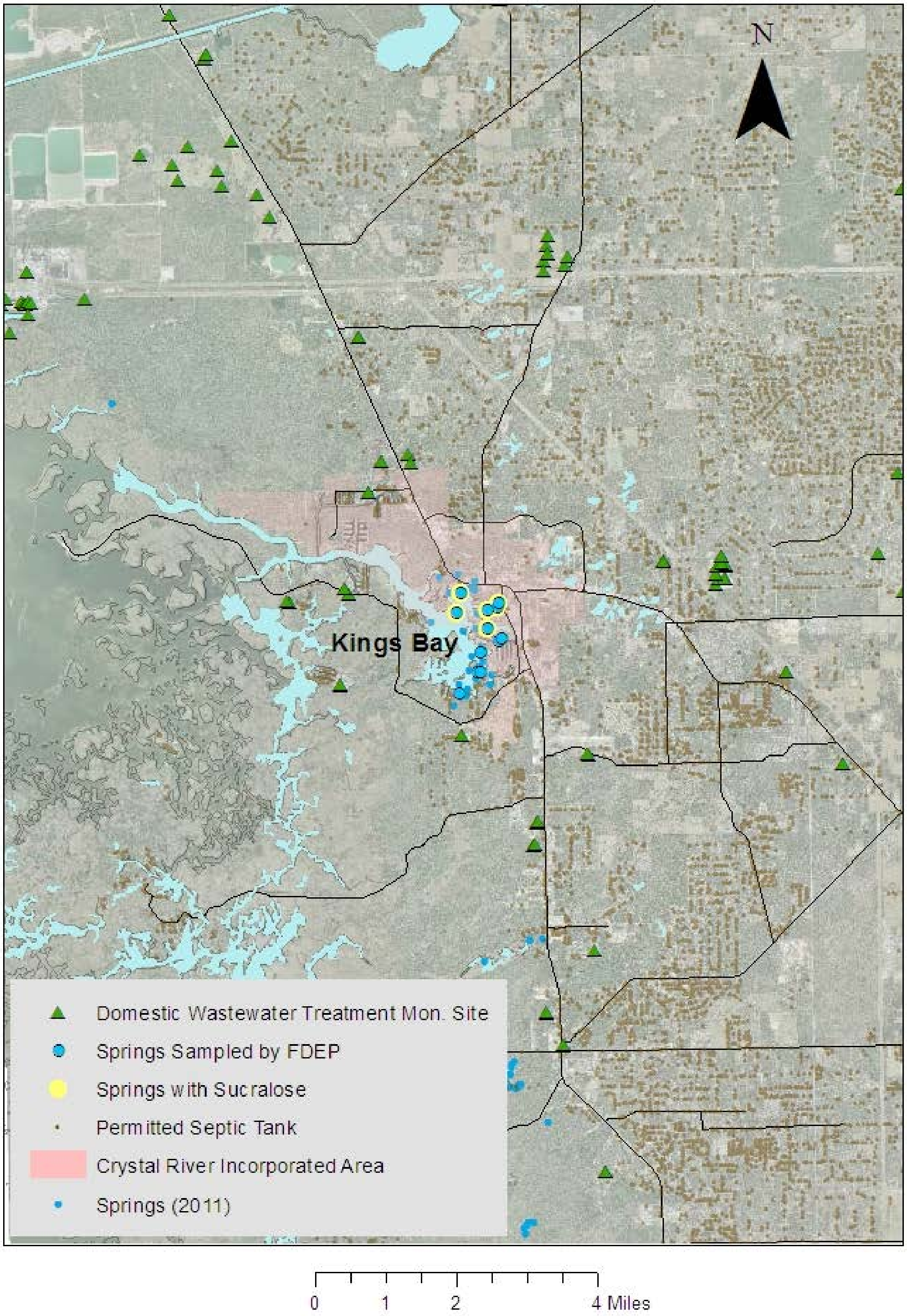

Figure 4.2. Locations of Springs with Presumed or Positive Detections of Sucralose and Nearby Potential Domestic Wastewater Sources

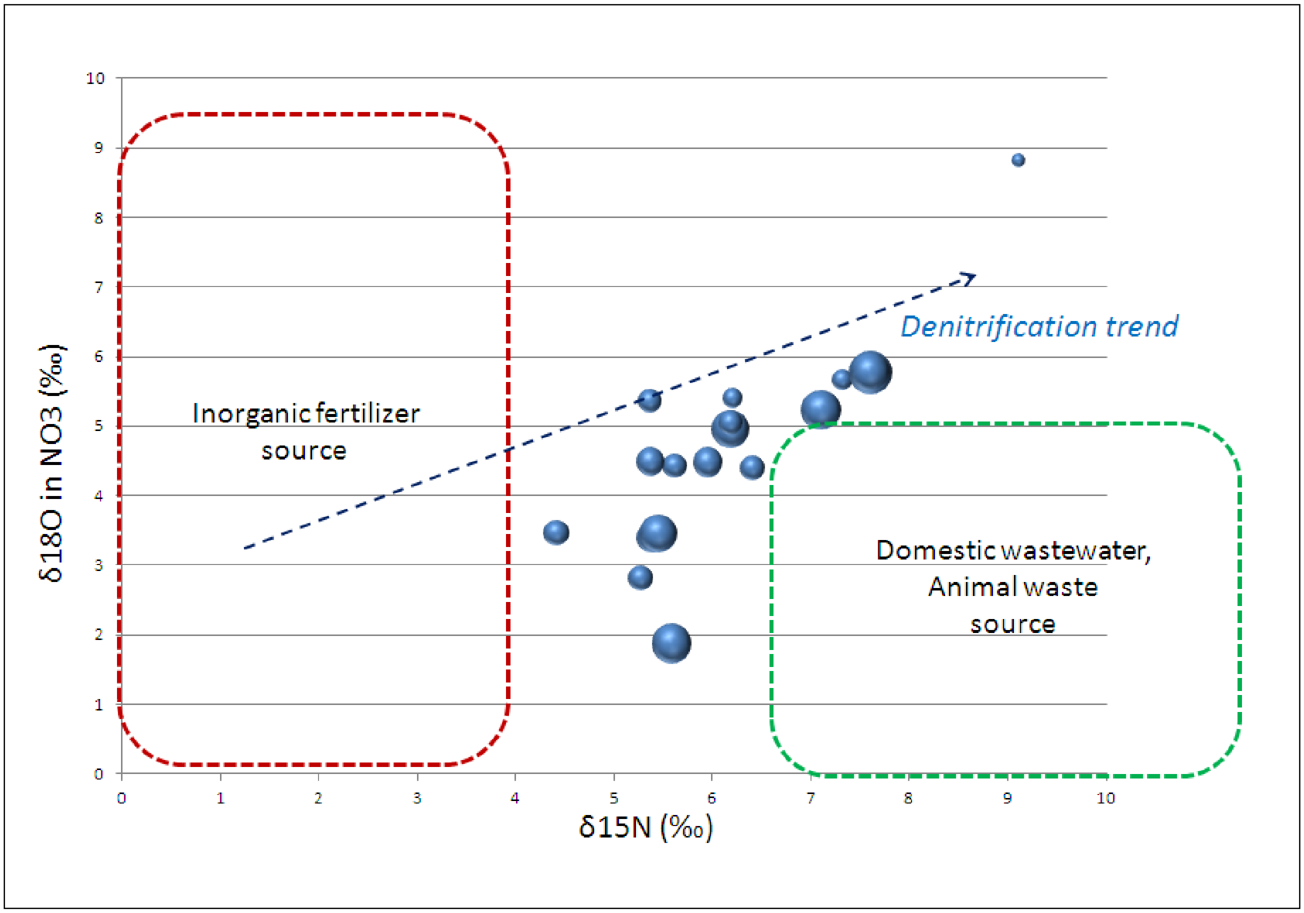

Figure 4.3. **Distribution of δ15N and δ18ONO3 Ratios in** Kings Bay Group Spring Samples and Approximate Nitrate Source Ranges (modified after Roadcap et al. 2002). Symbol size is proportionate to nitrate concentration.

4.2.2 Wastewater and Stormwater Sources

Wastewater

The term "wastewater" is used to describe domestic and industrial wastewater discharges to surface water or ground water. At this time, there are no NPDES permitted wastewater facilities in the Kings Bay contributing area that directly discharge to the impaired surface waters addressed in this TMDL. All of the existing wastewater application sites discharge to ground water via sprayfields, rapid infiltration basins (RIBs), drainfields, or percolation ponds. Domestic wastewater facilities are of primary interest as sources of nitrate. According to the Department's Wastewater Facilities Regulation (WAFR) database, there are 24 permitted domestic wastewater treatment facilities (WWTFs) in the contributing area. Of the permitted domestic wastewater facilities, 6 have design capacities greater than 0.1 million gallons per day (MGD) (**Table 4.2**). The largest facility is the city of Crystal River wastewater treatment plant (WWTP), which has a sprayfield, but its wastewater stream will be diverted to the nearby Progress Energy power plant to be used as cooling water.

Table 4.2. Permitted Domestic WWTFs with Design Capacities Greater than 0.1 MGD in the Kings Bay Contributing Area

Facility ID Number	Facility Name	Design Capacity (MGD)
FLA011877	Citrus Springs WWTF	0.2
FLA126594	Dunnellon City Of	0.25
FLA011844	Brentwood Regional WWTF	0.5
FLA011845	Meadowcrest WWTF	0.5
FLA011869	Beverly Hills WWTF	0.575
FLA011848	City of Crystal River WWTF	1.5

Municipal Separate Storm Sewer System (MS4) Permittees

Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring are not located within the service area of a local government currently holding an MS4 permit.

4.2.3 Land Uses and Nonpoint Sources

In the contributing area, nutrient loading may come from nonpoint sources that discharge to ground water or runoff directly into Kings Bay or a tributary to the bay. Population density and land uses dictate which sources may contribute the most to the impairment of receiving waters. These sources include septic tanks, atmospheric deposition, and fertilizers from home gardens, lawns, golf courses, and agricultural operations. Domestic wastewater application sites that discharge to ground water are also considered potential nonpoint sources of nitrogen.

Population

Kings Bay and most of its contributing area are in Citrus County, and the city of Crystal River adjoins the bay. In 2010, the U.S. Census Bureau reported that the total population of Citrus County was 141,236, with 59,915 households (HH) and 78,423 housing units (HU). The population density was 242.8 people per square mile of land area. In 2010, the U.S. Census Bureau reported that the total population within the city of Crystal River's urbanized area was 3,111. The population of Citrus County has increased from approximately 19,000 in 1970 to more than 141,236 in 2010 (**Table 4.3**). During this period, Citrus County and the city of Crystal River were among the fastest growing counties and cities in the state.

A large percentage of this increase has been attributed to retirees moving into the area (SWFWMD 2000). The economy of the Kings Bay region is supported by ecotourism and the population of retired residents. Growth in these areas has led to an associated growth in real estate, construction, wholesale and resale trade, and service sectors of the economy. **Figure 4.4** shows the population density within the Kings Bay contributing area based on the U.S. Census Bureau census tracts for Citrus County.

Table 4.3. Population of Citrus County and the City of Crystal River, 1970–2010

- = Empty cell/no data

Location	1970	1980	1990	2000	2010
Citrus County	19,196	54,703	93,515	118,085	141,236
City of Crystal River	-	2,778	4,195	3,507	3,111

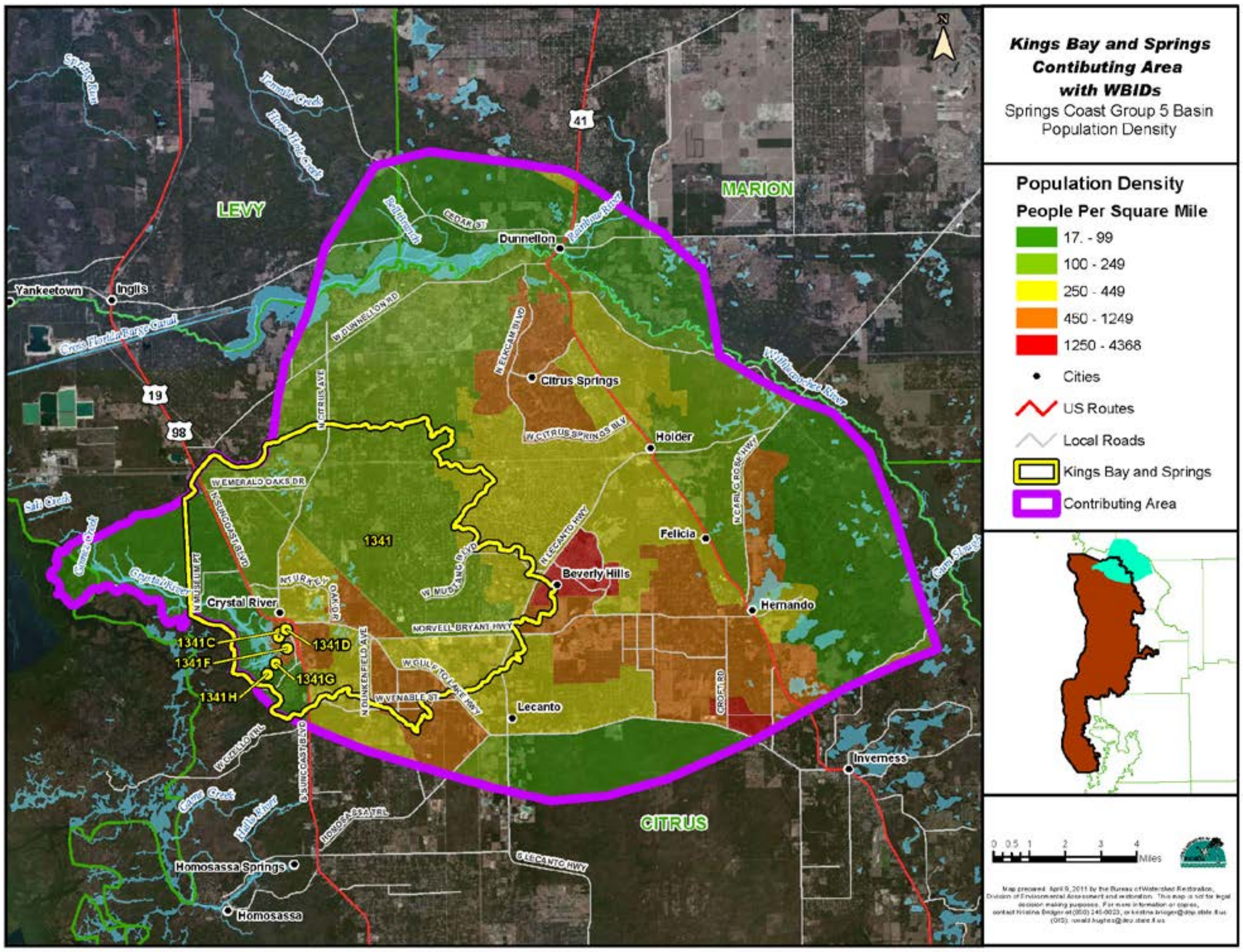

Figure 4.4. Population Density in the Kings Bay Contributing Area in 2010

Land Uses

The land uses in the contributing area for Kings Bay were identified using the most recent (2009) SWFWMD land use Geographic Information System (GIS) coverage and were aggregated using the simplified Level 1/Level 2 codes. **Table 4.4** summarizes the land uses and land cover category breakdowns, and **Figure 4.5** shows the principal land uses in the contributing area. Urbanized areas are the predominant land use category in the contributing area (45%), followed closely by "forestry/rural open" (26%). Agricultural land uses comprise only about 10% of the contributing area. Urbanized areas increased from 95.21 mi^2 in 1989 to 117.56 mi^2 in 2009. Conversely, agricultural areas decreased from 34.95 mi^2 in 1989 to 24.58 mi^2 in 2009. In this same period, forest/rural open areas also decreased from 80.04 to 67.46 mi^2 in 1989 and 2009, respectively. Both of these decreases were a result of agricultural and forest/rural open areas converting to urbanized areas.

The Floridan aquifer's vulnerability to sources of nitrate can be observed in the nitrate concentrations in springs and wells within the contributing area. Nitrate concentrations in ground water and springs increased as land use transitioned from natural land to agricultural and urban development. Anthropogenic sources of nitrate in the contributing area include atmospheric deposition, agricultural and residential fertilizers, and human and animal wastes. **Table 4.5** shows the land use categories for the Kings Bay contributing area by decade.

Table 4.4. Classification of Land Use Categories for the Kings Bay Contributing Area in 2009

SWFWMD 2009 Land Use	Code	Acres	Mi^2	% Contributing Area
Residential Low Density	1100	43,842	68.50	26.24%
Residential Medium Density	1200	8,511	13.30	5.09%
Residential High Density	1300	2,512	3.93	1.50%
Commercial and Services	1400	2,315	3.62	1.39%
Industrial	1500	349	0.55	0.21%
Extractive/Quarries/Mines	1600	344	0.54	0.21%
Institutional	1700	696	1.09	0.42%
Recreational (golf courses, parks, marinas, etc.)	1800	2,403	3.75	1.44%
Open Land	1900	14,265	22.29	8.54%
Agriculture	2000	15,732	24.58	9.42%
Rangeland	3000	1,959	3.06	1.17%
Forest/Rural Open	4000	43,177	67.46	25.84%
Water	5000	5,147	8.04	3.08%
Wetlands	6000	22,808	35.64	13.65%
Barren Land	7000	270	0.42	0.16%
Communication, Transportation, Utilities	8000	2,759	4.31	1.65%
TOTAL	**-**	**167,089**	**261.08**	**100.00%**

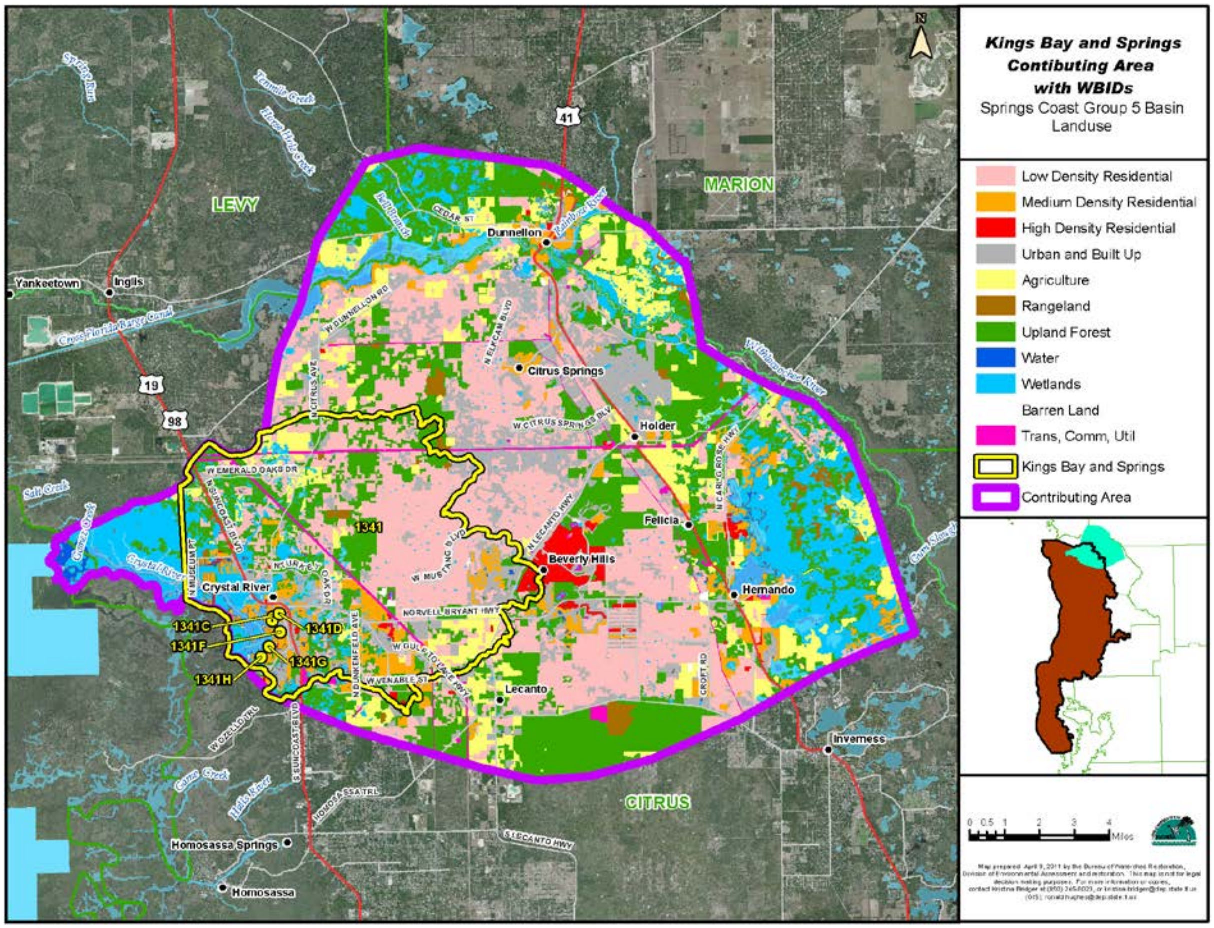

Figure 4.5. Principal Land Uses in the Kings Bay Contributing Area in 2009

Table 4.5. Classification of Land Use Categories for the Kings Bay Contributing Area by Decade

SWFWMD Land Use	Code	1989 Mi^2	1999 Mi^2	2009 Mi^2
Urban and Built-Up	1000	95.21	104.18	117.56
Agriculture	2000	34.96	30.40	24.58
Rangeland	3000	1.04	3.03	3.06
Forest/Rural Open	4000	80.04	73.63	67.46

Nonpoint Sources

SEPTIC TANKS

Onsite sewage treatment and disposal systems (OSTDS) are used for the disposal of domestic wastes at homes that are not on central sewer, often because providing central sewer is not cost-effective or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS are a sanitary means of disposing of domestic waste. The effluent from a well-functioning OSTDS is generally higher in TN concentration than secondarily treated wastewater from a sewage treatment plant, although the wastewater profile can vary from home to home. The physical setting of an OSTDS (soil and aquifer characteristics and proximity) is also a factor in the amount of nitrogen that it can contribute to ground water and springs (USGS 2010b). The risk of contamination is greater for unconfined (water table) aquifers than for confined aquifers because the former usually are nearer to the land surface and lack an overlying confining layer to impede the movement of contaminants (USGS 2010b).

On average, the TN concentration in the effluent from a typical septic tank is 57.7 mg/L (Hazen and Sawyer 2009). In a low-density residential setting, nitrogen loadings by OSTDS may not be significant, but under a higher density setting, one could expect a potential TN input of up to 129 pounds per acre per year (lb/acre/yr) by conventional septic tanks (Harrington *et al.* 2010). However, some nitrogen reduction would occur in the drainfield and soil above the water table, and, as discussed previously, the actual load to ground water would vary based on actual use and setting.

Data for septic tanks are based on the Florida Department of Health (FDOH) statewide inventory of OSTDS (Hall and Clancy 2009). According to the FDOH parcel coverage, approximately 39,919 OSTDS were found in the Kings Bay contributing area (**Figure 4.6**).

SANITARY SEWER OVERFLOWS (SSOS)

Untreated sewage can be a potential source of nitrogen in areas where there are leaky sewers, breaks, or lift station overflows. Leaks and overflows are common in many older sanitary sewers where capacity is exceeded, high rates of infiltration and inflow occur (*i.e.,* outside water gets into pipes, reducing capacity), frequent blockages occur, or there is pipe deterioration associated with older systems. Power failures at pumping stations can also cause SSOs. The greatest risk of an SSO occurs during storm events; however, few comprehensive data are available to quantify SSO frequency and nutrient loads in most watersheds. Data for parcels connected to sewer are based on the FDOH statewide inventory of sewer systems (Hall and Clancy 2009). According to the FDOH parcel coverage, approximately 219 parcels were connected to sewer located in the Kings Bay contributing area (**Figure 4.6**).

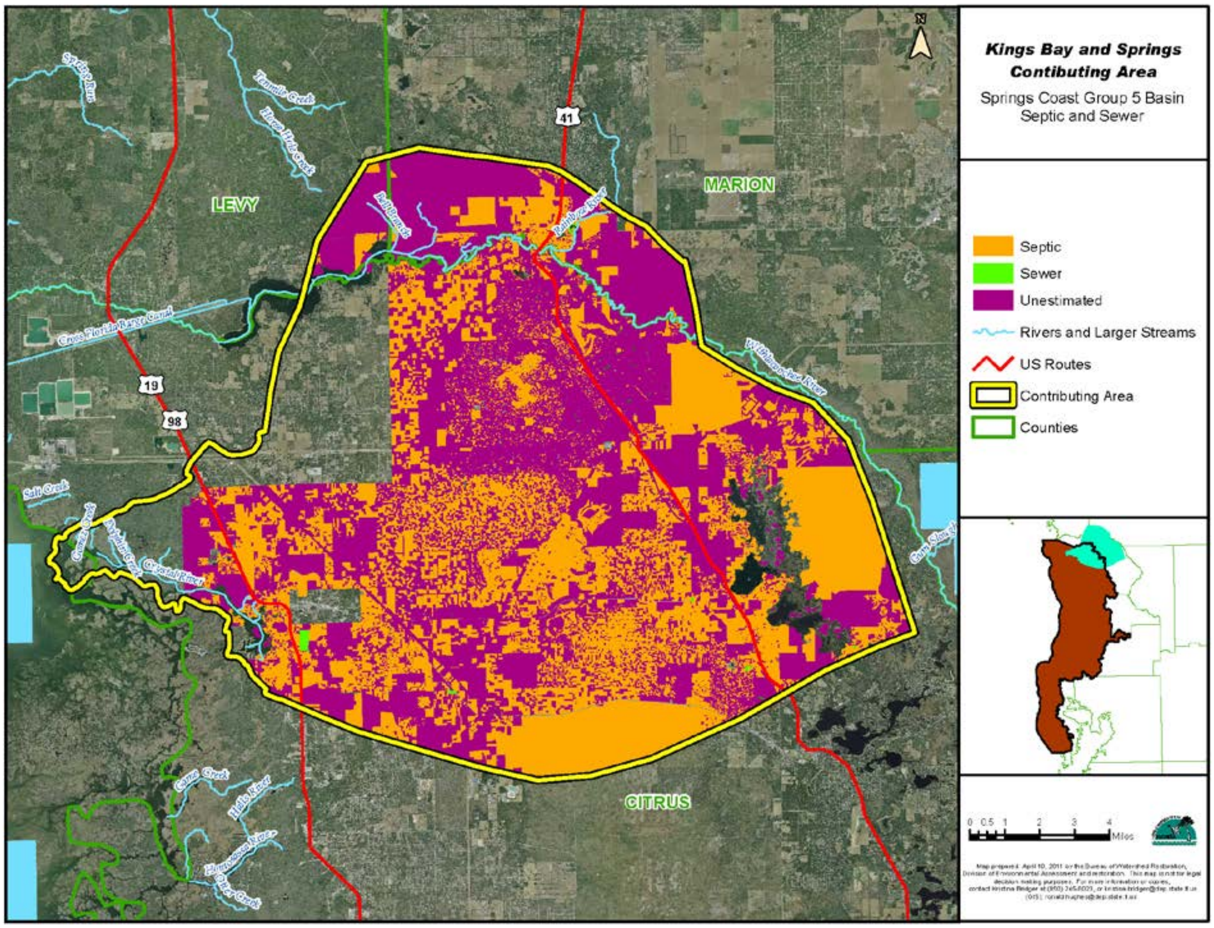

Figure 4.6. Density of OSTDS (Septic Tanks) and Sewer Systems in the Kings Bay Contributing Area in 2009 (Hall and Clancy 2009)

RUNOFF FROM URBANIZED AREAS

Urban areas include land uses such as residential, industrial, utility easements, recreational, institutional, commercial, and extractive (mining). Nutrient loading from urban areas (whether within an MS4 jurisdiction or not) is attributable to multiple sources, including ground water seepage, stormwater runoff, illicit discharges of sanitary waste as a result of SSOs, septic systems, domestic animals, and fertilizers from home gardens, lawns, and golf courses. Approximately 45% of the total land area within the Kings Bay contributing area is designated as urban.

SEDIMENTS

Studies have shown that an additional source of nutrients is present in sediments, which can be resuspended in the water column when conditions are right (Jamieson *et al.* 2005). Currently no studies have quantified the exact amount of nutrient loading coming from sediments in Kings Bay. Therefore, the Department is unable to provide estimates of nutrient loading from sediments in the TMDL analysis. However, at the time of TMDL development, the SWFWMD hired the University of Florida to conduct a study examining the nutrient loadings from sediments.

FERTILIZER

As discussed previously, inorganic fertilizer is also a contributing source of nitrate in these impaired springs and the bay. Fertilizer application to both urban and agricultural areas occurs within the Kings Bay contributing area, but in the areas closest to the springs most land use is urban. Within the contributing area, a total of 86 of 118 square miles of urban areas is residential, and 24.5 square miles consist of agricultural lands. **Table 4.6** summarizes the potential nitrogen inputs from fertilizer use on residential and agricultural lands and potential loads from the land use acreage in the Kings Bay contributing area, based on UF–IFAS fertilizer recommended application rates.

Using the Level 3 SWFWMD (2009) land use GIS coverage, the Department estimated the nitrogen inputs by multiplying the acreage of land use categories by the corresponding UF–IFAS recommended fertilization rates. According to the U.S. Department of Housing and Urban Development (HUD) (2013) the average residential lot size in the state is one-third of an acre. The average percent of pervious area is 70% for a one-third acre residential lot size (USDA 1986). The total acreage of residential areas in the Kings Bay contributing area is 54,866. Assuming 70% pervious area, 38,406 acres of the 54,866 acres is pervious.

According to MACTEC (2010) 50% of residential lawns in the Wekiva study area are fertilized. If the same percentage is assumed for the Kings Bay contributing area, the total estimated pervious area that is fertilized is 19,203 acres. Based on this information and the assumptions, residential lawns and forage grass (pasture) may be the most significant fertilizer use categories.

Table 4.6. Potential Annual Nitrogen Inputs from Typical Fertilizer Sources Utilizing UF–IFAS Recommended Fertilizer Application Rages in the Kings Bay Contributing Area, 2012

- = Empty cell/no data
*= Based on UF–IFAS recommended fertilization rates

Land Use Category	Acres	N (lb/ac/yr)*	Estimated Nitrogen Application lb/yr)	Estimated Nitrogen Application (tons/yr)
Residential Lawns	19,203	130	2,496,390	1,248
Golf Courses	1,894	260	492,440	246
Nurseries and Vineyards	78	60	4,680	2
Forage	11,702	100	1,170,200	585
Vegetables	69	200	13,800	7

WILDLIFE

Wildlife contribute nitrogen loading by depositing feces onto land surfaces, where they can be transported to nearby streams during storm events or by direct deposition to the waterbody. Wildlife includes birds, reptiles, manatees, and other warm-blooded animals. Nitrogen loads originating from local wildlife are generally considered to represent natural background concentrations. In most impaired watersheds, the contribution from wildlife is small compared with the load from urban and agricultural areas.

Within the Kings Bay contributing area, approximately 67.46 square miles (~26%) of the land area is designated as forested/rural open. A total of 35.64 mi^2 (13.65%) of wetlands and 8.04 mi^2

(3.08%) of water are found within the contributing area. Wildlife could be a potential source of nitrogen loading in these natural land use areas.

LIVESTOCK

The Department estimated the potential nitrogen loading in Citrus County from livestock by using the U.S. Department of Agriculture (USDA) 2007 Agricultural Census data on the Citrus County livestock population (**Table 4.7**). The American Society of Agricultural Engineers (ASAE) (2005) provided estimates of nitrogen generated by animal waste. The actual livestock counts in the Kings Bay contributing area are not known.

Table 4.7. Potential Annual Livestock Nitrogen Contribution in Citrus County in 2007

[1] USDA 2007
[2] ASAE 2005

Animals	Citrus County Head Count[1]	lbs-N/head/day[2]	lbs-N/head/yr	lbs-N/yr	tons-N/yr
Cattle	6,916	0.44	160.6	1,110,710	555
Chickens (layers)	1,230	0.0035	1.3	1,599	1
Horses/Ponies	1,044	0.2	73.0	76,212	38
Hogs and Pigs	667	0.91	332.2	221,544	111

ATMOSPHERIC DEPOSITION

Atmospheric deposition was also identified as an important potential nitrogen source; however, there is no atmospheric deposition monitoring station at Kings Bay. Atmospheric deposition from wet fall was estimated from the closest National Atmospheric Deposition Program (NADP) monitoring station, located at the Chassahowitzka National Wildlife Refuge. This station has been in operation since August 1996 (NADP 2013). Wet deposition is computed by multiplying the precipitation-weighted mean ion concentration (mg/L) for valid samples by the total precipitation amount in centimeters for the summary period and dividing by 10.

Records indicate that the annual average input of nitrogen from wet deposition was 2.84 kilograms per hectare (kg/ha) at the station from 1996 to 2013, or about 2.53 lb/ac/yr. The wet and dry depositions of nitrogen are not proportional, with dry deposition sometimes exceeding wet deposition in arid regions or in urban areas where air emissions are high. Dry deposition data were not available for this area. The Progress Energy Coal Generation Plant north of Kings Bay was suggested as a potential local source of atmospheric nitrogen (Czerwinski 2012).

DECOMPOSING ORGANIC MATTER

Decomposing vegetation, algal mats, and decaying aquatic organisms will also release nutrients as they break down. As aquatic weeds and algae slowly decompose, nitrogen and phosphorus are released back into the water column and some of it settles into the sediments.

Chapter 5: DETERMINATION OF ASSIMILATIVE CAPACITY

The Department often uses hydraulic and water quality models to simulate loading and the effect of the loading within a given waterbody. However, there are other appropriate methods to develop a TMDL that are just as credible as a modeling approach. Such an alternative approach was used to estimate existing mean concentrations and calculate the TMDL for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring.

5.1 Determination of Loading Capacity

Typically, the target loading and existing loading for an estuary or watershed are based on hydrologic and water quality modeling. Many of these models depend on the relationship between flow and surface water drainage area, as well as the relationship between land use, soil type, and pollutant delivery.

The predominant source of nutrient loading to Kings Bay is ground water. Ground water discharges from springs (including Hunter, House, Idiot's Delight, Tarpon, and Black Spring vents) provides the majority of the water and nutrient loading to Kings Bay. The contributing area of Kings Bay is a karst environment. Rainwater percolates directly through the soil profile, and surface drainage flows toward sinkholes and closed depressions, where it infiltrates and reaches Kings Bay via ground water. This diffuse loading situation requires the use of an alternative approach for establishing the nutrient TMDL.

Estimates of current nutrient loads from Hunter, House, Idiot's Delight, Tarpon, and Black Spring could still be made based on spring flow and concentration. However, as both current and TMDL loads would be generated from the same flow data, there would be a linear or proportional relationship based on current and target concentrations. Therefore, nutrient loads were not explicitly calculated.

Instead, the percent load reduction required to achieve the target concentration was calculated. The percent reduction required to achieve the water quality target was calculated using the following formula and is further discussed in **Section 5.6**:

[(existing mean concentration – target concentration)/existing mean concentration] x 100

Once the target concentration has been reached, each WBID will be re-evaluated to determine if an imbalance of flora and fauna still exists as a result of algal smothering. If such a condition still exists, the TMDL will be reassessed and the target concentration may be changed if further reductions in the nutrient concentrations are needed to address the imbalance.

5.2 Unique Nature of Kings Bay

Kings Bay is a tidally influenced, large, and shallow (600 acres, 3 to 10 feet deep) coastal embayment with a low flushing rate (or residence time) of approximately 150 hours (6.25 days) (X. Chen, SWFWMD, pers. comm.). Shallow water depths allow warming and greater sunlight penetration, which result in a deepening of the photic zone and higher plant growth potential (Livingston 2001). Long residence times coupled with warm temperatures affect nutrient cycling through the system. In most estuaries around the world, the combination of increased residence time and nutrients yields greater primary productivity, which in Kings Bay is translated into increased filamentous algae and phytoplankton production.

Comprehensive flow measurements in 2009 of all measured springs in Kings Bay add up to an average flow of approximately 500 cfs from all the springs combined (VHB 2010). Nitrate levels in the Kings Bay springs have been increasing; including the springs that are the subject of this TMDL report (see **Chapter 2**, **Figures 2.12** through **2.16**). Studies have estimated that approximately 94% of the TN and 84% of the TP entering the bay originate from spring discharge (SWFWMD 1990). Therefore, the single largest known source of nutrients appears to be spring flow (Romie 1990).

Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring were listed as impaired for nutrients (algal mats) during the Cycle 2 verified period (January 1, 2004, to June 30, 2011). **Figure 5.1** displays the location of filamentous algae biomass in Kings Bay and the spring locations mapped by Jacoby *et al.* (2011) in May 2011.

The Department acknowledges that multiple factors such as nutrients, flow, salinity, temperature, and light contribute to the distribution, abundance, and growth rate of filamentous algae in Kings Bay. However, nutrient enrichment contributes significantly to the increased aquatic plant and algal growth rates and must be addressed. Algal growth rates are enhanced in areas near spring vents where spring flows deliver a steady concentration of nutrients (Stevenson as cited in Heffernan 2010). However, the nutrient inputs contributing to algal growth in Kings Bay may not be exclusively related to spring discharge, as the bay also receives nutrients via stormwater and shallow ground water inflows from nearby sources.

Reductions of either nitrogen or phosphorus in the water discharging from springs, nearby stormwater, and nearby ground water inflows should reduce macroalgal accumulation because they will slow the growth rate of macroalgae (Stevenson 2007). Therefore, it is the purpose of this TMDL document to establish the maximum allowable nitrogen and phosphorus target concentration limits in water delivered to Kings Bay by the above mechanisms, which would restore the waterbody so that it meets its applicable water quality criterion for nutrients. The Department thinks that reducing the growth rate of macroalgaes (including *Lyngbya and Chaetomorpha*) through nutrient reduction (nitrate and orthophosphate concentrations) will cause filamentous algae biomasses and phytoplankton productivity to decrease. The bulk of the chlorophyll found in the water column is derived from phytoplankton (mainly diatoms).

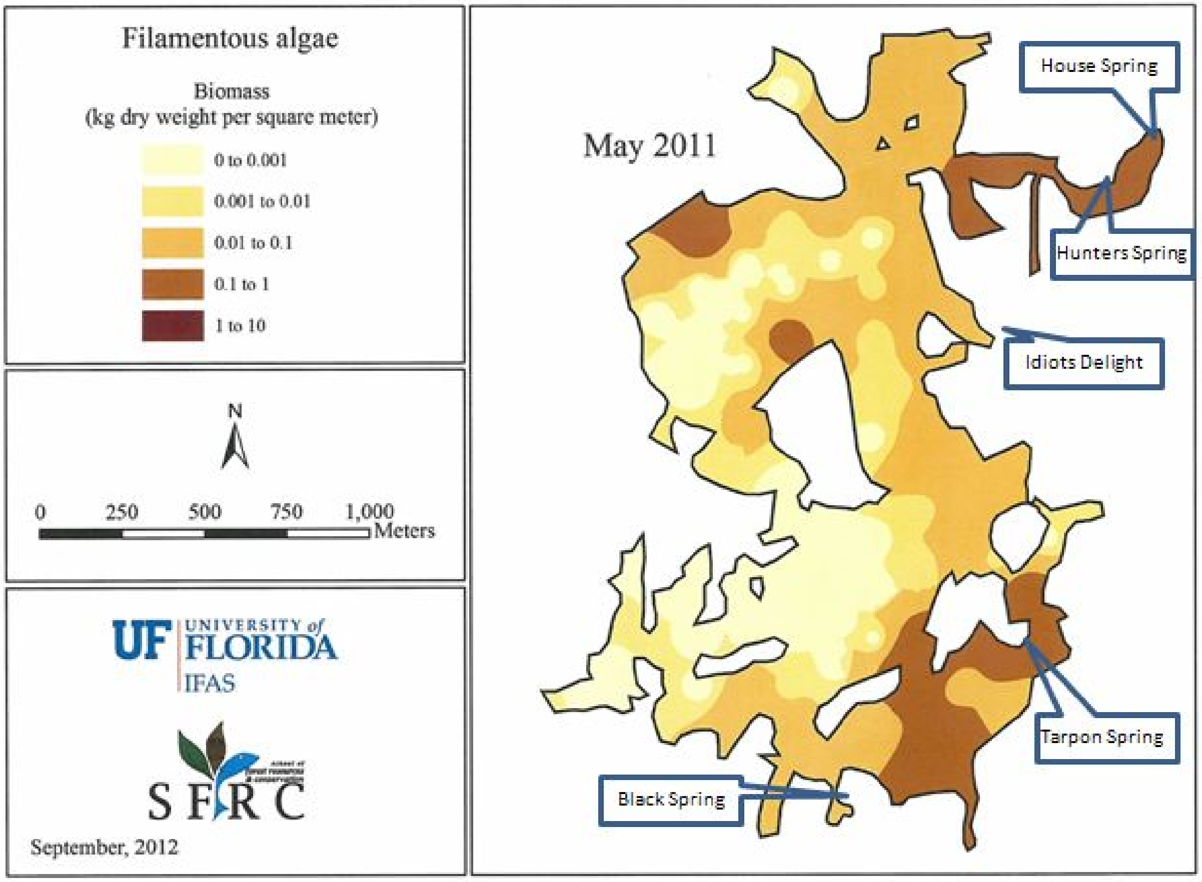

Figure 5.1. Filamentous Algae Biomass Map (May 2011) and Impaired Springs (modified after Jacoby *et al.* 2011)

5.3 Historical and Present Data for Kings Bay (Ambient Bay Stations)

From 1980 to 1985, 2 ambient bay water quality stations located in Kings Bay were monitored. The nitrate concentrations at these 2 stations ranged from 0.02 to 0.05 mg/L (**Figure 5.2**). From 1980 to 1985, the distribution and growth of filamentous algae in the bay was not monitored. The Department sampled ambient bay station 21FLA 24040925, and the SWFWMD sampled ambient bay station 21FLSWFDCRYS.RIV.1.

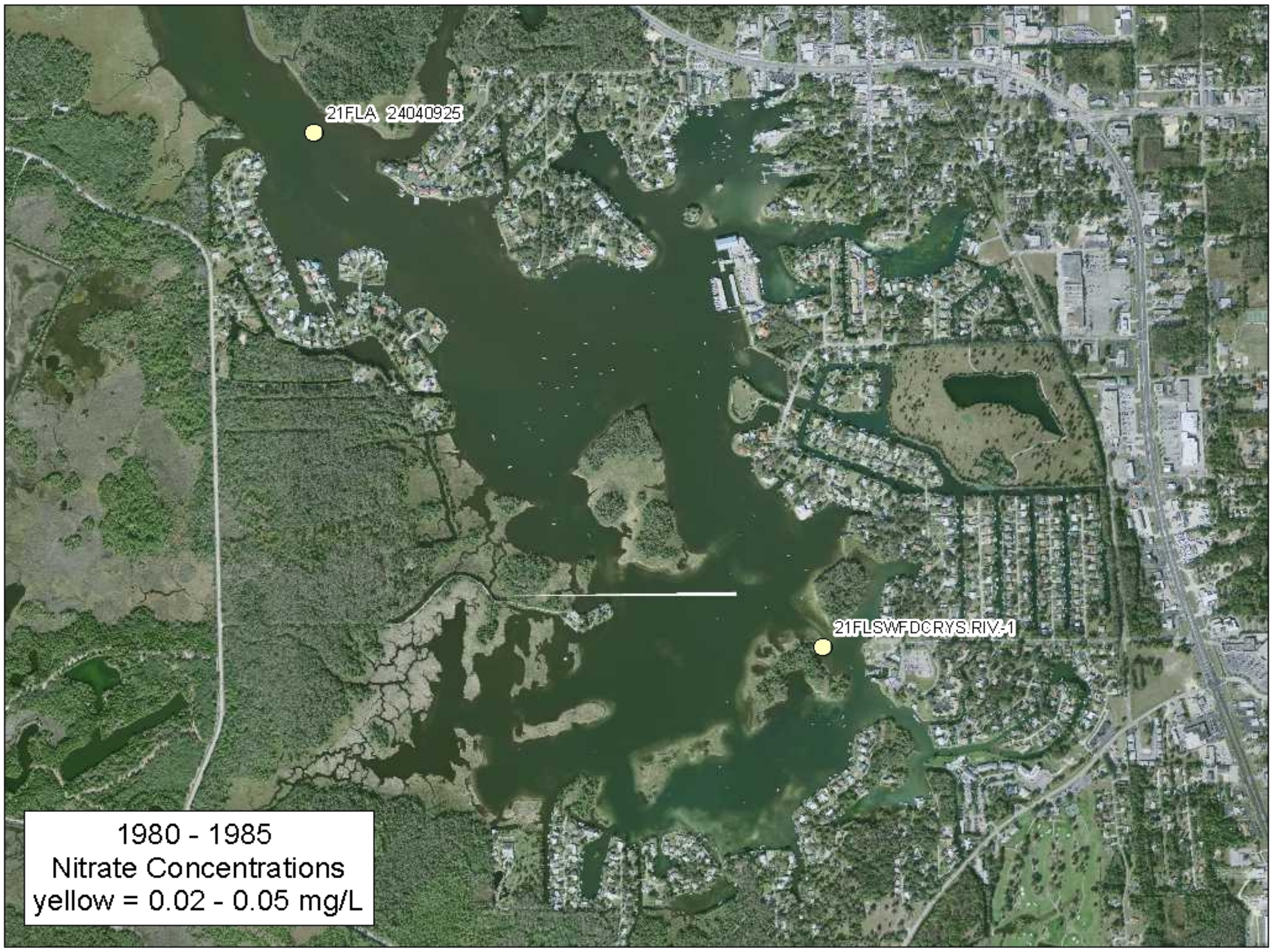

Figure 5.2. Location of Water Quality Ambient Bay Stations with Nitrate Data in Kings Bay, 1980–85

From March 1989 to February 1990, the SWFWMD (Romie 1990) collected water quality samples and performed SAV surveys, including filamentous algae, at 13 ambient bay water quality stations. Three stations were located in Hunters Cove, and 10 stations were located in the main portion of Kings Bay. The 10 stations located in the main portion of Kings Bay had low filamentous algae biomasses (**Figure 5.3**), and their nitrate concentrations ranged from 0.02 to 0.10 mg/L (**Figure 5.4**). The 3 stations located in Hunters Cove had high filamentous algae biomasses (**Figure 5.3**), and their nitrate concentrations were higher, ranging from 0.12 through 0.14 mg/L (**Figure 5.4**).

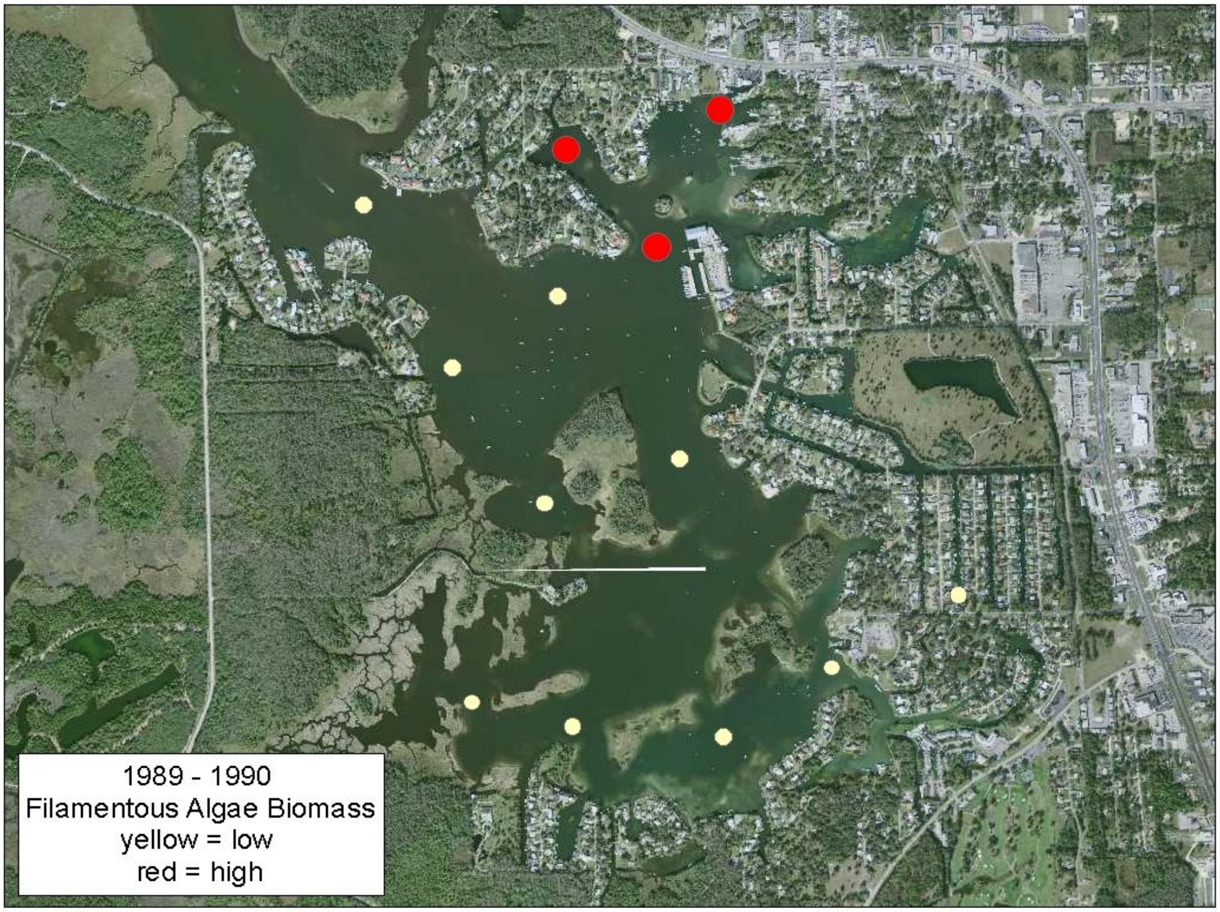

Figure 5.3. Filamentous Algae Biomass Map, March 1989–February 1990 (modified from Romie 1990)

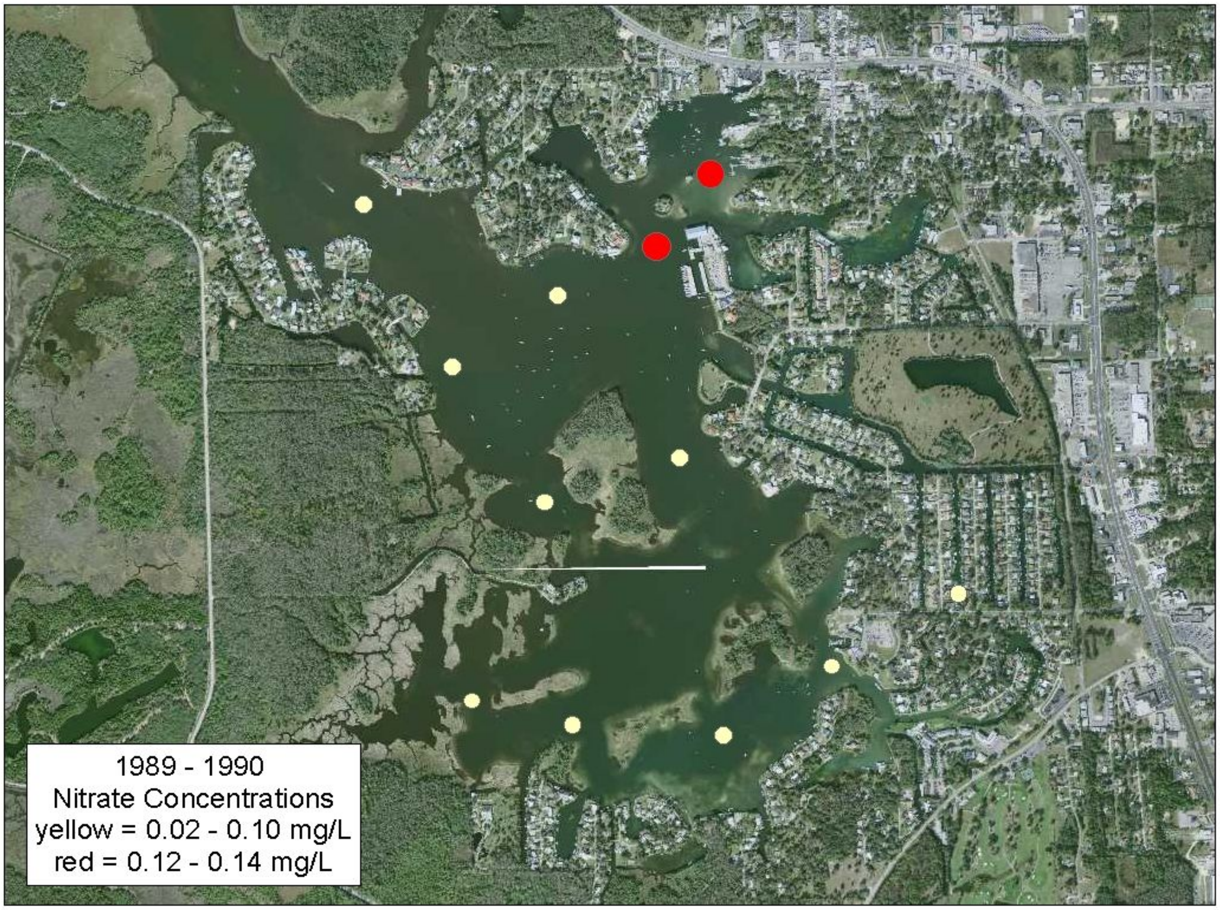

Figure 5.4. Location of SWFWMD Water Quality Ambient Bay Stations with Nitrate Data in Kings Bay, March 1989–February 1990 (modified from Romie 1990)

From 2004 to 2006, the SWFWMD collected water quality samples at 12 ambient bay water quality stations. During the same period, the SWFWMD commissioned the University of Florida (Jacoby *et al.* 2007) to perform SAV surveys, including filamentous algae. **Figure 5.5** displays the distribution of filamentous algae within Kings Bay. Eight of the 12 ambient bay stations had low filamentous algae biomasses, higher specific conductance, and lower nitrate concentrations. The nitrate concentrations found at these stations ranged from 0.03 to 0.10 mg/L—concentrations that were similar to those collected during the 1980s. The volume of the bay and the tidal cycle are possibly diluting and dampening the effect of nitrates within the bay proper.

Areas dominated by filamentous algae were located in Hunters Cove (Hunter Spring and House Spring) and Tarpon Spring Group. These areas also had the highest nitrate concentrations and were adjacent to urbanized areas (**Figure 5.6**). The ambient bay stations located within these areas had nitrate concentrations ranging from 0.15 to 0.38 mg/L. Nitrates are delivered by spring discharge from the contributing area, stormwater runoff, and ground water inputs from nearby sources. Also, the areas within Kings Bay with the lowest salinity are near the springs because of their freshwater discharges, which are the areas where freshwater filamentous algae are most abundant.

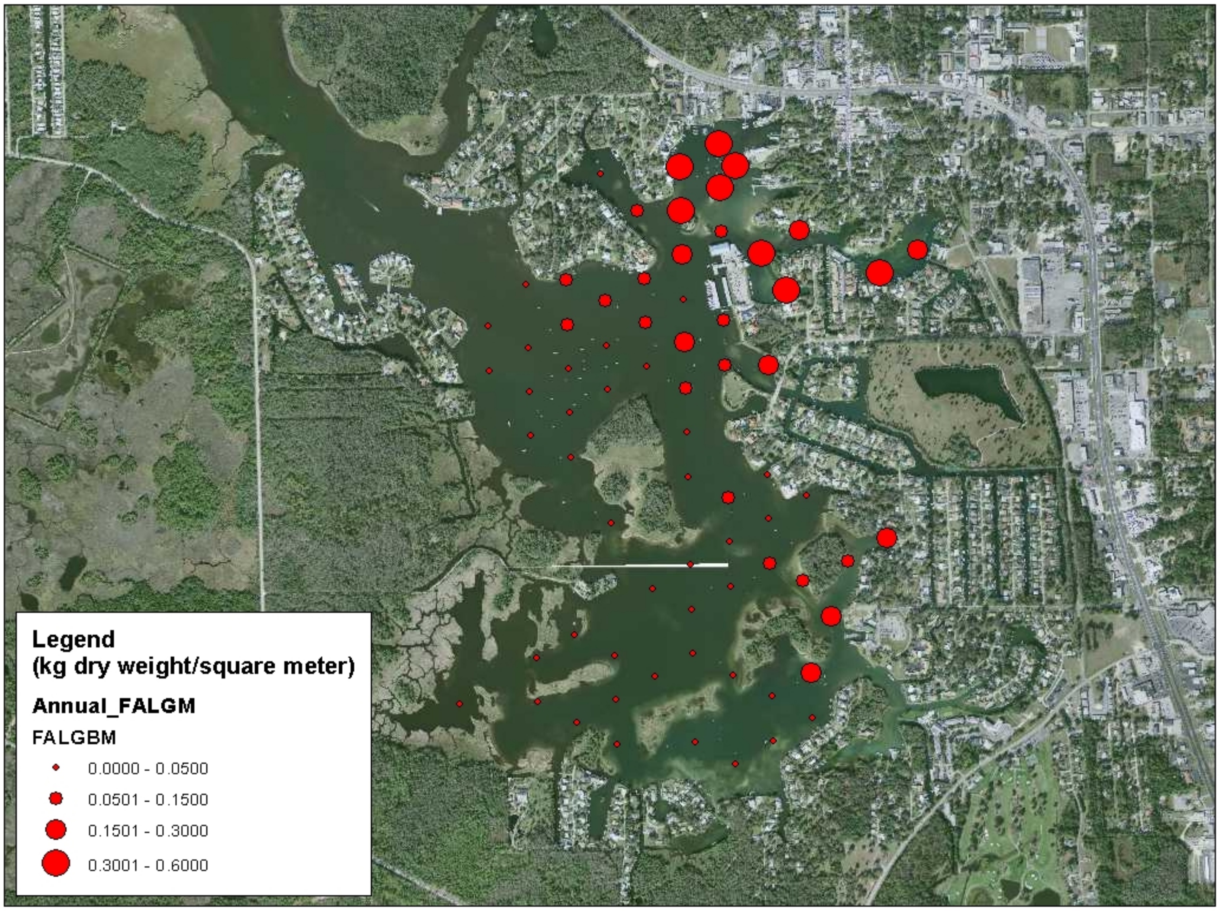

Figure 5.5. Filamentous Algae Biomass Map, 2004–06 (modified from Jacoby *et al.* 2007)

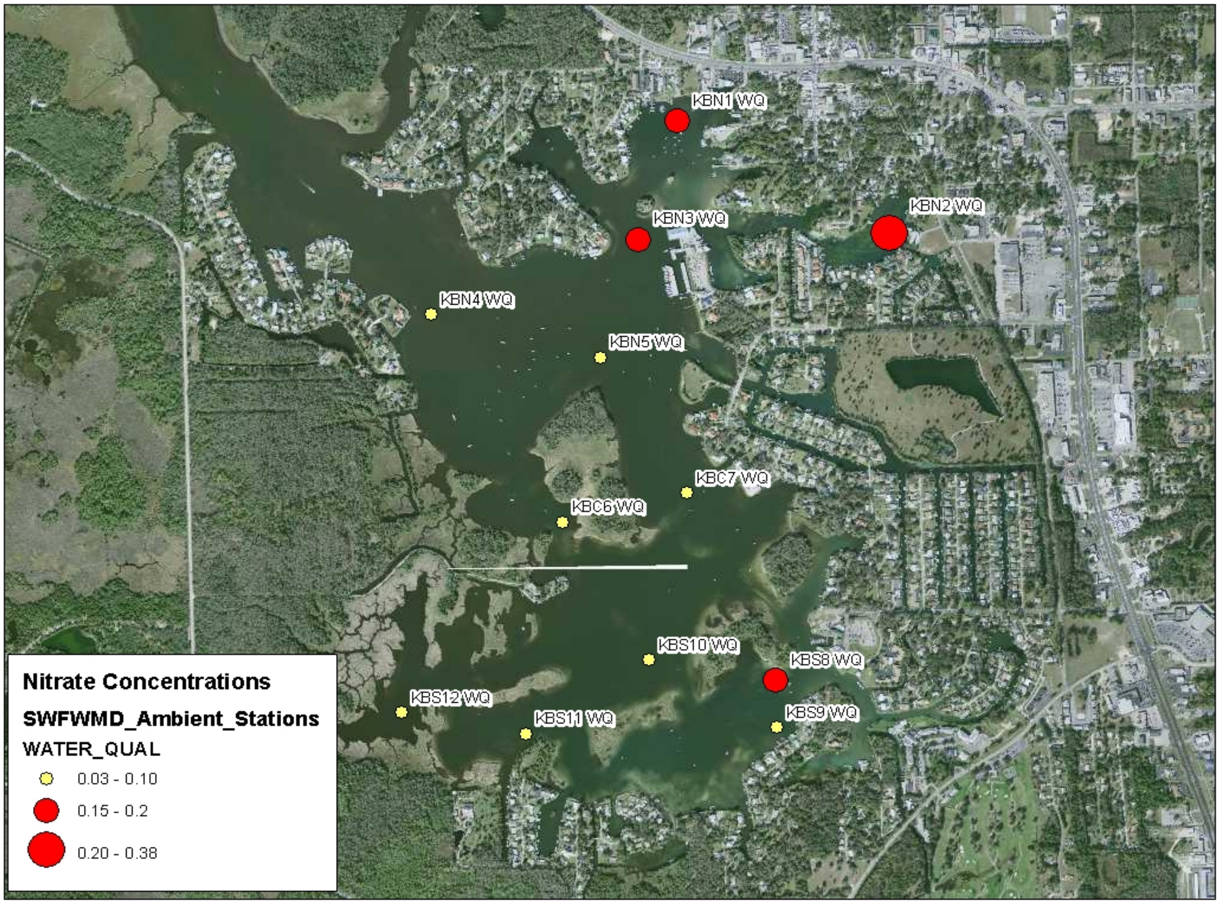

Figure 5.6. Location of SWFWMD Water Quality Ambient Bay Stations with Nitrate Data in Kings Bay, 2004–06

Both of the SWFWMD studies showed that greater accumulations of algae occurred in the areas where spring discharges occurred and where nitrate concentrations were higher. Restoration efforts that reduce nutrients delivered by spring discharge should focus on the filamentous algae–dominated areas located in Hunters Cove (Hunter Spring and House Spring) and in the vicinity of Tarpon Spring. As of May 2011, filamentous algae continued to dominate these areas (**Figure 5.1**). These areas also have the highest nitrate concentrations (**Chapter 2**). The Department thinks that reducing the growth rate of macroalgaes (including *Lyngbya and Chaetomorpha*) through nutrient reduction (nitrogen and phosphorus concentrations) will cause filamentous algae biomasses and chlorophyll concentrations to decrease. As a result, additional restoration activities will become more effective and efficient.

5.4 Critical Conditions/Seasonality

Establishing the critical condition for nitrogen and phosphorus inputs that affect algal growth in a given contributing area depends on many factors, including the presence of point sources and the land use pattern in the contributing area. The critical condition for point source loading to a waterbody typically occurs during periods of low flow, when dilution is minimized. Typically, the critical condition for nonpoint source loading is a period of rainfall-related flushing preceded by an extended dry period. During the wet weather period, rainfall mobilizes nitrogen and phosphorus that has accumulated on the land surface and in the soil under dry conditions, resulting in higher pollutant concentrations. However, significant nonpoint source contributions can also appear under dry conditions without any major surface runoff event. Also, there can be a lag time between nitrogen and phosphorus inputs into ground water and discharge from the spring vents.

The water from the springs that discharge into Kings Bay comes from infiltrating precipitation somewhere in the springshed that migrated within the upper Floridan aquifer to the spring vents. Water that discharges from the vents comes from a mixture of nonpoint sources and may range from days to decades in age. At Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, fluctuations in spring water quality have been observed, and these could be a response to flushing from seasonal rainfall events or seasonal nonpoint impacts such as fertilization.

Tables 5.1a through **5.1f** and **Tables 5.2a** through **5.2f** summarize the monthly averages for the Kings Bay area. The nitrate and orthophosphate concentrations in the springs are much more constant and do not vary greatly from month to month. However, the monthly fluctuations in TN and TP concentrations in Kings Bay vary greatly. For Kings Bay, the higher nitrate and orthophosphate concentrations occurred from September through March. In particular, elevated TP concentrations were observed from January through March, and elevated TN concentrations were observed from September through March.

5.5 Effects of Salinity

Data from 1989 to 2012 showed an increase in salinity in Kings Bay. Salinity represents a primary determinant of long-term patterns in the distribution of SAV (including filamentous algae) in spring-fed systems along Florida's Gulf Coast, including Kings Bay (Hoyer *et al.* 2004). Freshwater macrophyte and macroalgae biomasses decrease in response to increases in salinity and are lowest in saline environments (Hoyer *et al.* 2004).

Bishop and Canfield (1995), Terrell and Canfield (1996), and Hoyer *et al.* (1997) determined that acute variation in salinity resulting from storm surges is one of the major forces affecting aquatic plant biomass in Kings Bay. More subtle variations in salinity that also affect the ecology of this system arise when weather patterns alter rainfall, ground water supply, sea level, and spring discharge (Jacoby *et al.* 2011). In addition, man-made hydrologic alterations can alter the natural flow of the system, cutting off freshwater inflows from natural watershed areas (SWFWMD 2000). Gradual increases in bay and spring salinities may also be tied to sea-level rise. From 1920 to 2001 the estimated sea-level rise along the Florida Gulf Coast is approximately six inches (Douglas 1991; Zervas 2001). The areas within Kings Bay with the lowest salinity are near the springs because of their freshwater discharges and these are the areas where filamentous algae are most abundant.

Table 5.1a. Monthly Average TN and Nitrate Concentrations for Kings Bay (WBID 1341), 2004–12

Month	N	TN (mg/L)
January	101	0.31
February	30	0.33
March	66	0.34
April	54	0.24
May	47	0.22
June	48	0.26
July	77	0.27
August	29	0.26
September	54	0.33
October	61	0.23
November	59	0.32
December	18	0.35

Table 5.1b. Monthly Average TN and Nitrate Concentrations for Hunter Spring (WBID 1341C), 2004–12

Month	N	Nitrate-Nitrite (mg/L)
January	10	0.52
February	5	0.47
March	2	0.50
April	9	0.44
May	4	0.50
June	3	0.28
July	10	0.48
August	5	0.45
September	2	0.45
October	8	0.50
November	4	0.47
December	2	0.43

Table 5.1c. Monthly Average TN and Nitrate Concentrations for House Spring (WBID 1351D), 2004–12

- = Empty cell/no data

Month	N	Nitrate-Nitrite (mg/L)
January	-	-
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	3	0.47
August	-	-
September	-	-
October	-	-
November	-	-
December	-	-

Table 5.1d. Monthly Average TN and Nitrate Concentrations for Idiot's Delight Spring (WBID 1341F), 2004–12

- = Empty cell/no data

Month	N	Nitrate-Nitrite (mg/L)
January	1	0.31
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	8	0.20
August	-	-
September	2	0.21
October	-	-
November	1	0.22
December	-	-

Table 5.1e. Monthly Average TN and Nitrate Concentrations for Tarpon Spring (WBID 1341G), 2004–12

Month	N	Nitrate-Nitrite (mg/L)
January	10	0.23
February	4	0.21
March	3	0.22
April	9	0.24
May	5	0.20
June	4	0.07
July	10	0.19
August	6	0.19
September	2	0.10
October	9	0.20
November	4	0.22
December	2	0.18

Table 5.1f. Monthly Average TN and Nitrate Concentrations for Black Spring (WBID 1341H), 2004–12

- = Empty cell/no data

Month	N	Nitrate-Nitrite (mg/L)
January	1	0.24
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	8	0.25
August	-	-
September	-	-
October	-	-
November	-	-
December	-	-

Table 5.2a. Monthly Average TP and Orthophosphate Concentrations for Kings Bay (WBID 1341), 2004–12

Month	N	TP (mg/L)
January	89	0.037
February	31	0.030
March	66	0.037
April	54	0.028
May	48	0.031
June	49	0.025
July	77	0.029
August	28	0.033
September	54	0.033
October	59	0.029
November	59	0.029
December	18	0.028

Table 5.2b. Monthly Average TP and Orthophosphate Concentrations for Hunter Spring (WBID 1341C), 2004–12

Month	N	Orthophosphate (mg/L)
January	9	0.022
February	4	0.024
March	1	0.026
April	8	0.026
May	3	0.022
June	1	0.022
July	9	0.023
August	3	0.025
September	1	0.024
October	8	0.024
November	3	0.026
December	1	0.022

Table 5.2c. Monthly Average TP and Orthophosphate Concentrations for House Spring (WBID 1341D), 2004–12

- = Empty cell/no data

Month	N	Orthophosphate (mg/L)
January	-	-
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	3	0.023
August	-	-
September	-	-
October	-	-
November	-	-
December	-	-

Table 5.2d. Monthly Average TP and Orthophosphate Concentrations for Idiot's Delight Spring (WBID 1341F), 2004–12

- = Empty cell/no data

Month	N	Orthophosphate (mg/L)
January	1	0.030
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	8	0.025
August	-	-
September	-	-
October	-	-
November	-	-
December	-	-

Table 5.2e. Monthly Average TP and Orthophosphate Concentrations for Tarpon Spring (WBID 1341G), 2004–12

- = Empty cell/no data

Month	N	Orthophosphate (mg/L)
January	9	0.022
February	4	0.028
March	0	-
April	8	0.028
May	3	0.026
June	1	0.028
July	9	0.027
August	4	0.030
September	1	0.019
October	7	0.028
November	3	0.029
December	1	0.031

Table 5.2f. Monthly Average TP and Orthophosphate Concentrations for Black Spring (WBID 1341H), 2004–12

- = Empty cell/no data

Month	N	Orthophosphate (mg/L)
January	1	0.026
February	-	-
March	-	-
April	-	-
May	-	-
June	-	-
July	8	0.016
August	-	-
September	-	-
October	-	-
November	-	-
December	-	-

5.6 TMDL Development Process

5.6.1 Lyngbya sp. Studies in Florida Springs

Nuisance algal growth has been observed in many springs and has been associated with increases in anthropogenic activities and nutrients (Stevenson 2007). Several studies have evaluated the growth of *Lyngbya* sp*.* in response to nutrients in Florida springs. These studies were performed in the laboratory under different flow regimes. Similar types of studies were used in the development of Florida's nitrate standard of 0.35 mg/L for free-flowing freshwater spring runs (http://www.dep.state.fl.us/water/wqssp/nutrients/docs/tsd-nnc-lakes-springs-streams.pdf). However, this criterion is not appropriate for the springs that discharge into Kings Bay because Kings Bay is tidally influenced, which results in a much longer residence time for nitrate in the bay compared with a free-flowing stream. A spring threshold less than 0.35 mg/L was found to be more appropriate for Kings Bay due to its basin characteristics.

Growth Response of *Lyngbya wollei* to Nitrate Additions

Albertin (2009) used a series of recirculating stream channels (**Figure 5.7**), operated under controlled laboratory conditions, to determine threshold nitrate values for *L. wollei* growth. The experiments were performed under optimal light, temperature, and high-flow conditions. The nutrient concentration at which macroalgae growth is predicted to be elevated by 90% above the level for which no effects of nutrient reduction would be expected is referred to as the saturating concentration. Under these laboratory conditions, the threshold concentration for the growth of *Lyngbya* sp. was found to have a saturating nitrate concentration of 0.11 mg/L (**Figure 5.8**).

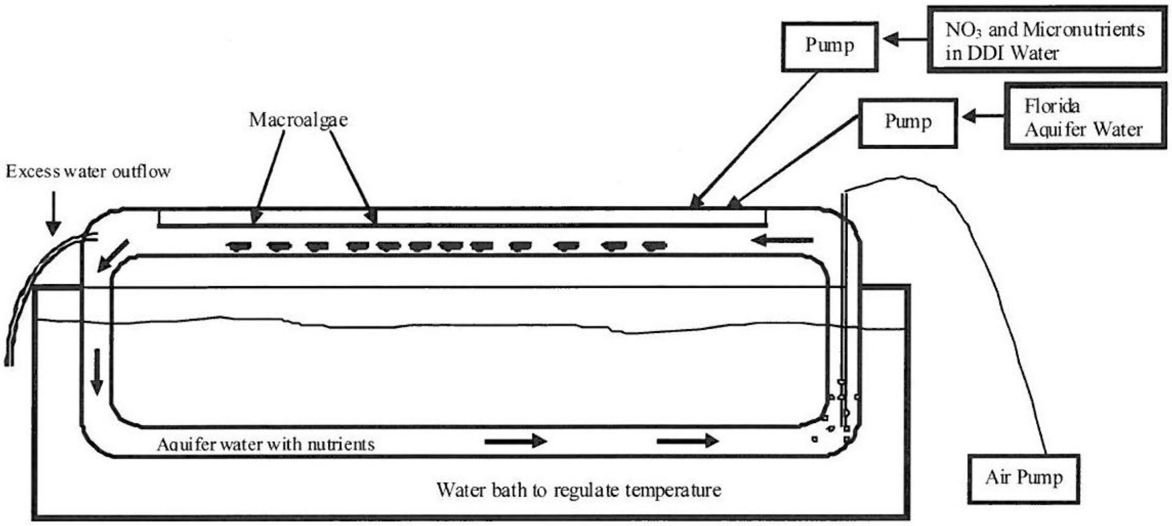

Figure 5.7. Albertin (2009) Recirculating Stream Channel Experimental Design

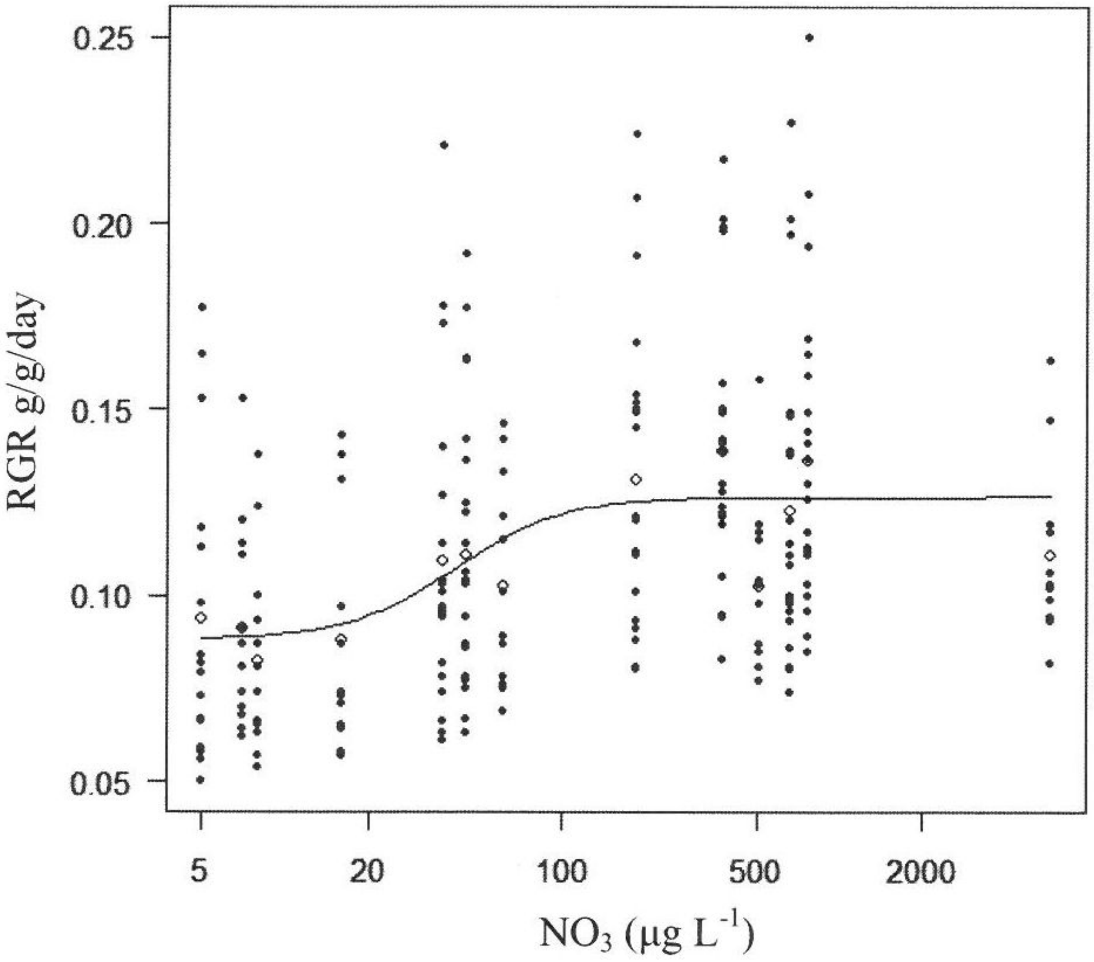

Figure 5.8. Relative Growth Rates (RGR) of *L. wollei* at Different Nitrate Concentrations in Recirculating Stream Channels (Albertin 2009)

Growth and Nitrate-Nitrogen Uptake by the Cyanobacterium *L. wollei*

The nutrient amendment bioassay work was conducted by Cowell and Dawes (2004), who examined the required nitrate concentration in the Rainbow River, Marion County, to achieve a reduction of biomass of *L. wollei*. In the laboratory, the experiment was conducted in 400 mL flasks, and water was continuously replenished at a rate of 960 mL per day (a low-flow environment). Using *Lyngbya* sp. cultures incubated in a series of nitrate increments (concentrations of 1.5, 1.2, 0.9, 0.6, 0.30 and 0.07 mg/L), Cowell and Dawes (2004) found that at the end of the nutrient amendment experiments, both the biomass and growth rates were low in treatment groups with nitrate concentrations at or below 0.30 mg/L, and significantly higher in groups with nitrate concentrations at or higher than 0.60 mg/L. Significant differences in growth rate and biomass between the above-0.60 mg/L treatment groups and the below-0.30 mg/L treatment groups were not observed until 8 to 12 days after the nutrient amendment study started. This apparently suggested a time lag between a change in nitrate concentration and a response from the *Lyngbya*. A decrease in growth rate response was observed at nitrate concentrations equal to or less than 0.30 mg/L.

Examining the Ecological Condition of Algae and Nutrients in the 2007 Florida Springs Report

The study examined 28 springs throughout Florida, including nearby Homosassa and Chassahowitzka Springs (**Figure 5.9**). Surveys of Florida springs indicated that almost all springs had macroscopic algae growing in them, an average of 50% of the spring bottoms were covered by macroalgae, and the thickness of macroalgal mats was commonly 0.5 meters (m) and as thick as 2 m in one spring boil. *L. wollei* and *Vaucheria* sp. were the 2 most common taxa of macroalgae that occurred in areas with extensive growths in the studied springs; however, 23 different macroalgal taxa were observed in the spring survey.

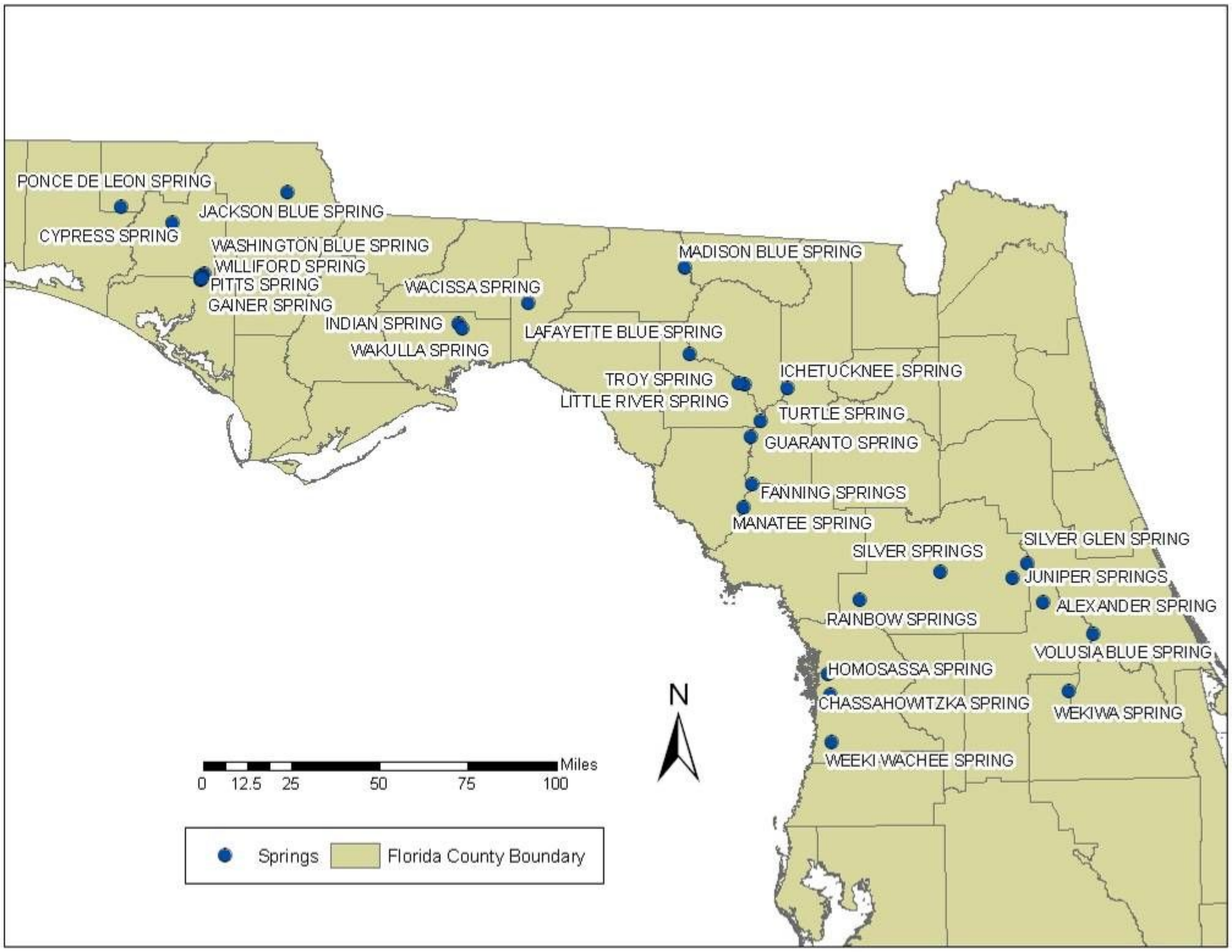

Figure 5.9. Springs Included in the Florida Springs Report (Stevenson *et al.* 2007)

The nutrient concentration at which macroalgae growth is predicted to be elevated by 90% above the level for which no effects of nutrient reduction would be expected is referred to as the saturating concentration. The saturating concentration was documented by Stevenson *et al.* (2007) for 2 species of macroalgae (*L. wollei* and *Vaucheria* sp.) that have been documented to produce extensive algal mats. The microcosms (microcentrifuge tubes) used for the laboratory experiments measured algal growth rates for the following experiments:

- *Eleven different nitrate concentrations under nonflowing conditions with orthophosphate in luxury supply.*
- *Ten different orthophosphate concentrations under nonflowing conditions with nitrate in luxury supply.*

Using *L. wollei* cultures incubated in a series of refined nitrate increments (concentrations of 5, 2.5, 1.5, 1.0, 0.75, 0.50, 0.25, 0.125, 0.06, 0.03, and 0.01 mg/L), the threshold concentration for growth of *Lyngbya* sp. under these conditions was found to have a saturating nitrate concentration of 0.23 mg/L (**Figure 5.10**). Using *L. wollei* cultures incubated in a series of refined orthophosphate increments (concentrations of 0.25, 0.1, 0.08, 0.06, 0.04, 0.03, 0.02, 0.01, 0.005, and 0.001 mg/L), the threshold concentration for growth of *Lyngbya* sp. under these conditions was found to have a saturating orthophosphate concentration of 0.028 mg/L (**Figure 5.10**). According to Stevenson *et al.* (2007), the most accurate and conservative experimental results, those from microcentrifuge tube experiments, suggest that nutrient concentrations less than 0.028 mg/L orthophosphate and 0.23 mg/L nitrate are needed to slow the growth of *L. wollei*.

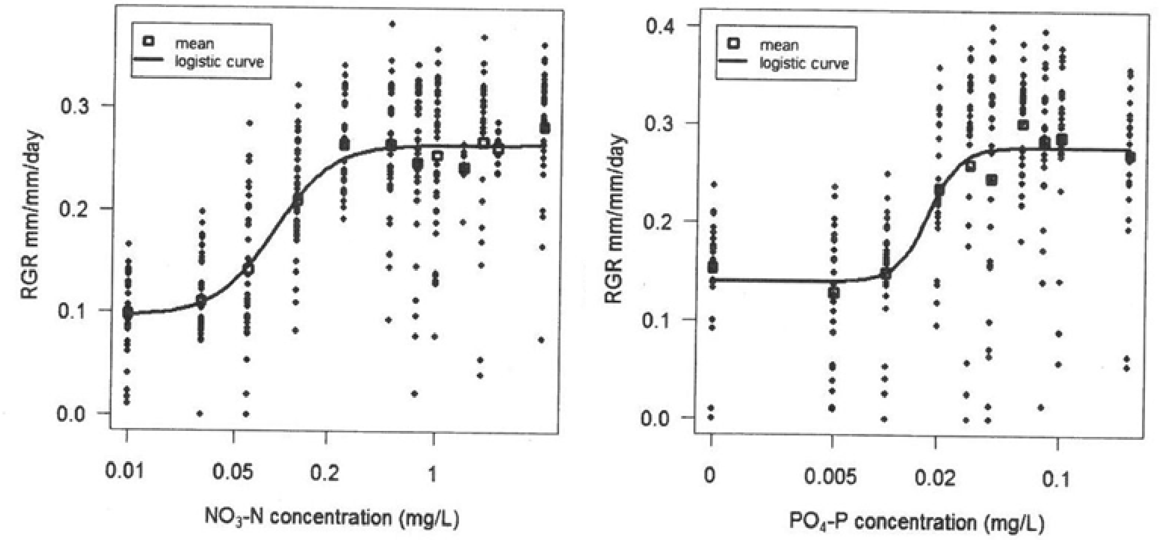

Figure 5.10. Relative Growth Rates (RGR) of *L. wollei* at Different Nitrate and Orthophosphate Concentrations in Microcentrifuge Tubes (Stevenson *et al.* 2007)

5.6.2 Setting the TMDL Water Quality Target Concentrations for Nutrients

The Department acknowledges that multiple abiotic (flow, salinity, temperature, light) and biotic (nutrients and food web complexity) factors contribute to the distribution and growth of *Lyngbya sp*. In summation, understanding the described studies and the constraints associated with each study will help develop nitrate and orthophosphate target concentrations and reduction goals for the springs of Kings Bay.

The above studies examined *L. wollei* growth rates under three different flow regimes: Albertin (2009) high flow, Cowell and Dawes (2004) low flow, and Stevenson *et al.* (2007) no flow. The residence time (T) is equal to the capacity of the system (V) divided by the flow of the system (q):

$$\mathbf{T = V/q}$$

Where:

T = Residence time
V = Capacity of the system
q = Flow of the system

Albertin (2009) examined *L. wollei* growth rates under a high flushing environment with optimal light and temperature. Compared with free-flowing spring runs (flushing rates on the order of hours), Kings Bay is a tidally influenced, shallow (3 to 10 feet), 600-acre coastal embayment with a low flushing rate (long residence time) of approximately 6.25 days (X. Chen, SWFWMD, pers. comm.). The studies by Cowell and Dawes (2004) and Stevenson *et al.* (2007) examined *L. wollei* growth rates under conditions that model low-flushing environments with long residence times similar to those in Kings Bay. The effect of residence time (rate of flushing) on nitrate and orthophosphate concentrations water discharged from the springs into this low-flushing environment should be taken into consideration when determining appropriate water quality targets.

When examining *L. wollei* growth rates, Cowell and Dawes (2004) measured algal growth under six nitrate concentration increments and could only provide a relatively broad range of concentrations at which a response was observed. Stevenson *et al.* (2007) provided a more refined growth response prediction by using multiple nitrate concentration increments. Stevenson *et al.* (2007) also examined the growth rates of *L. wollei* at different orthophosphate concentrations. According to Stevenson *et al.* (2007), nitrate concentrations lower than 0 0.23 mg/L and orthophosphate concentrations lower than 0.028 mg/L are needed to reduce the growth of *L. wollei*.

After carefully reviewing the above studies, the Department has selected the saturating nitrate concentration of 0.23 mg/L and the saturating orthophosphate concentration of 0.028 mg/L as the maximum allowable nitrogen and phosphorus target concentration limits for the springs that discharge into the bay, which include Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H)). Nitrate and orthophosphate are the most abundant forms of nitrogen and phosphorus available in spring discharge. As discussed previously, the nitrate and orthophosphate thresholds selected for the Kings Bay springs are based on algal growth studies performed in low-flushing (long residence time) conditions similar to those in Kings Bay.

To estimate a corresponding nitrate target concentration that would be appropriate for Kings Bay itself (WBID 1341), the nitrate concentrations for Hunter Spring were plotted against the nitrate concentrations for the nearby ambient bay water quality station KBN2 (data period 2003 – 2012). Hunter Spring and KBN2 are located in Hunters Cove. Due to the seasonal fluctuations within Kings Bay, the data was deseasonalized based on the following equation (Intelligent Decision Technologies as cited in Copeland et al 2011):

$$\text{Transformed X} = \text{original value} - (\text{seasonal mean}_{\text{year}}) + (\text{overall mean}_{\text{year}})$$

In addition, plotting the Hunter Spring and the ambient bay station KBN2 nitrate data over time displays the dilution and attenuation of nitrate as nitrate-enriched water migrates from the spring vent through the water column to a nearby station in the bay (**Figure 5.12**). Nitrate is readily available for uptake by phytoplankton and benthic organisms (Woods Hole Group 2007). Nitrate concentrations in water discharged from the springs are also decreased by dilution.

Using this methodology, a nitrate target concentration of 0.23 mg/L for Hunter Spring translates to a nitrate target concentration of 0.10 mg/L for the ambient bay station KBN2. Based on the following regression equation shown in **Figure 5.11**:

$$\text{KBN2 WQ} = -0.060205 + 0.6678637 * \text{Hunter Spring}$$

This relationship may not be representative of the relationship in the bay proper, but it does provide the maximum amount of protection for areas beyond Hunters Cove by being more conservative. A reduction in nitrates at KBN2 is expected to be accompanied by a similar reduction in the bay proper. Therefore, the nitrate target concentration for the bay proper will also be 0.10 mg/L.

However, the Department has selected a TN target for Kings Bay (WBID 1341) because nitrate is not the dominant form of nitrogen in the bay and all sources of nitrogen in the bay would not be addressed using a springs-based threshold. Other sources of nitrogen in the bay could include ground water inputs from nearby sources, stormwater runoff, and microbial cycling. In Kings Bay, based on the long-term annual average (2004–12), 36% of the TN is nitrate and 64% of the TN is organic nitrogen and ammonium. Derived from the long-term annual average (2004–12) a nitrate concentration of 0.10 mg/L equals a TN concentration of 0.28 mg/L (**Chapter 2**). Therefore, the maximum allowable TN target concentration limit for Kings Bay that corresponds with a 0.10 mg/L concentration of nitrate is 0.28 mg/L.

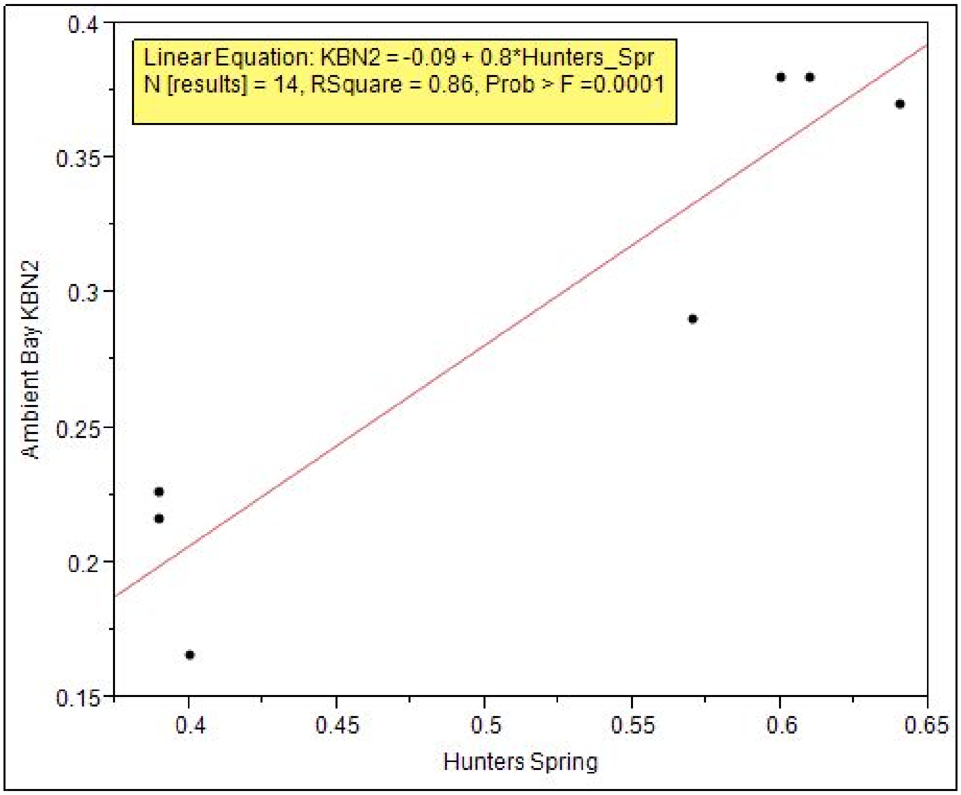

Figure 5.11. Plot Corresponding Hunter Spring and Ambient Bay Station KBN2 Nitrate Concentrations (mg/L) and Regression Curve

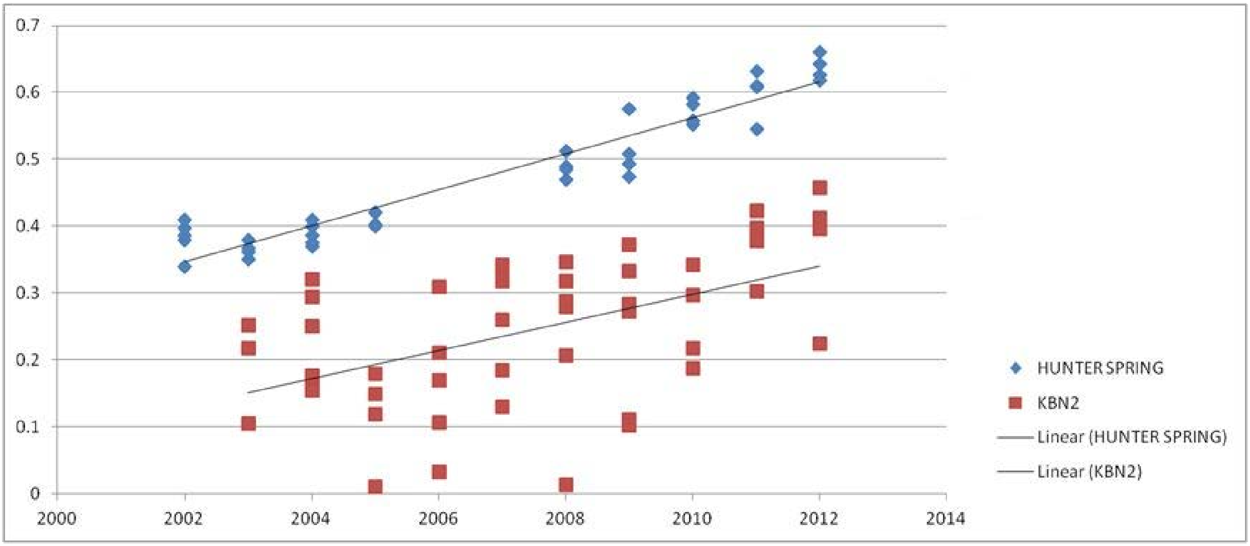

Figure 5.12. Graph Showing Nitrate Concentrations for Hunter Spring and Station KBN2 and Effects of Dilution and Attenuation

The phosphorus thresholds for Kings Bay and its springs developed by the Department are based on a conservative approach. Similarly to other estuaries, Kings Bay is mostly phosphorus limited, and so taking a conservative approach is important. If current phosphorus concentrations were to increase, this could translate to an even-greener bay regardless of nitrogen concentrations. The SWFWMD and the Department are taking a great interest in phosphorus and factoring in phosphorus reductions to help improve water quality in the bay.

For Kings Bay, based on the long-term annual average (2004–12) the TP concentration is 0.032 mg/L, which corresponds with a long-term annual average (2004–12) of 0.013 mg/L for orthophosphate (**Table 5.3**). Since 41% of the TP is orthophosphate and 59% of the TP is organic phosphorus, TP is considered the target nutrient for Kings Bay (WBID 1341). Setting a TP target for Kings Bay accounts for phosphorus sources associated with stormwater runoff, resuspended bay sediment, and microbial cycling, which includes inorganic (orthophosphate) and organic sources of phosphorus. Therefore, the maximum allowable TP target concentration limit for Kings Bay (WBID 1341) is 0.032 mg/L.

Orthophosphate is the predominant form of phosphorus in water from Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. This is typical of all springs because orthophosphate occurs in the natural geologic material. Stevenson *et al.* (2007) found that the growth of *L. wollei* was limited at orthophosphate concentrations less than 0.028 mg/L. Therefore, the Department has selected the saturating orthophosphate concentration of 0.028 mg/L from Stevenson *et al.* (2007) as the maximum allowable target concentration limit for the springs. For Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, orthophosphate is the major component of TP, with an average difference of only 0.004 mg/L between orthophosphate and TP (**Table 5.3**). An orthophosphate concentration of 0.028 mg/L corresponds to a TP concentration of 0.032 mg/L (0.028 + 0.004 = 0.032) in the spring samples.

Table 5.3. Orthophosphate as the Major Component of TP Based on the Long-Term Annual Average for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring, 2004–12 (in mg/L)

- = Empty cell/no data
LTA = Long-term average (2004–12)

Waterbody Name	Waterbody Type	Orthophosphate LTA	TP LTA	Difference
Kings Bay	Bay	0.013	0.032	0.019
Hunter Spring	Spring	0.024	0.029	0.005
House Spring	Spring	0.023	0.024	0.001
Idiot's Delight Spring	Spring	0.026	0.027	0.001
Tarpon Spring	Spring	0.027	0.034	0.007
Black Spring	Spring	0.017	0.024	0.007

Average Difference of Springs = 0.004

The TMDL nitrogen and phosphorus maximum allowable target concentration limits are being applied as annual averages instead of daily values. Annual averages are more appropriate because changes in aquatic vegetation biomass do not respond instantaneously to changes in nutrient concentrations. Murray *et al.* (1999) found that nutrient enrichment response differed for SAV on the order of months (two to two and a half months).

As discussed in **Chapter 3**, these TMDL target concentrations for Kings Bay, Hunter Spring, House Spring, Idiot’s Delight Spring, Tarpon Spring, and Black Spring will be submitted to EPA for approval as site specific hierarchal interpretations of the narrative nutrient criteria for these water bodies as stated in Rule 62-302.531, F.A.C.

5.6.3 Setting the Existing Mean Concentration for Nutrients

For Hunter Spring, House Spring, Idiot’s Delight Spring, Tarpon Spring, and Black Spring, the annual average nitrate and orthophosphate concentrations were calculated for each year during the Cycle 2 verified period (2004–12). For Kings Bay, the annual average TN and TP concentrations were calculated for each year during the Cycle 2 verified period (2004–12). For Kings Bay, Hunter Spring, House Spring, Idiot’s Delight Spring, Tarpon Spring, and Black Spring, the percent reductions required for the TMDL were calculated using the water quality values averaged for each year over the most recent eight-year period (January 1, 2004, through December 31, 2012). The longer period includes the Cycle 2 verified period (January 1, 2004, through June 30, 2011) and more recent data.

The SWFWMD performed the majority of water quality sampling in the Kings Bay contributing area. Many of the smaller springs are sampled annually every July, and the larger springs are sampled four times a year. Hunter Spring and Tarpon Spring are typically sampled four times a year (January, April, July, and October). Idiot’s Delight Spring, House Spring, and Black Spring are sampled annually in July. This schedule is the part of the SWFWMD routine spring sampling.

To provide confidence that the annual average concentrations will meet the target concentrations even under the worst-case scenario, the highest annual average concentrations were used as the existing mean concentrations to calculate the percent reduction. Expressing the existing mean concentration as an annual average concentration provides a margin of safety, because restoration activities designed to address the highest annual average concentration should help ensure that average nitrogen and phosphorus concentrations from year to year will remain low. This approach adds to the margin of safety of the TMDL.

Due to the minimal monthly variation of the nitrate concentrations for Hunter Spring and Tarpon Spring and the limited dataset for House Spring, Idiot’s Delight Spring, and Black Spring, the percent reductions were established based on the data for the year with the highest annual average concentration. This will be protective for all months and add to the implicit margin of safety.

Table 5.4 displays the highest annual average TN concentration for Kings Bay and the highest annual average nitrate concentrations for Hunter Spring, House Spring, Idiot’s Delight Spring, Tarpon Spring, and Black Spring. **Table 5.5** displays the highest annual average TP concentration for Kings Bay and the highest annual average orthophosphate concentrations for Hunter Spring, House Spring, Idiot’s Delight Spring, Tarpon Spring, and Black Spring. The highest annual average for each WBID will be compared with the target concentration. For each WBID, if the existing mean concentration exceeds the target concentration, then the needed percent reduction will be calculated.

Table 5.4. Nitrogen Target and Highest Annual Average for Nitrogen for Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G, and Black Spring (WBID 1341H), 2004–12

Waterbody Name (WBID)	Waterbody	Parameter	Nitrogen Target (mg/L)	Existing Condition Highest Annual Average (mg/L)	Year
Kings Bay (WBID 1341)	Ambient bay	TN	0.28	0.36	2008
Hunter Spring (WBID 1341C)	Spring vent	Nitrate	0.23	0.64	2012
House Spring (WBID 1341D)	Spring vent	Nitrate	0.23	0.49	2012
Idiot's Delight Spring (WBID 1341F)	Spring vent	Nitrate	0.23	0.31	2004
Tarpon Spring (WBID 1341G)	Spring vent	Nitrate	0.23	0.29	2012
Black Spring (WBID 1341H)	Spring vent	Nitrate	0.23	0.31	2010 2012

The highest annual average TN concentration for Kings Bay (WBID 1341) during this period was 0.36 mg/L in 2010. For Hunter Spring (WBID 1341C) and Idiot's Delight Spring (WBID 1341F), the highest annual average nitrate concentrations were 0.64 and 0.31 mg/L in 2012 and 2004, respectively. Only 3 nitrate samples were collected from House Spring (WBID 1341D) during this period, in July 2010, July 2011, and July 2012. Therefore, the highest annual average nitrate concentration for House Spring during the Cycle 2 verified period plus more recent data was 0.49 mg/L in 2012. For Tarpon Spring (WBID 1341G) and Black Spring (WBID 1341H), located in the southern portion of Kings Bay, the highest annual average nitrate concentrations during the TMDL evaluation period were 0.29 and 0.31 mg/L, respectively. For Tarpon Spring, the highest annual average concentration occurred in 2012, and the highest annual average concentration for Black Spring occurred in 2010 and 2012.

Table 5.5. Phosphorus Target and Highest Annual Average for Phosphorus for Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G, and Black Spring (WBID 1341H), 2004–12

Waterbody Name (WBID)	Waterbody	Parameter	Phosphorus Target (mg/L)	Existing Condition Highest Annual Average (mg/L)	Year
Kings Bay (WBID 1341)	Ambient Bay	TP	0.032	0.037	2012
Hunter Spring (WBID 1341C)	Spring Vent	Orthophosphate	0.028	0.027	2010
House Spring (WBID 1341D)	Spring Vent	Orthophosphate	0.028	0.025	2012
Idiot's Delight Spring (WBID 1341F)	Spring Vent	Orthophosphate	0.028	0.030	2004
Tarpon Spring (WBID 1341G)	Spring Vent	Orthophosphate	0.028	0.031	2005
Black Spring (WBID 1341H)	Spring Vent	Orthophosphate	0.028	0.026	2004

The highest annual average TP concentration for Kings Bay (WBID 1341) during this period was 0.037 mg/L in 2012. For Hunter Spring (WBID 1341C) and Idiot's Delight Spring (WBID 1341F), the highest annual average orthophosphate concentrations were 0.064 and 0.031 mg/L in 2012 and 2004, respectively. Only 3 orthophosphate samples were collected from House Spring (WBID 1341D) during this period, in July 2010, July 2011, and July 2012. Therefore, the highest annual average orthophosphate concentration for House Spring during the Cycle 2 verified period plus more recent data was 0.049 mg/L in 2012. For Tarpon Spring (WBID 1341G) and Black Spring (WBID 1341H), located in the southern portion of Kings Bay, the highest annual average orthophosphate concentrations during the TMDL evaluation period were 0.029 and 0.031 mg/L, respectively. For Tarpon Spring, the highest annual average concentration occurred in 2012, and the highest annual average concentration for Black Spring occurred in 2010 and 2012.

5.7 Calculation of the TMDL Percent Reduction

To obtain a percent reduction that is reasonably representative of the WBIDs and adequately protective, the highest annual average nitrogen and phosphorus concentrations for each WBID were used. The percent reductions required to achieve the water quality targets were calculated using the following formula:

[(highest annual average concentration – target concentration)/highest annual average concentration] x 100

5.7.1 Nitrogen

Based on the highest annual condition for Kings Bay, the calculated percent reduction in total nitrogen is 22%. Using the same calculation and their highest annual conditions, 64% and 53% reductions in nitrate concentrations would be needed for Hunter Spring and House Spring, respectively. Under the same scenario, a 26% reduction in nitrate concentration would be needed for both Idiot's Delight Spring and Black Spring, and a 21% reduction would be needed for Tarpon Spring. **Table 5.6** displays the highest annual average concentration for nitrogen, the water quality target for each impaired waterbody, and the calculated percent reduction in concentration to meet applicable water quality criterion (using the worst-case scenario).

Once the target concentration is consistently achieved, the WBID will be re-evaluated to determine if an imbalance of flora and fauna still exists as a result of algal smothering. If such a condition still exists, the TMDL will be reassessed as part of the Department's watershed assessment cycle. The target concentration may be changed if the Department determines that further reductions in the nitrogen concentration are needed to address the imbalance. The purpose of a TMDL is to set a pollutant reduction goal that, if achieved, will result in the attainment of the designated uses for that waterbody.

Table 5.6. Highest Annual Average Concentration, Water Quality Target by Impaired Waterbody, and Needed Percent Reduction in Concentration for Nitrogen, 2004–12

Waterbody Name (WBID)	Waterbody	Parameter	Highest Annual Average (mg/L)	Nitrogen Target (mg/L)	% Reduction
Kings Bay (WBID 1341)	Ambient bay	TN	0.36	0.28	22%
Hunter Spring (WBID 1341C)	Spring vent	Nitrate	0.64	0.23	64%
House Spring (WBID 1341D)	Spring vent	Nitrate	0.49	0.23	53%
Idiot's Delight Spring (WBID 1341F)	Spring vent	Nitrate	0.31	0.23	26%
Tarpon Spring (WBID 1341G)	Spring vent	Nitrate	0.29	0.23	21%
Black Spring (WBID 1341H)	Spring vent	Nitrate	0.31	0.23	26%

5.7.2 Phosphorus

Based on the highest annual condition for Kings Bay (a worst-case scenario), the calculated percent reduction in TP is 14%. No reduction in orthophosphate concentrations would be needed for Hunter Spring, House Spring, and Black Spring. A 7% reduction in orthophosphate concentration would be needed for Idiot's Delight Spring, and a 10% reduction would be needed for Tarpon Spring, using their highest annual average orthophosphate concentrations. **Table 5.7** displays for phosphorus the highest annual average concentration, the water quality target for each impaired waterbody, and the calculated percent reduction in concentration to meet the applicable water quality criterion (using the worst-case scenario).

Once the target concentration is consistently achieved, the WBID will be re-evaluated to determine if an imbalance of flora and fauna still exists as a result of algal smothering. If such a condition still exists, the TMDL will be reassessed as part of the Department's watershed assessment cycle. The target concentration may be changed if the Department determines that further reductions in the phosphorus concentration are needed to address the imbalance. The purpose of a TMDL is to set a pollutant reduction goal that, if achieved, will result in attainment of the designated uses for that waterbody.

Table 5.7. Highest Annual Average Concentration, Water Quality Target by Impaired Waterbody, and Needed Percent Reduction in Concentration for Phosphorus, 2004–12

Waterbody Name (WBID)	Waterbody	Parameter	Highest Annual Average (mg/L)	Phosphorus Target (mg/L)	% Reduction
Kings Bay (WBID 1341)	Ambient bay	TP	0.037	0.032	14%
Hunter Spring (WBID 1341C)	Spring vent	Orthophosphate	0.027	0.028	No reduction
House Spring (WBID 1341D)	Spring vent	Orthophosphate	0.025	0.028	No reduction
Idiot's Delight Spring (WBID 1341F)	Spring vent	Orthophosphate	0.030	0.028	7%
Tarpon Spring (WBID 1341G)	Spring vent	Orthophosphate	0.031	0.028	10%
Black Spring (WBID 1341H)	Spring vent	Orthophosphate	0.026	0.028	No reduction

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The percent concentration reductions listed in **Table 6.3** should achieve the annual average nutrient target concentration for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring. While these percent reductions are the expression of the TMDL that will be implemented, the EPA recommends that all TMDLs and associated load allocations and wasteload allocations include a daily time increment in conjunction with other appropriate temporal expressions that may be necessary to implement the relevant water quality standards.

The nitrogen and phosphorus TMDL targets are presented as annual averages instead of daily values because changes in aquatic vegetation biomass do not respond instantaneously to changes in nutrient concentrations. Murray *et al.* (1999) found that nutrient enrichment response differed for SAV on the order of months (two to two and a half months). Also, it is impractical to collect daily nitrogen and phosphorus water quality data to evaluate water quality for Kings Bay and its impaired springs. These Monthly Maximum Limit targets for nitrogen and phosphorus account for variability within the system and were established using the following equation, established by the EPA (2006) (in the equation, it is assumed that the nitrate data distributions are lognormal):

$$\mathbf{MDL = LTA * exp(Z_p\sigma_y - 0.5\sigma y^2)}$$

$$\mathbf{\sigma_y = sqrt(ln(CV^2 + 1))}$$

Where:

LTA = Long-term average (mg/L)
Z_p = p^{th} *percentage point of the standard normal distribution, at 95%* ($Z_p = 1.645$)
σ = *Standard deviation*
CV = Coefficient of variance

For the monthly maximum nitrate and orthophosphate concentrations, it was assumed that the average annual target concentration should be the same as the average monthly concentration. Also, it was assumed that the target dataset would have the same CV as the existing measured dataset, allowing for a 5% exceedance (EPA 2007, pp. 19 and 20). For Kings Bay (WBID 1341), the monthly maximum TN concentration is 0.38 mg/L, and the monthly maximum TP concentration is 0.040 mg/L. The monthly maximum nitrate concentration for Hunter Spring is 0.31 mg/L; for House Spring, 0.24 mg/L; for Idiot's Delight Spring, 0.31 mg/L; for Tarpon Spring, 0.33 mg/L; and for Black Spring, 0.36 mg/L.

Table 6.1 shows the monthly maximum TN concentration for Kings Bay and monthly maximum nitrate concentrations for the springs. The monthly maximum orthophosphate concentration for Hunter Spring is 0.031 mg/L; for House Spring, 0.032 mg/L; for Idiot's Delight Spring, 0.032 mg/L; for Tarpon Spring, 0.032 mg/L; and for Black Spring, 0.044 mg/L. **Table 6.2** shows the monthly maximum TP concentration for Kings Bay and monthly maximum orthophosphate concentrations for the springs. It should be emphasized that these monthly maximum targets were developed for illustrative purposes. The implementation of the TMDL will be based on the annual average concentration targets.

Table 6.1. Monthly Maximums for Target TN and Nitrate Concentrations (mg/L)

Waterbody Name (WBID)	Parameter	Standard Deviation	Long-term Average Nitrate Target (mg/L)	Coefficient of Variance	Monthly Maximum To Achieve Annual Average Nitrate Target
Kings Bay (WBID 1341)	TN	0.06	0.28	0.21	0.38
Hunter Spring (WBID 1341C)	Nitrate	0.09	0.23	0.20	0.31
House Spring (WBID 1341D)	Nitrate	0.02	0.23	0.044	0.24
Idiot’s Delight Spring (WBID 1341F)	Nitrate	0.04	0.23	0.19	0.31
Tarpon Spring (WBID 1341G)	Nitrate	0.05	0.23	0.25	0.33
Black Spring (WBID 1341H)	Nitrate	0.07	0.23	0.31	0.36

Table 6.2. Monthly Maximums for Target TP and Orthophosphate Concentrations (mg/L)

Waterbody Name (WBID)	Parameter	Standard Deviation	Long-term Average Orthophosphate Target (mg/L)	Coefficient of Variance	Monthly Maximum To Achieve Annual Average OPO4 Target
Kings Bay (WBID 1341)	TP	0.005	0.032	0.14	0.040
Hunter Spring (WBID 1341C)	Orthophosphate	0.002	0.028	0.06	0.031
House Spring (WBID 1341D)	Orthophosphate	0.002	0.028	0.08	0.032
Idiot’s Delight Spring (WBID 1341F)	Orthophosphate	0.002	0.028	0.07	0.032
Tarpon Spring (WBID 1341G)	Orthophosphate	0.002	0.028	0.08	0.032
Black Spring (WBID 1341H)	Orthophosphate	0.005	0.028	0.31	0.044

A TMDL provides a basis for allocating acceptable loads among all of the known pollutant sources in the contributing area of an impaired waterbody so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (wasteload allocations, or WLAs), nonpoint source loads (load allocations, or LAs), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\textbf{TMDL} = \sum \square \text{WLAs} + \sum \square \text{LAs} + \text{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\textbf{TMDL} \cong \sum \square \text{WLAs}_{\textbf{wastewater}} + \sum \square \text{WLAs}_{\textbf{NPDES Stormwater}} + \sum \square \text{LAs} + \text{MOS}$$

It should be noted that the various components of the revised TMDL equation may not sum up to the value of the TMDL because (1) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is also accounted for within the LA, and (2) TMDL components can be expressed in different terms (for example, the WLA for stormwater is typically expressed as a percent reduction, and the WLA for wastewater is typically expressed as mass per day).

WLAs for stormwater discharges are typically expressed as "percent reduction" because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges also differs from the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored, and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the "maximum extent practical" through the implementation of best management practices (BMPs).

This approach is consistent with federal regulations (40 CFR § 130.2[I]), which state that TMDLs can be expressed in terms of mass per time (e.g., pounds per day), toxicity, or other appropriate measure. The TMDL for Kings Bay (WBID 1341), Hunter Spring (WBID 1341C), House Spring (WBID 1341D), Idiot's Delight Spring (WBID 1341F), Tarpon Spring (WBID 1341G), and Black Spring (WBID 1341H) is expressed in terms of concentration of nutrients and represents the nutrient loading these waterbodies can assimilate and maintain a balanced natural population of flora and fauna (**Table 6.3**).

6.2 Load Allocation

Because no target loads were explicitly calculated in this TMDL analysis, the TMDL was represented as the percent reduction required to achieve the nitrate target concentration. The percent reduction assigned to the nonpoint source loading category (LA) is the same as that defined for the TMDL percent reduction. To achieve the annual average TN target of 0.28 mg/L in Kings Bay (WBID 1341), the nitrogen loads from the nonpoint source areas contributing to this impaired WBID would need to be reduced by 22% based on the use of the highest annual average TN concentration for the bay. To achieve the annual average nitrate target of 0.23 mg/L for Hunter Spring (WBID 1341C) and House Spring (WBID 1341D), the nitrate loads from the nonpoint source areas contributing to these impaired WBIDs would need to be reduced by 64% and 53%, respectively. To achieve the annual average nitrate target of 0.23 mg/L for Black Spring (WBID 1341H) and Idiot's Delight Spring (WBID 1341F), the nitrate loads from the nonpoint source areas contributing to these impaired WBIDs would need to be reduced by 26%. To achieve the annual average nitrate target of 0.23 mg/L in Tarpon Spring (WBID 1341G), the nitrate loads from the nonpoint source areas contributing to this impaired WBID would need to be reduced by 21%. The reductions needed for Kings Bay and its springs are also based on their highest annual average nitrate concentrations, which portray a worst-case scenario.

To achieve the annual average TP target of 0.032 mg/L in Kings Bay (WBID 1341), the phosphorus loads from the nonpoint source areas contributing to this impaired WBID would need to be reduced by 14% based on the use of the highest annual average orthophosphate concentration for the bay. No reductions in orthophosphate concentrations would be needed for Hunter Spring, House Spring, and Black Spring to meet the annual average orthophosphate target of 0.028 mg/L. To achieve the annual average orthophosphate target of 0.028 mg/L for Idiot's Delight Spring and Tarpon Spring, the orthophosphate loads from the nonpoint source areas contributing to these impaired WBIDs would need to be reduced by 7% and 10%, respectively. The reductions needed for Kings Bay and its springs are also based on their highest annual average orthophosphate concentrations, which portray a worst-case scenario.

Table 6.3. TMDL Components for Kings Bay, Hunter Spring, House Spring, Idiot's Delight Spring, Tarpon Spring, and Black Spring

N/A = Not applicable

Waterbody Name (WBID)	Parameter	TMDL (mg/L)	TMDL % Reduction	Wasteload Allocation for Wastewater	Wasteload Allocation for NPDES Stormwater % Reduction	LA % Reduction	MOS
Kings Bay (WBID 1341)	TN as annual average	0.28	22%	N/A	N/A	22%	Implicit
Kings Bay (WBID 1341)	TP as annual average	0.032	14%	N/A	N/A	14%	Implicit
Hunter Spring (WBID 1341C)	Nitrate as annual average	0.23	64%	N/A	N/A	64%	Implicit
Hunter Spring (WBID 1341C)	Orthophosphate as annual average	0.028	No reduction needed	N/A	N/A	No reduction needed	Implicit
House Spring (WBID 1341D)	Nitrate as annual average	0.23	53%	N/A	N/A	53%	Implicit
House Spring (WBID 1341D)	Orthophosphate as annual average	0.028	No reduction needed	N/A	N/A	No reduction needed	Implicit
Idiot's Delight Spring (WBID 1341F)	Nitrate as annual average	0.23	26%	N/A	N/A	26%	Implicit
Idiot's Delight Spring (WBID 1341F)	Orthophosphate as annual average	0.028	7%	N/A	N/A	7%	Implicit
Tarpon Spring (WBID 1341G)	Nitrate as annual average	0.23	21%	N/A	N/A	21%	Implicit
Tarpon Spring (WBID 1341G)	Orthophosphate as annual average	0.028	10%	N/A	N/A	10%	Implicit
Black Spring (WBID 1341H)	Nitrate as annual average	0.23	26%	N/A	N/A	26%	Implicit
Black Spring (WBID 1341H)	Orthophosphate as annual average	0.028	No reduction needed	N/A	N/A	No reduction needed	Implicit

6.3 Wasteload Allocation

6.3.1 NPDES Wastewater Discharges

Currently, there are no NPDES wastewater facilities that discharge directly into Kings Bay or any tributaries. Any new potential discharger is expected to comply with the Class III criterion for nutrients and with nitrogen limits consistent with this TMDL.

6.3.2 NPDES Stormwater Discharges

Currently, there are no NPDES MS4 stormwater facilities identified as discharging directly into Kings Bay or any tributaries. Any new potential discharger is expected to comply with the Class III criterion for nutrients and with nitrate limits consistent with this TMDL.

6.4 Margin of Safety

Consistent with the recommendations of the Allocation Technical Advisory Committee (Department 2001), an implicit MOS was used in the development of this TMDL and was provided by the conservative decisions associated with a number of assumptions and the development of assimilative capacity. In addition, when estimating the required percent reduction to achieve the water quality target, the highest annual average of measured nitrogen and phosphorus concentrations within the eight-year data period (2004–12) was used instead of the average of the annual averages. In several cases, these highest annual averages were considerably higher than current conditions. This made the estimates of required percent load reduction more conservative and therefore added to the MOS.

Chapter 7: NEXT STEPS—IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending on the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. BMAPs are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies.

If the Department determines that a BMAP is needed to support the implementation of this TMDL, it will be developed through a transparent, stakeholder-driven process intended to result in a plan that is cost-effective, is technically feasible, and meets the restoration needs of the applicable waterbodies. The restoration plan will take into account the sources of nitrogen within the contributing area, including legacy loads from past land use activities, as well as the complexity of the aquifer system that conveys pollutants to the impaired waters.

Once adopted by order of the Department Secretary, BMAPs are enforceable through wastewater and municipal stormwater permits for point sources and through BMP implementation for nonpoint sources. Among other components, BMAPs typically include the following:

- *Water quality goals (based directly on the TMDL).*
- *Refined source identification.*
- *Load reduction requirements for stakeholders (quantitative detailed allocations, if technically feasible).*
- *A description of the load reduction activities to be undertaken, including structural projects, nonstructural BMPs, and public education and outreach.*
- *A description of further research, data collection, or source identification needed in order to achieve the TMDL.*
- *Timetables for implementation.*
- *Implementation funding mechanisms.*
- *An evaluation of future increases in pollutant loading due to population growth.*
- *Implementation milestones, project tracking, water quality monitoring, and adaptive management procedures.*
- *Stakeholder statements of commitment (typically a local government resolution).*

BMAPs are updated through annual meetings and may be officially revised every five years. Completed BMAPs in the state have improved communication and cooperation among local stakeholders and state agencies; improved internal communication within local governments;

applied high-quality science and local information to the management of water resources; clarified the obligations of wastewater point source, MS4, and non-MS4 stakeholders in TMDL implementation; enhanced transparency in the Department's decision making; and built strong relationships between the Department and local stakeholders that have benefited other program areas.

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Appendices

Appendix A: Background Information on Federal and State Stormwater Programs

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, F.S., was established as a technology-based program that relies on the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Rule 62-40, F.A.C. In 1994, the Department's stormwater treatment requirements were integrated with the stormwater flood control requirements of the water management districts, along with wetland protection requirements, into the Environmental Resource Permit (ERP) regulations.

Rule 62-40, F.A.C., also requires the state's water management districts to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a Surface Water Improvement and Management (SWIM) plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, they have been established for Tampa Bay, Lake Thonotosassa, the Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka.

In 1987, the U.S. Congress established Section 402(p) as part of the federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES permitting program to designate certain stormwater discharges as "point sources" of pollution. The EPA promulgated regulations and began implementing the Phase I NPDES stormwater program in 1990. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific standard industrial classification (SIC) codes, construction sites disturbing 5 or more acres of land, and the master drainage systems of local governments with a population above 100,000, which are better known as MS4s. However, because the master drainage systems of most local governments in Florida are interconnected, the EPA implemented Phase I of the MS4 permitting program on a countywide basis, which brought in all cities (incorporated areas), Chapter 298 urban water control districts, and the FDOT throughout the 15 counties meeting the population criteria. The Department received authorization to implement the NPDES stormwater program in 2000.

An important difference between the federal NPDES and the state's Stormwater/ERP Programs is that the NPDES Program covers both new and existing discharges, while the state's program focuses on new discharges only. Additionally, Phase II of the NPDES Program, implemented in 2003, expands the need for these permits to construction sites between 1 and 5 acres, and to local governments with as few as 1,000 people. While these urban stormwater discharges are now technically referred to as "point sources" for the purpose of regulation, they are still diffuse sources of pollution that cannot be easily collected and treated by a central treatment facility, as are other point sources of pollution such as domestic and industrial wastewater discharges. It should be noted that all MS4 permits issued in Florida include a reopener clause that allows permit revisions to implement TMDLs when the implementation plan is formally adopted.

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