SOUTHWEST DISTRICT • SPRINGS COAST BASIN

Final TMDL Report

Nutrient TMDLs for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs
(WBIDs 1345G, 1348A, and 1348E)

Kristina Bridger, James Dodson, and Gary Maddox

Ground Water Management Section
Division of Environmental Assessment and Restoration
Florida Department of Environmental Protection

September 2014

2600 Blair Stone Road
Mail Station 3575
Tallahassee, FL 32399-2400

Acknowledgments

This analysis could not have been accomplished without significant contributions from Kirstin Eller, Edgar Wade, and Brian Katz in the Florida Department of Environmental Protection's Water Quality Evaluation and Total Maximum Daily Loads Program, Ground Water Management Section. The authors also appreciate the assistance provided by the Southwest Florida Water Management District in obtaining information on historical studies and in their review of this report.

Map production was provided by Ron Hughes in the Department's Office of Watershed Services.

Editorial assistance was provided by Linda Lord in the Department's Watershed Planning and Coordination Section.

For additional information on the watershed management approach and impaired waters in the Springs Coast Basin, contact:

Terry Hansen
Florida Department of Environmental Protection
Watershed Restoration Program
Watershed Planning and Coordination Section
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
terry.hansen@dep.state.fl.us
Phone: (850) 245–8561
Fax: (850) 245–8434

Access to all data used in the development of this report can be obtained by contacting:

Richard Hicks, P.G.
Florida Department of Environmental Protection
Water Quality Evaluation and TMDL Program
Ground Water Management Section
2600 Blair Stone Road, Mail Station 3575
Tallahassee, FL 32399-2400
richard.w.hicks@dep.state.fl.us
Phone: (850) 245–8229
Fax: (850) 245–8236

Contents

List of Tables

List of Figures

Websites

Florida Department of Environmental Protection, Bureau of Watershed Restoration

TMDL Program

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

Identification of Impaired Surface Waters Rule

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

2014 Integrated Report

http://www.dep.state.fl.us/water/docs/2014_integrated_report.pdf

Criteria for Surface Water Quality Classifications

http://www.dep.state.fl.us/legal/Rules/shared/62-302/62-302.pdf

Water Quality Status Report and Water Quality Assessment Report: Springs Coast

http://www.dep.state.fl.us/water/basin411/default.htm

Florida 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

http://www.epa.gov/storet/

Chapter 1: INTRODUCTION

1.1 Purpose of Report

This report presents the Total Maximum Daily Loads for nitrate nitrogen (NO_3N), which was determined to contribute to the ecological imbalance at the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. These waterbodies are located in the Middle Coastal Planning Unit of the Springs Coast Basin. They were verified by the Florida Department of Environmental Protection as impaired by nutrients, which contribute to the excessive growth of algae, and were included on the Verified List of impaired waters for the Spring Coast Basin adopted by Secretarial Order in February 2012. The TMDLs establish the allowable level of nutrient loadings that would restore these waterbodies so that they meet the applicable water quality criterion for nutrients. This report will be used as the basis for discussions during the development of the Basin Management Action Plan.

1.2 Identification of Waterbodies

Homosassa Springs (the major springs in this group of springs that contribute flow to the Homoasassa River) is located in western Citrus County, approximately 2,000 feet west of U.S. Highway 19 near West Fishbowl Drive (**Figure 1.1**). All of these springs makeup the headwaters of the Homosassa River, which flows westward approximately seven miles to the Gulf of Mexico. The springs contributing flow to the Homosassa River occur within an approximately four square-mile area. **Figure 1.2** is an aerial photograph showing the Homosassa River and its headwaters.

Spring Cove, located just south of Ellie Schiller Homosassa Springs Wildlife State Park along a southeast-trending tributary of the Homosassa River, contains six named springs: Pumphouse, McClain, Trotter Main, Trotter #1, Belcher, and Abdoney Springs.

Bluebird Springs is located in a county park approximately 0.7 mile southeast of Spring Cove, is included among the springs that contribute flow to the Homosassa River, as are the Hidden River Head and #2 springs, located about 2.2 miles south of the Homosassa Main Spring vents. Hidden River Springs (Hidden River Head and #2 Springs) discharge into the Hidden River, a spring run that flows west for approximately two miles before disappearing underground.

Each of these springs supports a complex aquatic ecosystem and together are an important cultural and economic resource for the state. According to the Citrus County Tourist Development Council

(Research Data Services 2013), based on field surveys Citrus County had an estimated 328,900 overnight visitors staying in commercial lodging from May 2012 through April 2013. Approximately 31.2% of the overnight visitors staying in commercial lodging (102,617 visitors) visited the park. The average party budget (~3 people) was $763, with a total economic impact of $26,088,661.

For assessment purposes, the Department inventories the waters of the state by the geographic water assessment polygons in which they occur, and each of these polygons has its own unique **w**ater**b**ody **id**entification (WBID) number that corresponds to watersheds or stream reaches. The Homosassa–Trotter–Pumphouse Springs Group is WBID 1345G, Bluebird Springs is WBID 1348A, and Hidden River Springs is WBID 1348E. **Figure 1.3** contains a map of these springs and their WBIDs, which have been identified as impaired.

Homosassa Springs, Trotter Springs, and Pumphouse Springs are located within WBID 1345G. Homosassa Springs (the main source of water to the river) is composed of the main spring, which includes three large vents contained within a collapsed-cavern feature, and many smaller secondary vents spread over an area of nearly four square miles (**Figure 1.3**) (Jones *et al.* 1997). The Homosassa River, having originated at the main springs, receives additional flow from the secondary vents, many of which are located along the southeast fork of the Homosassa River. After receiving additional flow from the spring-fed Halls River, the Homosassa River flows westward for approximately five miles before emptying into the Gulf of Mexico. The combined discharge from Homosassa Springs is consistently greater than 64.6 million gallons per day (100 cubic feet per second [cfs]), the discharge threshold for first-magnitude springs. Thus Homosassa Springs is considered one of Florida’s first-magnitude springs (Scott *et al.* 2002).

Trotter Springs, like Homosassa Springs, is located within WBID 1345G. The main vent of Trotter Springs (Trotter Main) is on private property within the southeast fork of the Homosassa River, approximately 1,000 feet south of the Homosassa Main spring area (Champion and Starks 2011). Trotter Main Spring emanates from one of several large fractures in the limestone bedrock and lies two to three feet below the water surface.

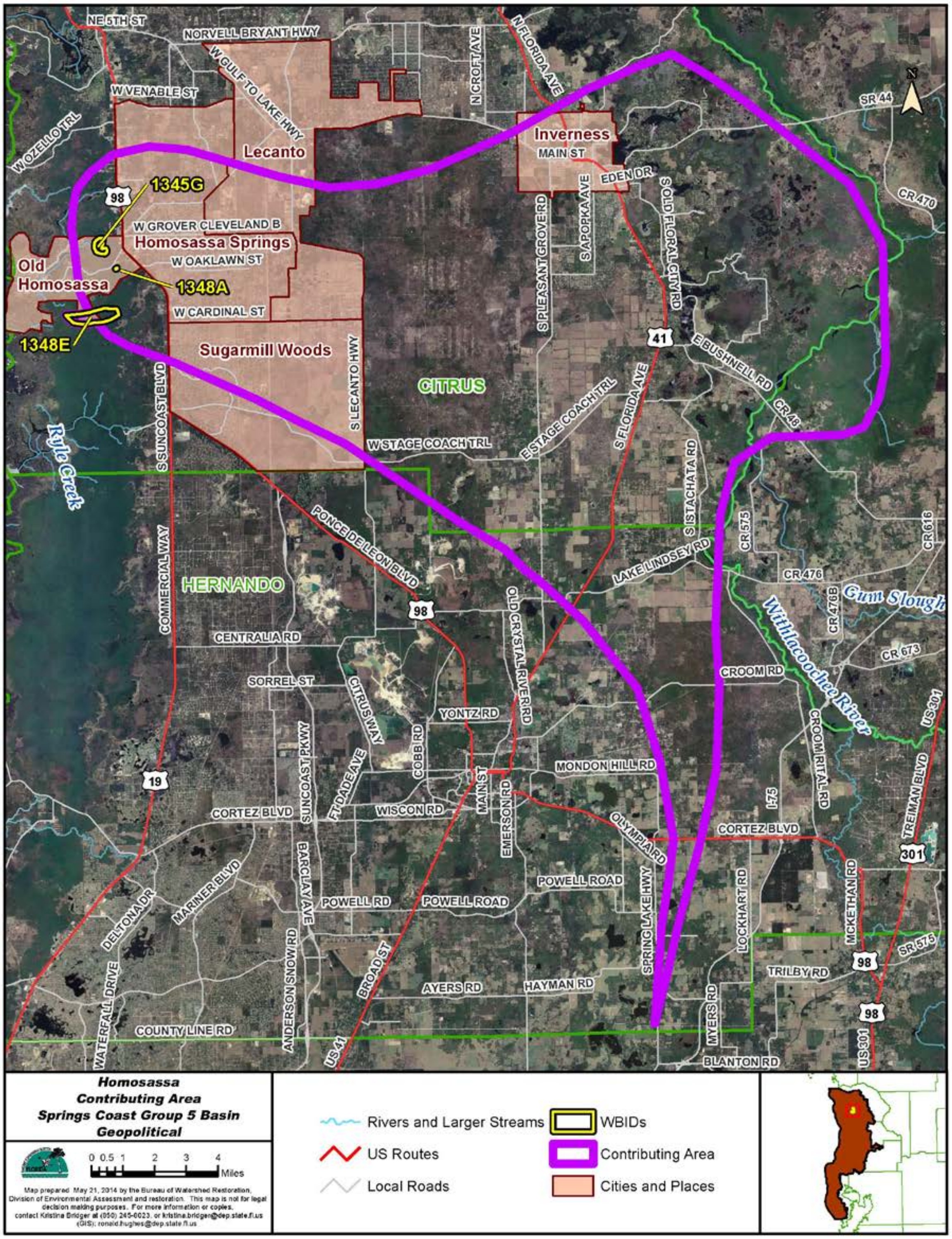
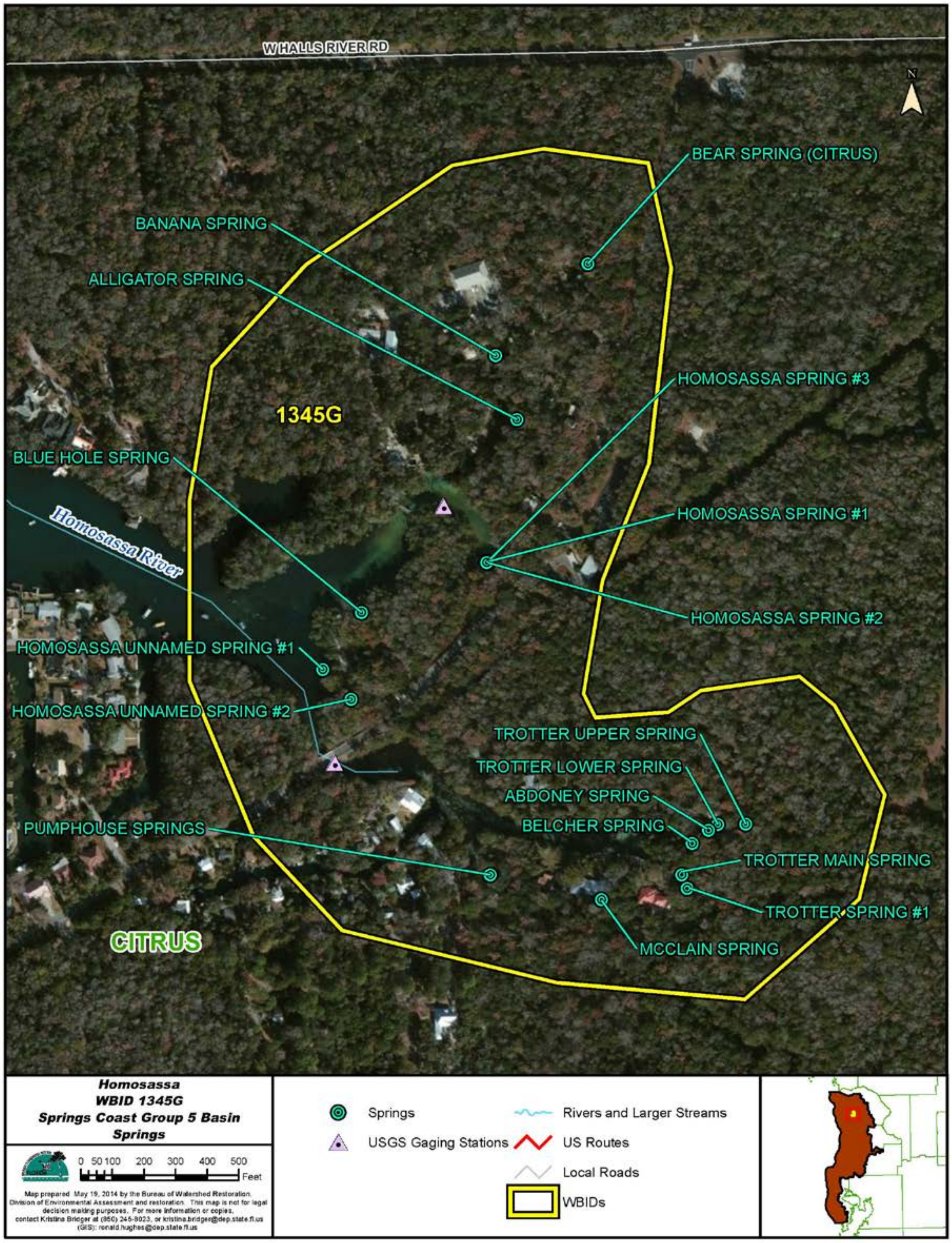


Figure 1.1. Major geopolitical and hydrologic features in the estimated contributing area of the three impaired WBIDs in Citrus and Hernando Counties

Figure 1.2. Aerial photograph of the Homosassa River and its headwaters (Department photo)



Map prepared May 19, 2014 by the Bureau of Watershed Restoration, Division of Environmental Assessment and restoration. This map is not for legal decision making purposes. For more information or copies, contact Kristina Bridger at (850) 245-8023, or kristina.bridger@dep.state.fl.us (GIS): ronald.hughes@dep.state.fl.us

Figure 1.3. Named springs and impaired WBID 1345G contributing flow to the Homosassa River

Pumphouse Springs is located within WBID 1345G on private property approximately 500 feet south of Homosassa Springs. It is at the head of a cove on the south side of a tributary of the Homosassa River (Scott *et al.* 2004). The spring consists of at least three separate small vents. The sand- and limestone-bottomed run from Pumphouse Springs flows northwest approximately 200 feet and joins Trotter Spring Run. Their combined flow travels northwest into the Homosassa River.

Hidden River Springs is located within WBID 1348E, approximately two miles south of Homosassa Spring (**Figure 1.4**) at the upstream end of Hidden River, approximately four feet below the water surface in a small circular depression, five feet in diameter. Hidden River flows overland approximately two miles before sinking underground (Champion and Starks 2011). It has not been determined where this water discharges. Popular opinion suggests the submerged water from Hidden River reappears in Otter Creek.

Bluebird Springs is located within WBID 1348A inside Citrus County Bluebird Springs Park (**Figure 1.5**), approximately one mile west of U.S. Highway 19 in the city of Homosassa Springs. In 1978 Bluebird Springs was acquired by the Citrus County Board of County Commissioners and designated as a county park.

In physiographic terms, Homosassa Springs, Pumphouse Springs, Trotter Springs, Bluebird Springs, Hidden River Springs, and their associated receiving waters are located in a karst plain region, where the landforms and surface water features depend on the underlying geology. In general, the topographic features and internal drainage in karst regions are caused by the underground dissolution, erosion, and subsidence of near-surface carbonate rocks. Within the rock, slightly acidic rainwater causes the limestone to dissolve, and further dissolution along zones of fractured rock and bedding planes causes the development of caves and interconnected openings known as conduits. Ground water migrates within these zones, and springs occur where hydraulic head differences in the aquifer coincide with openings in the earth.

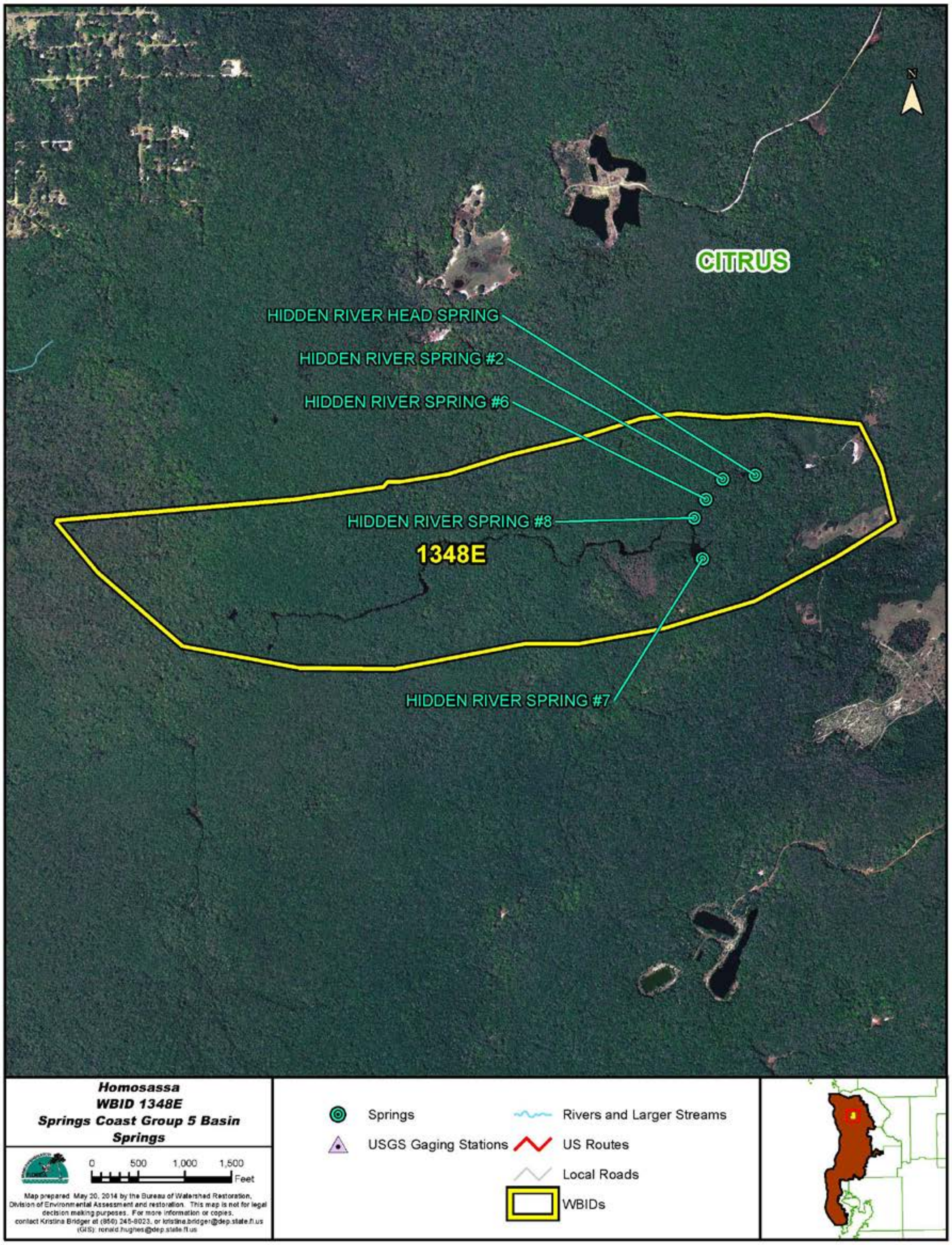


Figure 1.4. Named springs and impaired WBID 1348E in the Hidden River Springs area

Figure 1.5. Named springs and impaired WBID 1348A in the Bluebird Springs area

The entire area that contributes water to a spring via ground water and surface water inflows is known as a springshed. Springsheds are bounded by ground water divides rather than topographic divides because the principal drainage is by way of ground water flow in the Upper Floridan Aquifer (UFA) (Knochenmus and Yobbi 2001). The Southwest Florida Water Management District (SWFWMD) created a generalized springshed area for Homosassa Springs based on an analysis of ground water elevation maps, called potentiometric surface maps (Jones *et al.* 1997). Delineation based on potentiometric surface maps provides a good general description of springshed areas but is limited by the date and resolution of the potentiometric surface map, the climatic conditions that existed when the map was created, and the assumption of uniform drainage over the mapped area.

In evaluating the potential sources of nutrients impacting these springs, the Department considered the springshed as well as the surface drainage basin or watershed of the impaired receiving waters. The estimated combined contributing area of water to the springs includes the springshed of Homosassa Spring and their associated spring runs. Together this combined contributing area encompasses an area of 289 square miles. **Figure 1.1** shows the estimated contributing area and its major geopolitical and hydrologic features. This area includes 36 square miles in Citrus County, 242 square miles in Hernando County, and 11 square miles in Sumter County.

The geology of the Springs Coast Basin includes thick sequences of limestone exposed at or very near to (within 10 to 20 feet) the land surface in the eastern and western portions of the basin. Where the limestone is near the land surface, the thin veneer of sediment covering the limestone consists of unconsolidated deposits of primarily quartz sand. The limestone units include the Suwannee Limestone of Oligocene age and the Ocala Limestone of Eocene age. Underlying these exposed limestone units is the Avon Park Formation of Eocene age. The Avon Park Formation is the deepest formation containing potable water (based on total dissolved solids, which represent salinity). The Suwannee and Ocala Limestones and the Avon Park Formation comprise the UFA system in the basin, and the UFA is the source of water that discharges from springs (Jones *et al.* 1997).

In the Brooksville Ridge area (which includes the eastern part of the springs' contributing area), undifferentiated quartz sand and sediments of the Hawthorn Group overlie the UFA. The Hawthorn Group sediments were deposited in a variety of environments and consist of sand, silty sand, and waxy green clay. Phosphorite pebbles and fossil oyster bars are common. West of the Brooksville Ridge, the Hawthorn Group sediments are essentially absent, and limestone is near the surface and covered only by sand. These conditions are prevalent in the Coastal Lowlands, which include Homosassa Springs and the Homosassa River (Jones *et al.* 1997).

Karst processes play a dominant role in the rates and directions of ground water movement through the UFA in the basin. In karst areas, the dissolution of limestone creates and enlarges cavities along fractures in the limestone that eventually collapse and form sinkholes. Sinkholes capture surface water drainage and funnel it underground, promoting further dissolution of the limestone. This leads to the progressive integration of voids beneath the surface and allows larger and larger amounts of water to be funneled into the underground drainage system. Dissolution is most active at the water table or in the zone of water table fluctuation, where carbonic acid contained in atmospheric precipitation and generated by reaction with carbon dioxide in the soil reacts with limestone and dolostone.

Over geologic time the elevation of the water table has shifted in response to changes in sea level, and many vertical and lateral paths have developed in the underlying carbonate strata in the basin. Many of these paths or conduits lie below the present water table and greatly facilitate ground water flow. Openings along these paths or conduits provide easy avenues for the travel of water. Ground water rich in nutrients has the potential to flow rapidly through these passages within the limestone, or slowly through minute pore spaces within the rock matrix (SWFWMD 2001).

In evaluating the potential sources of nutrients impacting the springs and their impaired receiving waters, the Department considered the springshed as well as the combined surface drainage basin of the associated spring runs. With the exception of surface water drainage near the river corridor, most of the drainage in this area is internal, either directly into closed depressions or by seepage through overlying sediments into the unconfined limestone of the UFA.

Figure 1.6 shows the vulnerability of the Floridan aquifer system in the area contributing to these springs. This map is based on the Florida Aquifer Vulnerability Assessment (FAVA) model for the Floridan aquifer system that was developed by the Florida Geologic Survey using conditions such as soil characteristics, depth to ground water, recharge rate, and the prevalence of sinkhole features (Arthur *et al*. 2007). The FAVA model shows that most of the contributing area is more vulnerable to ground water contamination compared with other regions of the state.

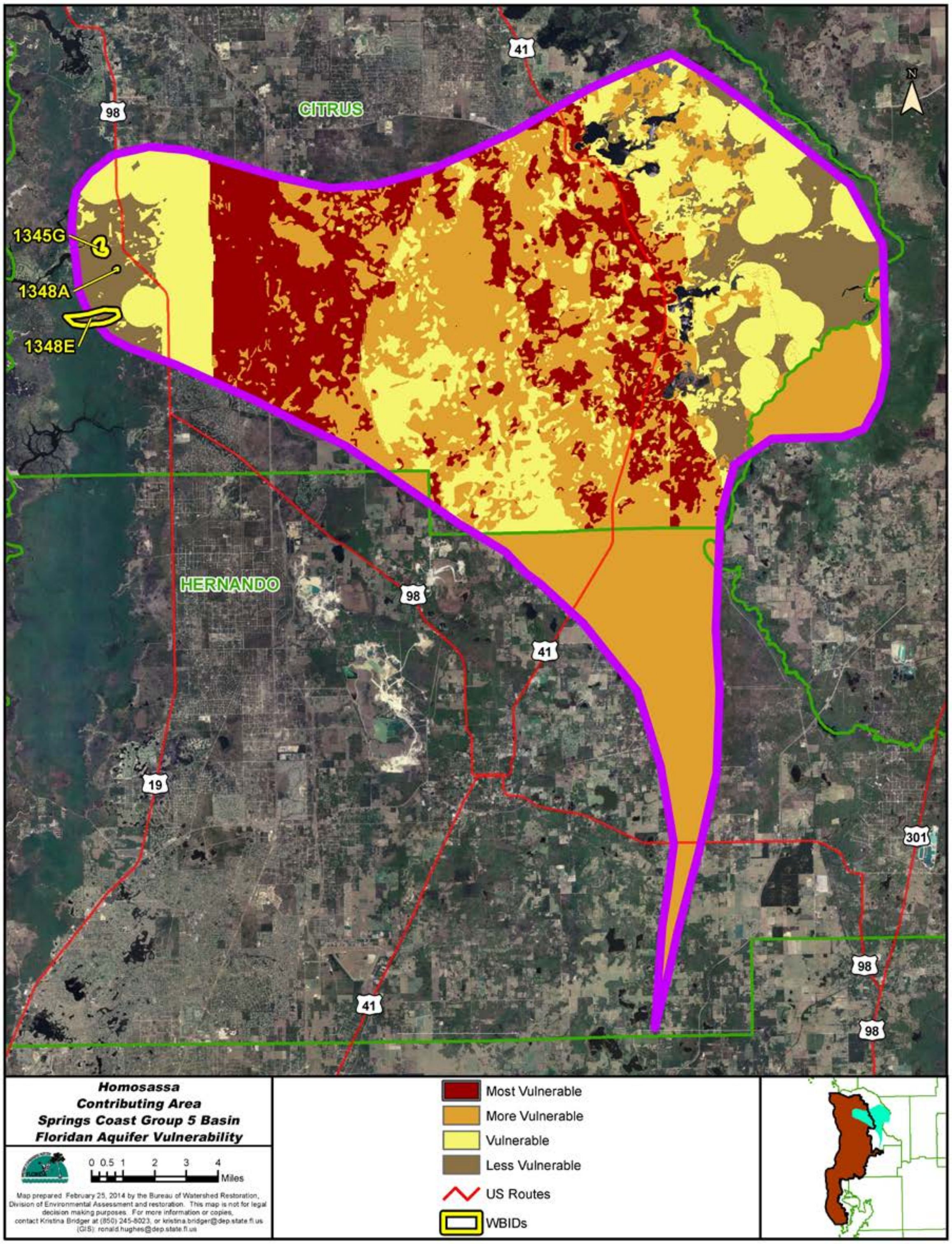


Figure 1.6. Aquifer vulnerability in the contributing area for the impaired springs

1.3 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 five-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 403.067, Laws of Florida).

The TMDL is a scientific determination of the maximum amount of a pollutant that a waterbody can receive each day and still be considered healthy. 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.

The adoption of nutrient TMDLs for Homosassa Springs, Trotter Spring, Pumphouse Spring, Bluebird Springs, and Hidden River Springs will be followed by the development and implementation of a BMAP for reducing the levels of nutrients. These springs are located in southwestern Citrus County but have a ground water contributing area that also includes part of northern Hernando County and a small portion of western Sumter County. The contributing area includes Old Homosassa, Homosassa Springs, and parts of Inverness, Lecanto, and Sugarmill Woods, in addition to smaller communities.

The restoration of these waterbodies will depend heavily on the active participation of the Department and stakeholders in the contributing area, including Hernando County, Citrus County, Sumter County, other local governments, Citrus/Hernando Waterways Restoration Council, Homosassa River Alliance, Friends of Homosassa Springs Wildlife Park, Save the Manatee Club, agricultural interests, landowners, businesses, and private citizens. The SWFWMD, Florida Department of Transportation (FDOT), and Florida Department of Agriculture and Consumer Services (FDACS) will also play important roles in the implementation of restoration activities.

1.3.1 Ellie Schiller Homosassa Springs Wildlife Park

The park has historically been a popular tourist attraction, with documented accounts of spring visitation dating back to the 1880s. At that time, the spring was a stop along the "Mullet Train," a rail line that probably ran along the shoulder of what is now Fishbowl Drive. Between 1920 and 1930, the tourist attraction was expanded, and several structures that are no longer standing were reportedly built. A public swimming area was located near the current garden area of the park. In the 1940s, under private ownership, the attraction underwent further development. During this period, the first underwater observatory, an iron tank with small windows on each side, was constructed. At least one structure from that era, the Children's Education Center, remains, although it has been expanded over the years.

In the early 1960s, the Norris Development Company purchased the tourist attraction and some land. The attraction was expanded during this period, and most of the structures currently located in the park date to that period. In 1964, the current floating underwater observatory, the Fishbowl, was moved into place.

In 1980, Canadian Pacific Investments Ltd. bought the Homosassa Springs attraction. It was sold to Taylor Simpson in 1982 and renamed Homosassa Springs Nature World. In late 1984, the site was purchased by Citrus County, and in December 1988 acquired by the state and given its present-day name.

The management of the park differs in many ways from that of a typical state park. The state park contains a zoological park (**Figure 1.7**) and well-developed visitor facilities, both located within sensitive natural communities that include a major spring, a spring run, and hydric hammock. Balancing the demands of a zoological park and tourist attraction with the proper management of the natural resources is a complex and delicate task.

The park and the associated springs are economically valuable to the state and local communities. Based on the *Economic Impact Assessment – Florida State Park System* report (Scruggs 2013), the Ellie Schiller Homosassa Springs Wildlife Park had an annual attendance of 314,544 visitors. Over 200 volunteers assist at the park in: administration, transportation, wildlife, maintenance, and concessions. The park employs 23 full-time state employees and 21 contracted concessionaires (Tenille 2014).

Figure 1.7. Ellie Schiller Homosassa Springs Wildlife Park map showing zoological area (Florida Park Service)

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.

Florida's 1998 303(d) list included 22 waterbodies in the Springs Coast Basin. 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 Chapter 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

Chapter 62-303, F.A.C., includes the methodology for listing nutrient-impaired surface waters based on documentation that supports the determination of a waterbody's imbalance in flora or fauna attributable to nutrients. In 2012, the Department used available water quality data from the SWFWMD, the Department's own monitoring activities, and other sources to document elevated nitrate concentrations and excessive algal growth in the impaired springs. Biological assessment documents prepared by researchers (Stevenson *et al.* 2004; Stevenson *et al.* 2007) also provided evidence of algal smothering. Water quality data collected by the SWFWMD and the Department comprised the bulk of the nitrate data used in the evaluation.

These spring-related waters were listed as impaired by nutrients because of their consistently elevated concentrations of nitrate (all above 0.6 milligrams per liter [mg/L]) and the corresponding evidence of imbalance in flora and fauna caused by algal smothering. This information was used in the determination of impairment for the 2012 Verified List of impaired waters. **Table 2.1** lists the waterbodies on the Cycle 2 Verified List that are addressed in this report.

Table 2.1. Cycle 2 verified impaired spring-related segments in this TMDL report

WBID	Waterbody Segment	Parameters Assessed Using the IWR	Criterion or Threshold
1345G	Homosassa–Trotter–Pumphouse Springs Group	Nutrients (Algal Mats)	Imbalance natural population of flora and fauna
1348A	Bluebird Springs	Nutrients (Algal Mats)	Imbalance natural population of flora and fauna
1348E	Hidden River Head Springs	Nutrients (Algal Mats)	Imbalance natural population of flora and fauna

2.3 Nutrient Enrichment

Nutrient overenrichment contributes to the impairment of many surface waters, including springs. The two major nutrient parameters 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. Historically, many spring systems have had sufficient naturally occurring phosphorus to trigger an imbalance. It is widely accepted that primary production in brackish spring-fed waterbodies is controlled by nutrients, sunlight, tidal flow, spring discharge, temperature, and 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 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 the Homosassa River may not be exclusively related to spring discharge, as the spring run also receives nutrients via stormwater and shallow ground water inflows from nearby sources. In addition, legacy nutrients found within the sediments can also diffuse from the sediments back into the water column.

2.4 Ecological Issues Related to Nutrients

2.4.1 Filamentous Algal Mats

The amount and type of aquatic vegetation are linked to water quality and clarity. SAV communities support wildlife species, stabilize sediments, prevent erosion, and remove contaminants from the water column and sediments (SWFWMD 2004). Evidence of an increasing trend in algal coverage, especially

Lyngbya sp. and Chaetomorpha sp., and algal smothering have been documented in Pumphouse Spring, Trotter Spring, and Homosassa Spring Run. *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.

Lyngbya may form tangles or mats, intermixed with other phytoplankton species. 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 to other areas, 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 earliest documentation of observed algal mats was recorded in an April 18, 1988 memo documenting a field inspection of the Homosassa River (Zarbock 1988). This work was conducted by Florida Land Design & Engineering, Inc. (FLD&E) to evaluate the water quality of the Homosassa River (FLD&E 1989). FLD&E had been contracted by the Citrus County Board of County Commissioners to conduct a water quality assessment of the river and identify areas that exhibited the most severe degradation.

The response of algae to nutrient enrichment in the Homosassa Group is not unique to this system. It is similar to the conditions documented in the nutrient TMDLs for the Suwannee and Santa Fe Rivers (Hallas and Magley 2008), Wekiva River and Rock Springs Run (Gao 2007), Wakulla River (Gilbert 2012), Silver Springs and River (Holland and Hicks 2012), and Rainbow Springs and River (Holland and Hicks 2013) and Kings Bay (Bridger, 2014). Unfortunately the overgrowth of algae in response to nutrient enrichment has also been documented in many other spring systems. Frazer *et al.* (2001; 2006) documented these conditions between 1998 and 2005 in Homosassa as well as two other spring-run river systems in the Springs Coast region: Weeki Wachee and Chassahowitzka (for which a TMDL is also being developed).

In comparison to the Weeki Wachee and Chassahowitzka Rivers, Frazer *et al.* (2006) and Camp *et al.* (2012; 2013) found that SAV in the Homosassa River was relatively sparse. Camp *et al.* (2012; 2013) reported only the existence of bare substrate and filamentous algae habitats in the Homosassa River, and Frazer reported that SAV was absent in 47% of the locations sampled from the Homosassa Main Spring through the Homosassa River in 2000. Frazer *et al.* (2006) stated, "At those stations where submersed aquatic vegetation did occur, filamentous macroalgae occurred most frequently and was the primary component of the overall vegetative biomass."

There are also many anecdotal accounts of nuisance algae in the attraction, including the need to routinely clean algae from the glass panels at the Homosassa Springs Park underwater observatory (B. Garvin, 2014, pers. comm.). **Figures 2.1** through **2.6** provide photographic documentation of the presence of algae through the years.

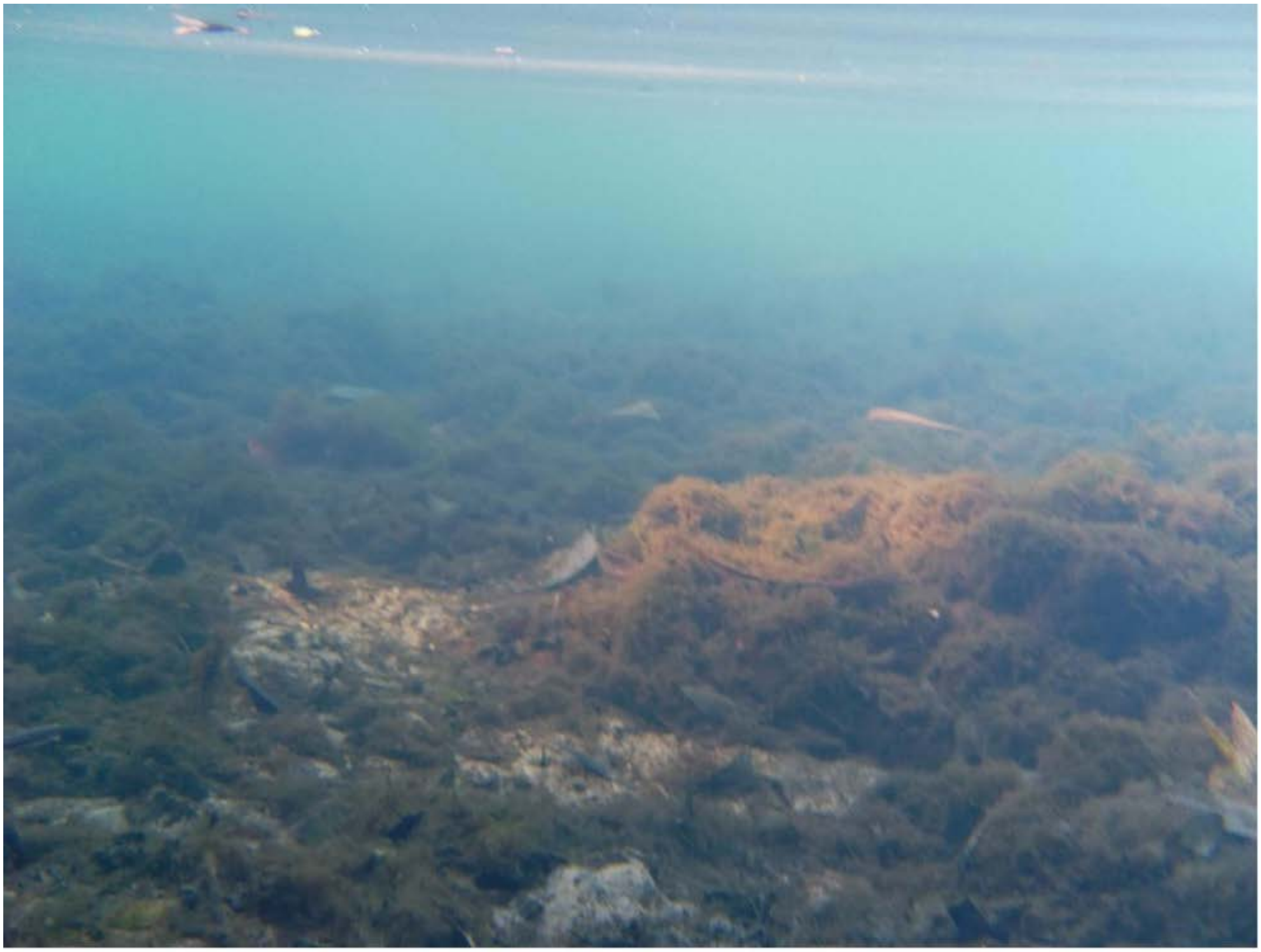


Figure 2.1. Underwater photo of Homosassa Springs Run algae and leaf litter, December 10, 2010 (photo by Chris Anastasiou, SWFWMD)

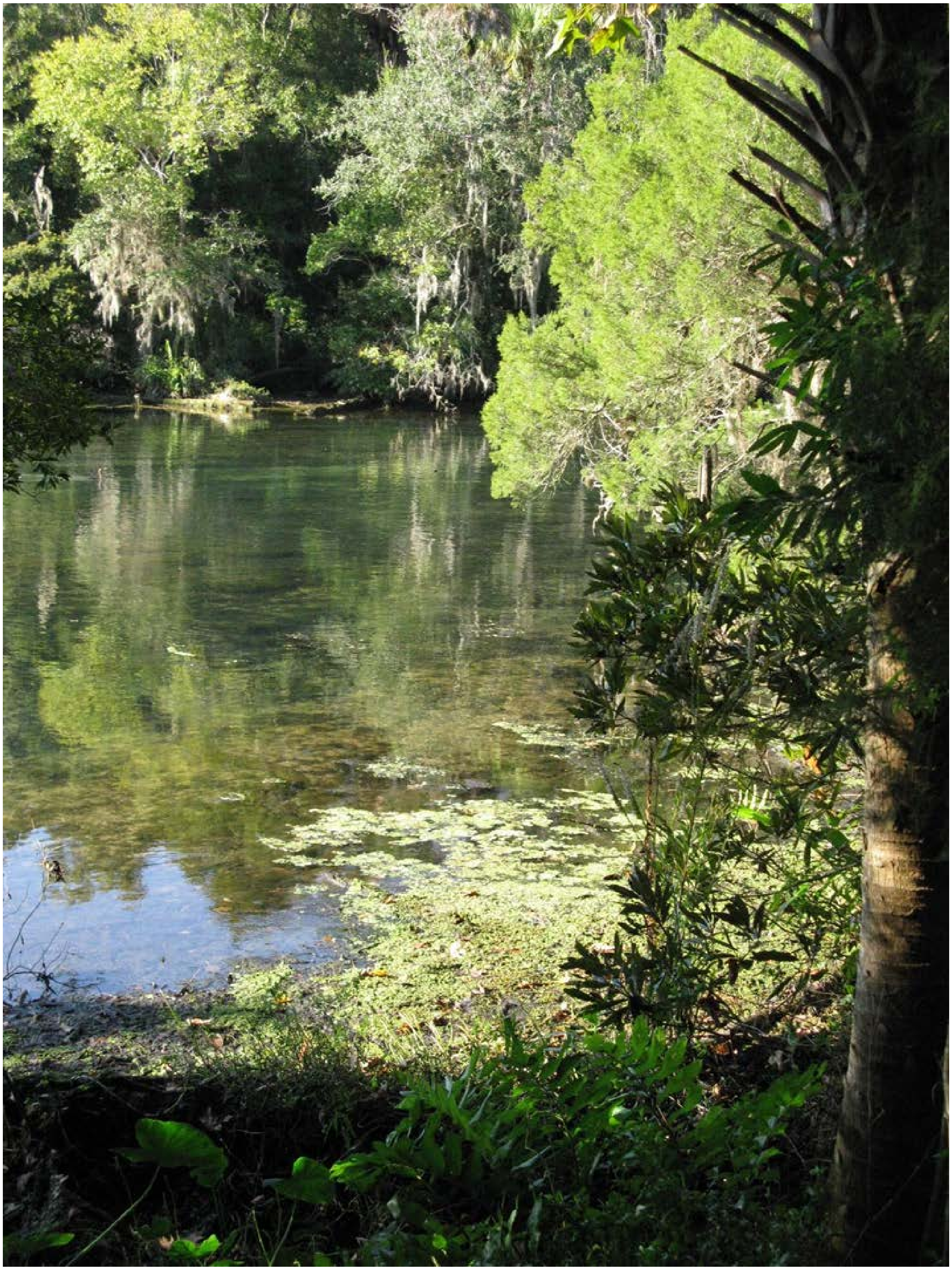


Figure 2.2. Homosassa Springs Run bottom covered with algae (photo by Laura Hester, Department)

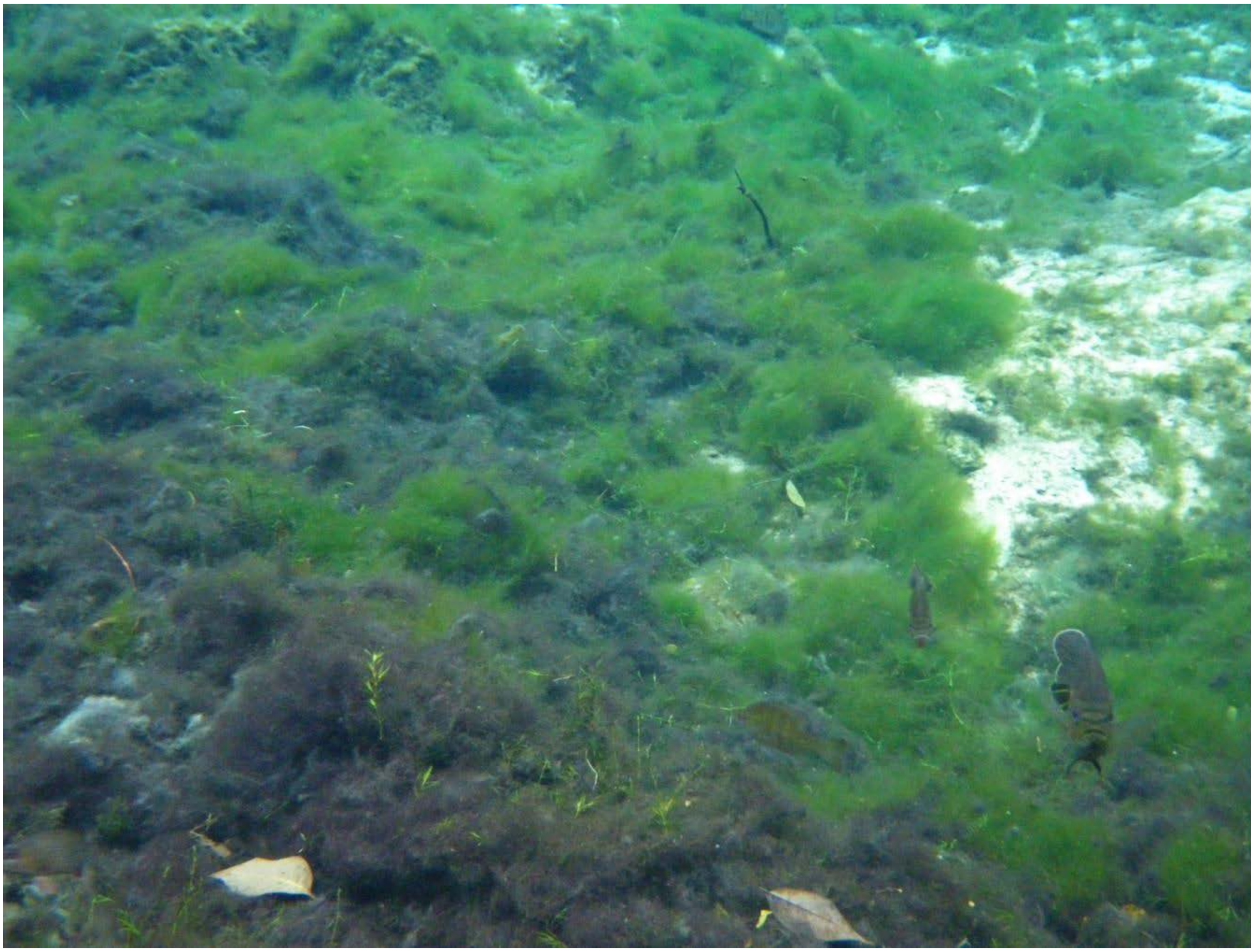


Figure 2.3. Trotter Spring Run algae coating bottom on December 10, 2010 (photo by Laura Hester, Department)

Figure 2.4. Algae Growth at Pumphouse Spring, December 10, 2010 (photo by Laura Hester, Department)

Figure 2.5. Algal growth at Bluebird Springs in 2010 (photo by Laura Hester, Department)

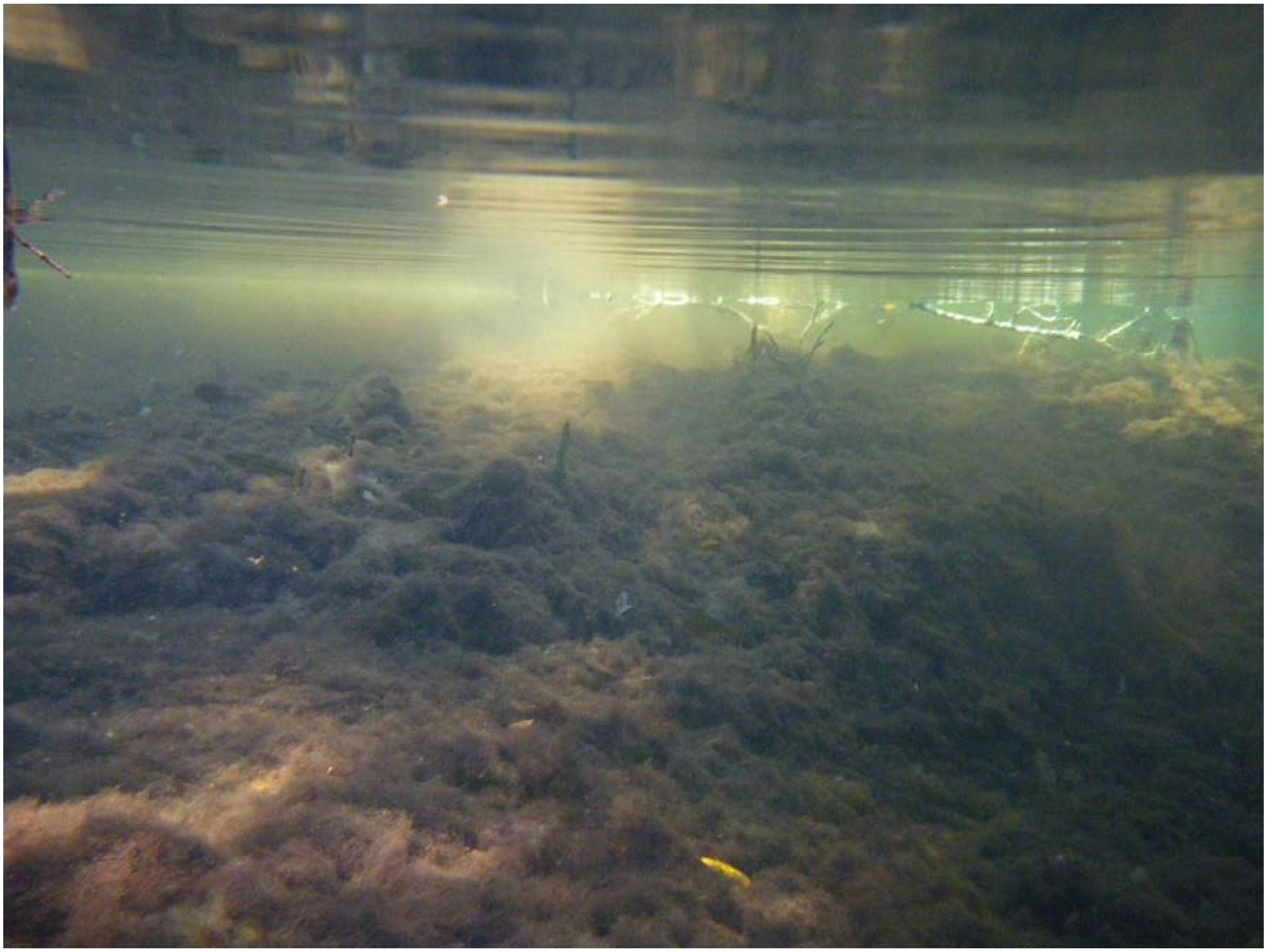


Figure 2.6. Underwater photo showing algae near the shoreline at Hidden River Springs on January 26, 2011 (photo by Laura Hester, Department)

2.4.2 Effects on Fishes and Macroinvertebrates

Camp *et al*. (2012; 2013) found that filamentous algae supported equal or greater densities of small-bodied fishes and macroinvertebrates than rooted monospecific stands of macrophytes. However, filamentous algae harbored smaller sized fish and a less diverse population of small-bodied fishes and macroinvertebrates (Camp *et al*. 2013). Also, based on capture-recapture data (Tetzlaff *et al*. 2010) found that for largemouth bass (*Micropterus salmoides*) populations, the weight-at-age and length-at-age were higher in the Chassahowitzka River, which is characterized by a patchy heterogeneous distribution of SAV, than in the Homosassa River, which is characterized by a current composition of SAV limited to primarily filamentous algae.

2.4.3 Other Ecological Issues

Nearly all of the natural land cover around the Homosassa Springs main spring and northern portion of the spring run has been extensively altered. The spring pool and adjacent areas underwent significant development with the construction of the historic tourist attraction, which includes buildings and weirs within the waterbody and the wildlife attraction.

Filamentous algal mats have the potential to trap sediments, causing the development and accumulation of muck sediments. Accumulated muck sediments and algal growth in the spring pool were removed from the Homosassa headsprings (around the underwater observatory) by a Department dredging project in 1992. Additional dredging of Homosassa Spring Run (also Blue Waters/Long River Bridge and Mitten Cove) occurred in 2006 through a cooperative project between the Department and the SWFWMD.

2.5 Monitoring Sites and Sampling

Historical water quality data for the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs are limited, but they do provide a glimpse of current versus “background” water quality. Water quality data have been collected from various locations around the springs and in the river. The Florida Storage and Retrieval (STORET), U.S. Geological Survey (USGS) National Water Information System (NWIS), and SWFWMD Water Management Information System (WMIS) databases contain many of these data.

The SWFWMD performed the majority of the water quality sampling. Many of the smaller springs are sampled annually every July, and the larger springs are sampled four times a year. Homosassa #1 Spring, Homosassa #2 Spring, Homosassa #3 Spring, Hidden River Main Spring, Hidden River #2 Spring, and Trotter Spring are typically sampled four times a year (January, April, July, and October). Bluebird Spring and Pumphouse Spring are sampled annually in July. This schedule is the part of the SWFWMD routine spring sampling. The Department performed supplementary water quality sampling.

Figure 2.7 shows the locations of the current and past routine water quality sampling stations and biological stations represented by data collected by or provided to the Department for the Homosassa–Trotter–Pumphouse Springs Group. **Figure 2.8** shows the locations of the current and past routine water quality sampling stations and biological stations represented by data collected by or provided to the Department for Bluebird Springs, and **Figure 2.9** shows the same for Hidden River Springs. To ensure that the nutrient TMDL was developed based on current conditions and that recent trends in the springs’ water quality were adequately captured, monitoring data were collected during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recent data (2012–13), and are the result of sampling done by the SWFWMD, USGS, LakeWatch, and Department. **Tables 2.6a** through **2.6h** summarize the monitoring results for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. The SWFWMD collected most of the water quality data for these waters (**Figure 2.10**).

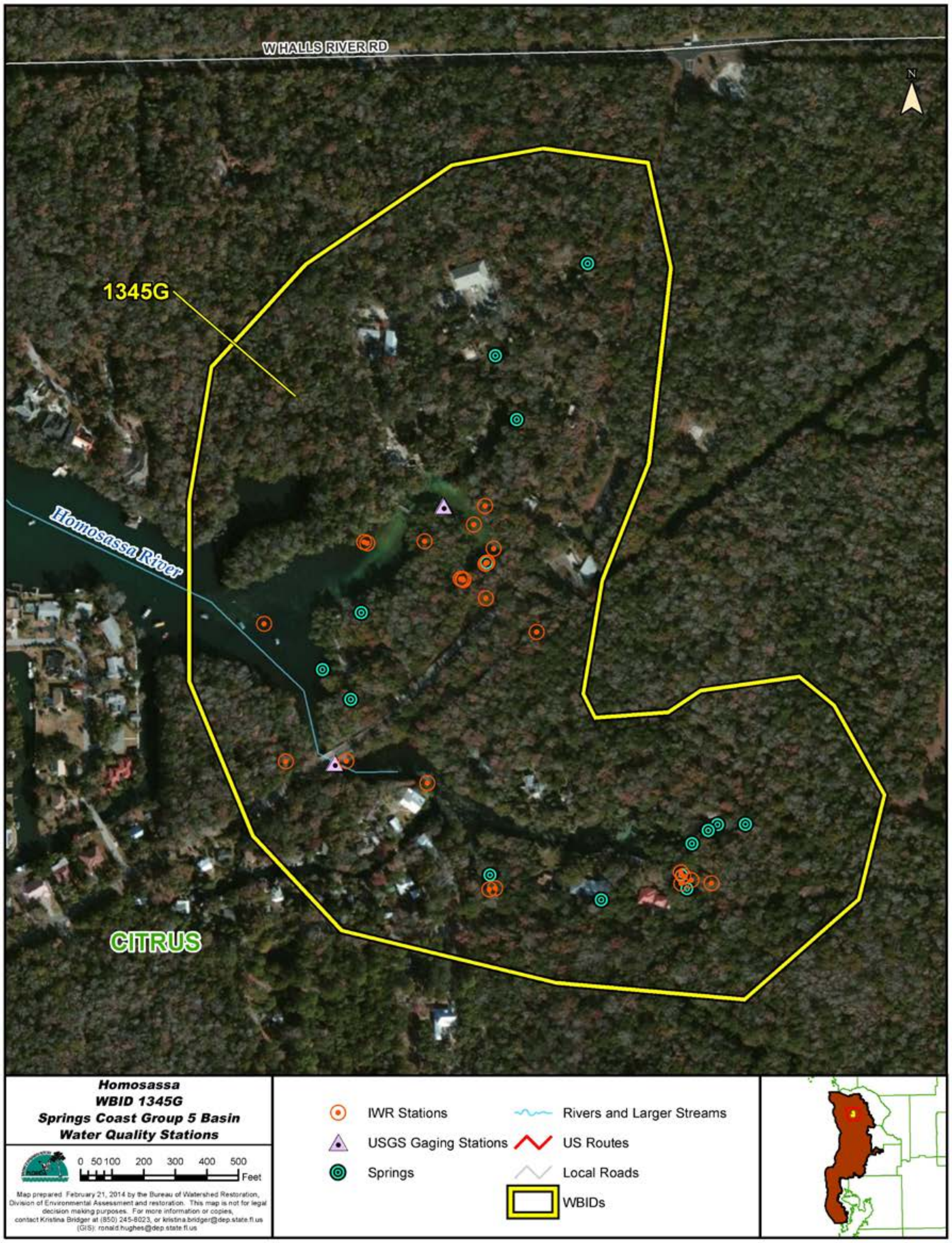


Figure 2.7. Surface water monitoring sites associated with impaired Homosassa–Trotter–Pumphouse Springs Group, WBID 1345G (based on Department dataset)

Figure 2.8. Surface water monitoring sites associated with impaired Bluebird Springs, WBID 1348A (based on Department dataset)

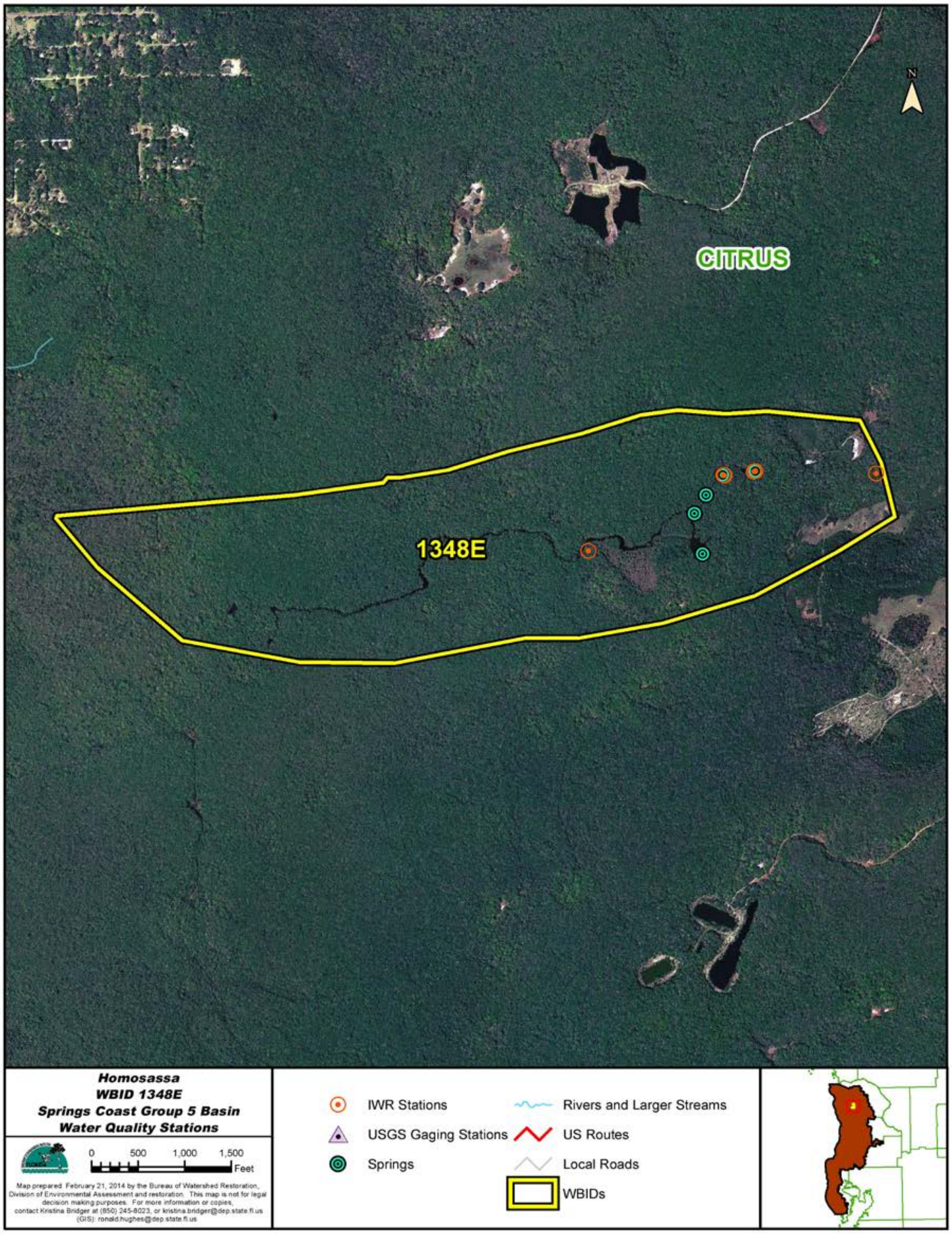


Figure 2.9. Surface water monitoring sites associated with impaired Hidden River Springs, WBID 1348E (based on Department dataset)

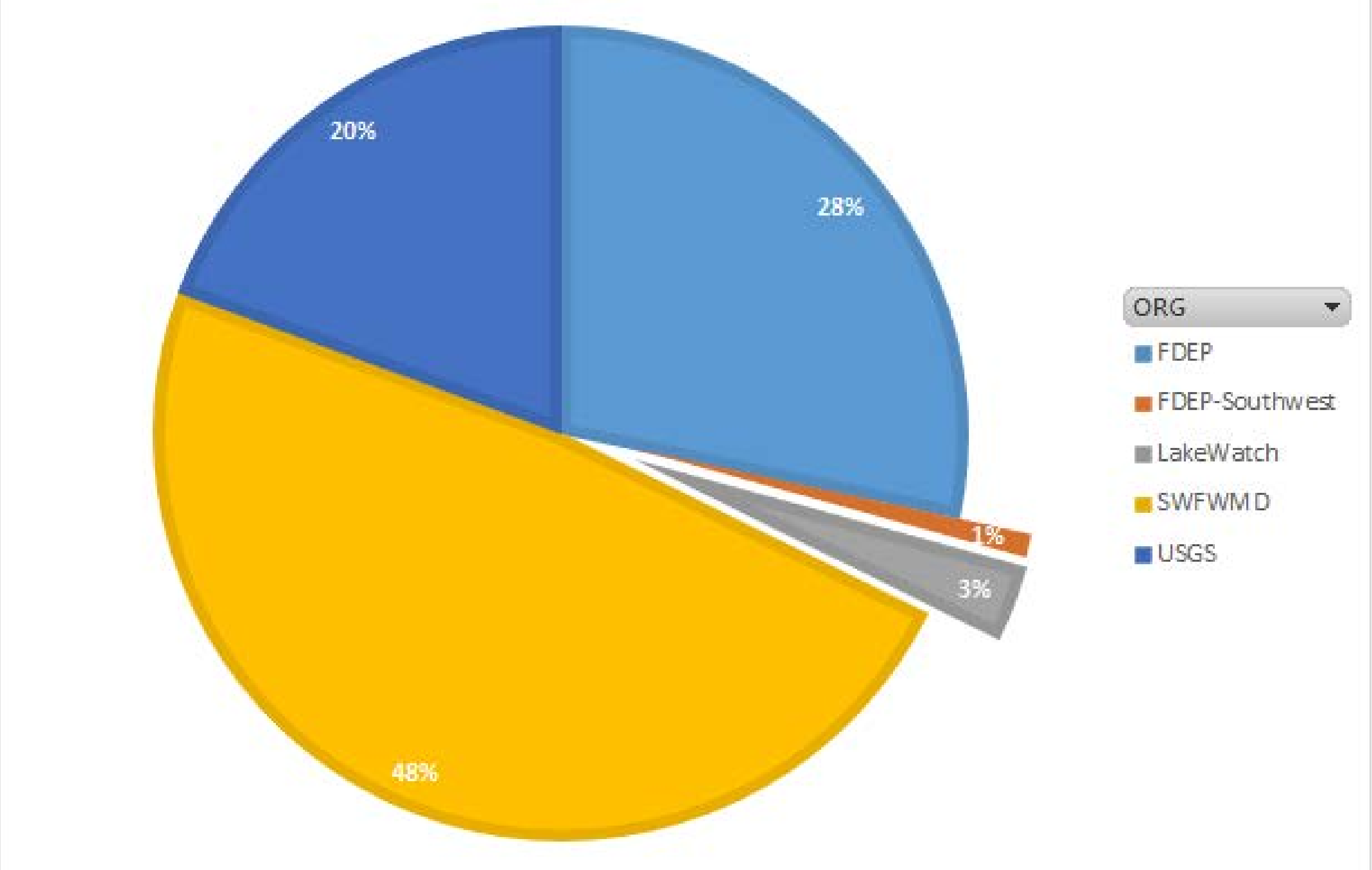


Figure 2.10. Water quality and biological data providers within the Homosassa River contributing area

2.6 Rainfall and Temperature Data

The climate in the Homosassa River area is humid subtropical, with hot, rainy summers and cool, generally dry winters. Recharge to ground water and flow in springs depend on rainfall. Rainfall and temperature data were reviewed for the 30-year period of record from Jan. 1983 to Dec. 2013 (SWFWMD 2014) (**Table 2.2**). Annual rainfall amounts average approximately 51.04 inches per year (in/yr), with an average air temperature of about 70.1° F. (National Oceanic and Atmospheric Administration [NOAA] 2013).

Figure 2.11 shows the 30-year historical rainfall trend for Citrus County. Over the 30-year period, the lowest annual rainfall of 37.36 inches occurred in 2000, and the highest annual rainfall of 64.27 inches occurred in 1988. The NOAA annual average rainfall from Jan. 1984 to Dec. 2013 is 51.04 inches.

Table 2.2. Citrus County temperature and precipitation, Jan 1984– Dec 2013 (SWFWMD 2014)

Analysis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
30-Year Mean– Maximum Temperature (°F.)	82.2	84.5	87.3	90.9	95.6	96.6	97.0	96.5	94.8	91.4	87.7	83.8	98.4
30-Year Mean– Minimum Temperature (°F.)	43.3	45.1	49.9	54.7	61.9	69.3	71.1	71.4	69.1	61.1	51.9	44.7	57.7
30-Year Mean– Average Temperature (°F.)	57.0	69.0	63.9	68.7	75.3	80.1	81.3	81.4	79.5	72.7	65.1	58.3	70.1
30-Year Mean– Precipitation (inches)	3.17	2.81	4.08	2.28	2.80	7.78	7.91	7.58	5.74	2.74	1.88	2.28	51.04

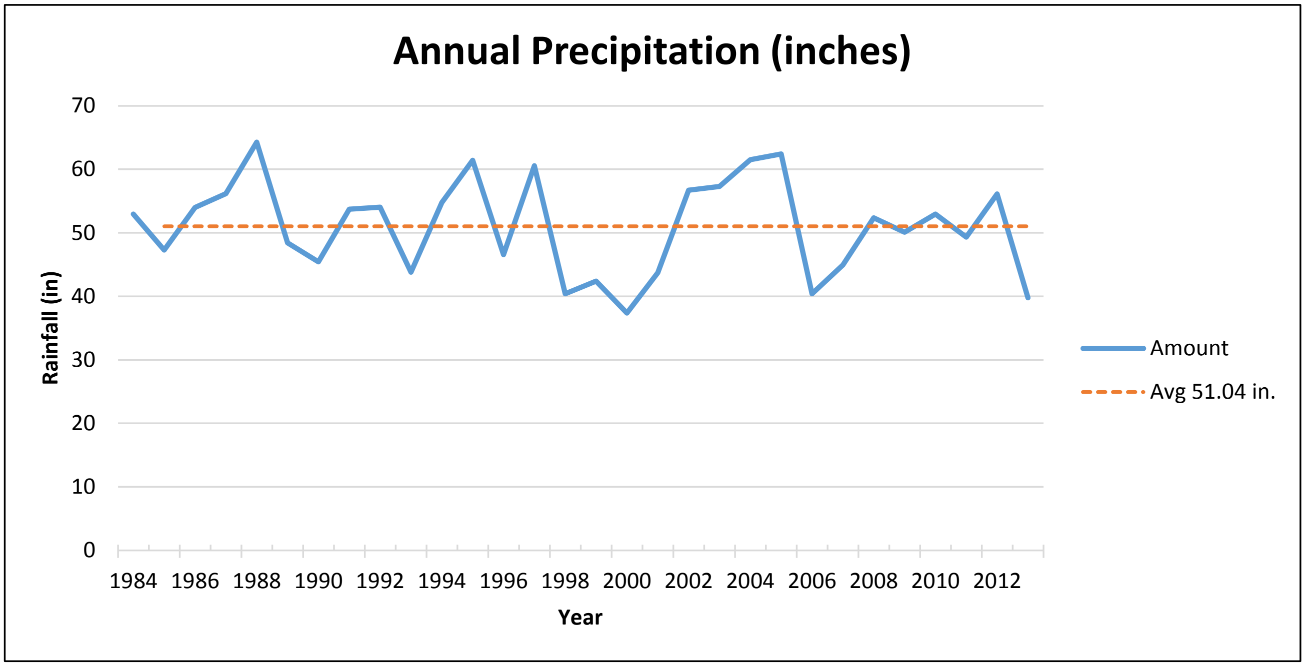


Figure 2.11. Precipitation for Citrus County, Jan 1984 – Dec 2013 (SWFWMD 2014)

2.7 Discharge Data and Residence Time

The USGS has collected flow measurements for Homosassa Springs (#02310678), SE Fork of Homosassa Spring (#02310688), and Hidden River (#02310675). The discharge measured at Homosassa Springs (#02310678) includes contributions from Homosassa Spring #1, #2, and #3 vents. **Figure 2.12** displays the daily mean discharge data, and **Table 2.3** shows the annual mean discharge data for Homosassa Springs from 1995 to June 2014. The discharge measured at SE Fork of Homosassa Spring (#02310688) includes contributions from Trotter Spring, Pumphouse Spring, and additional smaller springs. **Figure 2.13** displays the daily mean discharge data, and **Table 2.4** shows the annual mean discharge data for SE Fork Homosassa Spring from 2000 to June 2014. The discharge measured at Hidden River (#02310675) includes contributions from Hidden River Head Spring and Hidden River #2 Spring. **Figure 2.14** displays the daily mean discharge data, and **Table 2.5** shows the annual mean discharge data for Hidden River from 2003 to June 2014.

Tidal fluctuations have an effect on discharge. Spring discharge decreases during high tide and increases during low tide. Discharge from the springs in the Homosassa and Hidden Rivers tends to be lowest in late spring and early summer, likely as a result of the higher median and low tides during this period. Lower tides in the winter exert less hydraulic head pressure over the spring vents, thus allowing greater spring discharge relative to higher tide conditions. Changes in the ground water gradients in the contributing area also influence spring discharge. Precipitation events, ground water withdrawal, and sea-level rise also have an effect on the ground water gradients and spring discharge (SWFWMD, 2012). From 1920 to 2001 the estimated sea-level rise along the Florida Gulf Coast is approximately 6 – 9 inches (Douglas 1991; Zervas, 2001).

Compared to free-flowing freshwater spring runs (flushing rates on the order of hours), tidally influenced waterbodies such as the Homosassa River are typically characterized as low-flushing environments (flushing rates on the order of days). Residence time is the time needed to flush a pollutant, such as nitrogen or phosphorus, from a defined point within a waterbody. The effect of residence time on nutrients in the water (rate of flushing) should be taken into consideration when determining appropriate water quality targets for coastal spring-fed ecosystems with low-flushing environments such as the Homosassa River. 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.

The SWFWMD calculated the residence time for the Homosassa River. For the 1995 to 2009 benchmark period, median residence times for water in the river ranged from 6.2 to 8.9 days for the median and lowest daily discharge, respectively (SWFWMD 2012). Shallow water depths allow warming and greater sunlight penetration, resulting in higher plant growth potential (Livingston 2001).

In most coastal streams around the world, the combination of increased nutrients coupled with long residence time yields greater primary productivity, which in the Homosassa River is translated into increased filamentous algae and phytoplankton production.

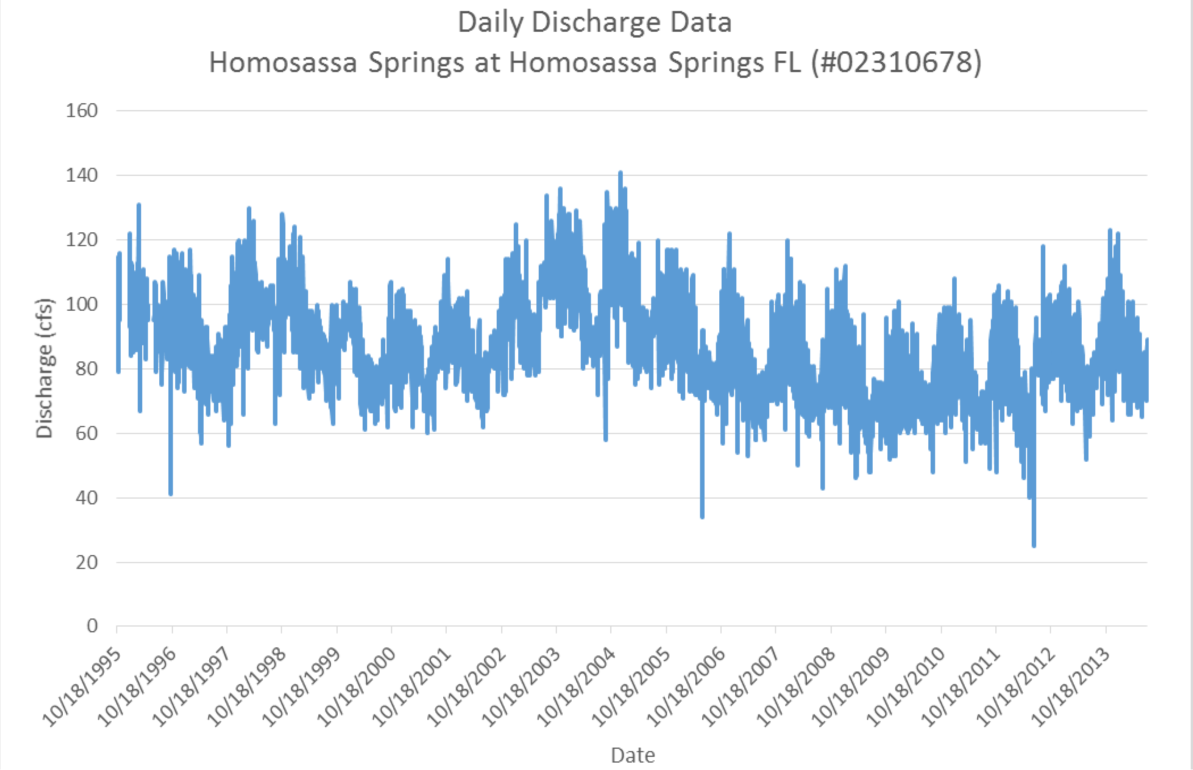


Figure 2.12. Daily mean discharge data for Homosassa Springs (#02310678), 1995–June 2014

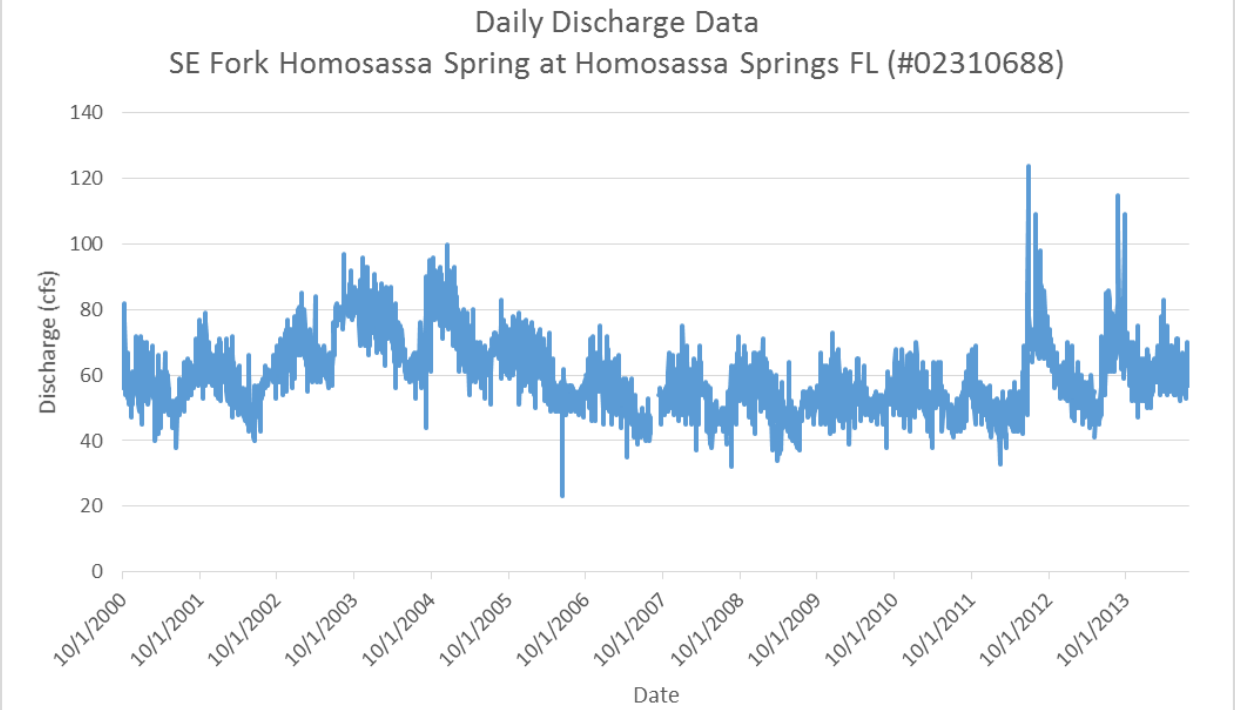


Figure 2.13. Daily mean discharge data for SE Fork Homosassa Springs (#02310688), 2000–June 2014

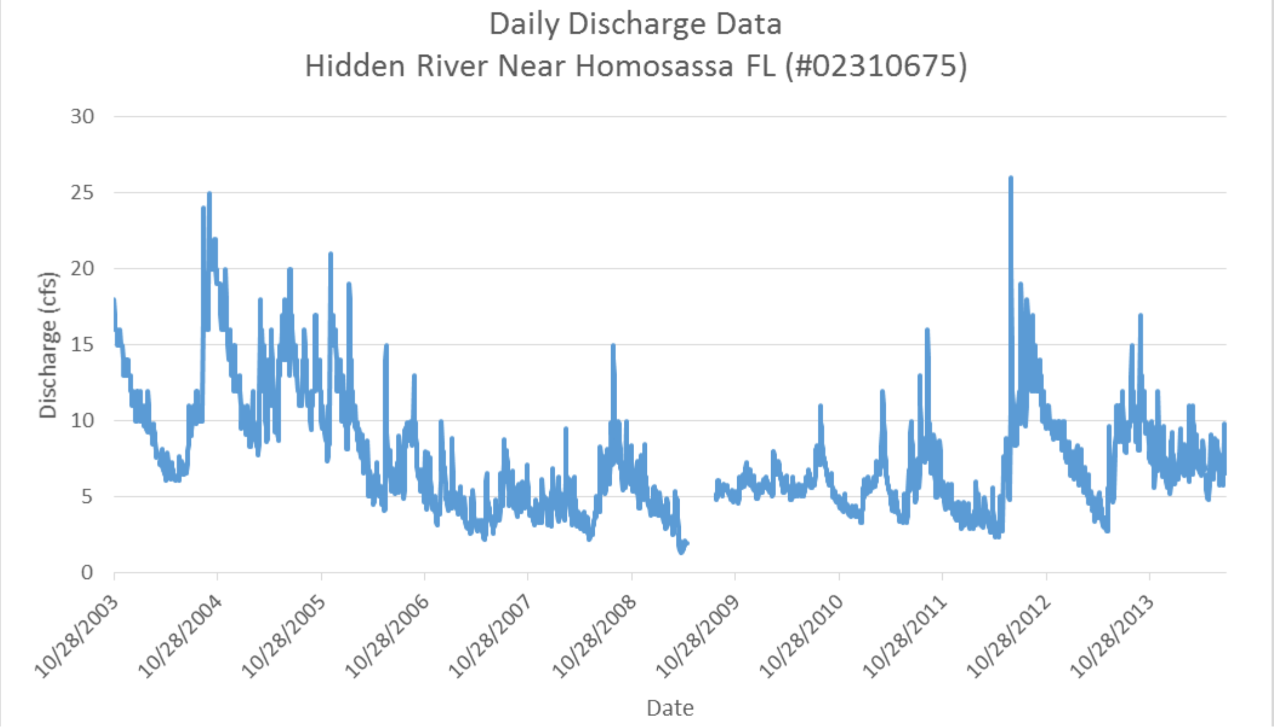


Figure 2.14. Daily mean discharge data for Hidden River (#02310675), 2003–June 2014

Table 2.3. Annual mean discharge for Homosassa Springs, 1995–June 2014

* Includes USGS provisional data.

Year	Adjusted Annual Mean Discharge (cfs)
1995	98.57
1996	96.30
1997	84.36
1998	101.54
1999	89.07
2000	82.43
2001	83.69
2002	85.75
2003	103.14
2004	103.32
2005	96.62
2006	85.09
2007	79.07
2008	80.11
2009	72.35
2010	75.47
2011	76.97
2012	79.25
2013	83.48
2014	83.96

Table 2.4. Annual mean discharge for SE Fork Homosassa Spring, 2000–June 2014

* Includes USGS provisional data.

Year	Adjusted Annual Mean Discharge (cfs)
2000	58.87
2001	58.02
2002	58.39
2003	73.79
2004	73.56
2005	68.37
2006	57.74
2007	52.10
2008	53.84
2009	51.32
2010	54.16
2011	52.66
2012	58.55
2013	60.45
2014	60.75*

Table 2.5. Annual mean discharge for Hidden River, 2003–June 2014

* Includes USGS provisional data.

Year	Adjusted Annual Mean Discharge(cfs)
2003	14.37
2004	11.62
2005	12.30
2006	7.45
2007	4.42
2008	5.48
2009	4.53
2010	5.71
2011	5.89
2012	7.89
2013	7.52
2014	7.24*

2.8 Monitoring Results

2.8.1 Nitrate

Nitrogen is found in several forms and is ubiquitous in the environment. Nitrate (NO_3) is the form of nitrogen that occurs in the highest concentrations in ground water and springs. The remaining nitrogen content (ammonium and nitrite) in spring discharge is low. 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 always insignificant. In this report nitrate is NO_3 as nitrogen (NO_3N) and, unless otherwise stated, the sum of NO_3 and NO_2 is used to represent NO_3 due to minimal contributions of NO2.

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). Historically, nitrogen was only a minor constituent of spring water, and typical nitrate concentrations in Florida were less than 0.2 mg/L until the early 1970s. Since then, elevated concentrations of nitrate have been found in many springs. The UFA's vulnerability to contamination can be observed in the increased nitrate concentrations at the springs and wells in the contributing area (Jones *et al.* 1997) as land use transitioned from natural land to urban development. Anthropogenic sources of nitrate in the contributing area include fertilizers (urban and agricultural) and waste (human and animal).

As in many Florida springs, nitrate levels in all of the monitored Homosassa River spring vents have trended upward during the period of analysis (2002–12), with an approximate increase of 0.010 mg/L nitrate + nitrite (measured as N) per year for the three Homosassa Main Spring vents. By the end of 2012, nitrate + nitrite values for these three vents were between 0.62 and 0.67 mg/L (**Figure 2.15**). Historical nitrate and nitrate + nitrite results collected from Homosassa Main Spring indicate that nitrate concentrations have been increasing for at least the past 66 years. In 1946, the nitrate concentration at Homosassa Main Spring was measured at 0.20 mg/L; in 1972 it was 0.26 mg/L; and by the 1980s the mean value of the three samples on record was 0.30 mg/L (no nitrate + nitrite samples were reported at this site during the periods from 1973 to 1984 and from 1989 to 2000).

The Spring Cove springs (Trotter Main and Pumphouse) and Bluebird Springs also showed increasing nitrate + nitrite trends, with values increasing about 0.017 mg/L per year for the years with water quality data available (**Figure 2.16**). These trends are very similar to those measured in the three Homosassa Main vents. In addition to similar trends, the nitrate + nitrite values from these spring vents are all similar, ranging from 0.54 to 0.74 mg/L at the end of 2012.

The Hidden River Head and Hidden River #2 Spring vents (**Figure 2.16**) also had increasing nitrate + nitrite trends during the period under analysis, and similarities in concentrations and trends also indicate a common ground water source area for these two springs. Nitrate + nitrite values for these springs were in the range of 0.86 to 0.92 mg/L at the end of 2012, the highest of any springs sampled within the Homosassa River area.

Tables 2.6a through **2.6h** summarize the monitoring results for selected analytes for each major spring. Nitrate is considered a target nutrient for the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs (WBIDs 1345G, 1348A, and 1348E). **Chapter 5** discusses the NO_3 nutrient impairment and the setting of the target concentration for NO_3.

2.8.2 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. The most common form of phosphorus in geologic material is orthophosphate, because phosphorus has an affinity to bind to the calcium found in the rock formation (Fitts 2013). Total phosphorus (TP) includes both orthophosphate and organic forms of phosphorus. Neither orthophosphate nor TP has shown an increasing temporal trend in these impaired waters, and concentrations remain close to those levels found in the early 1970s **(Figures 2.15** and **2.16)**. These levels most likely represent natural background conditions due to phosphate in the geologic material. Therefore, phosphorus was not considered a target nutrient for the TMDLs. In Florida, only the inorganic form of phosphorus, orthophosphate, is generally found at significant concentrations in ground water and springs. Orthophosphate present at elevated levels in spring discharge is typically due to nearby geologic sources that are naturally enriched in phosphorus (Upchurch and Lawrence 1984). The organic phosphorus content is normally low in spring water.

Orthophosphate is present in low concentrations in all Homosassa-area springs, with mean values ranging from 0.015 to 0.028 mg/L (**Tables 2.6a** through **2.6h**) during the period of study. This may be due to its attenuation by the Floridan aquifer, where orthophosphate reacts with the calcium carbonate of the limestone to produce low-solubility calcium phosphate minerals that remain within the host rock (Brown 1981). This precipitation process effectively removes orthophosphate from the waters within the aquifer and is the probable geochemical mechanism by which "hard rock" phosphate deposits have developed in the state.

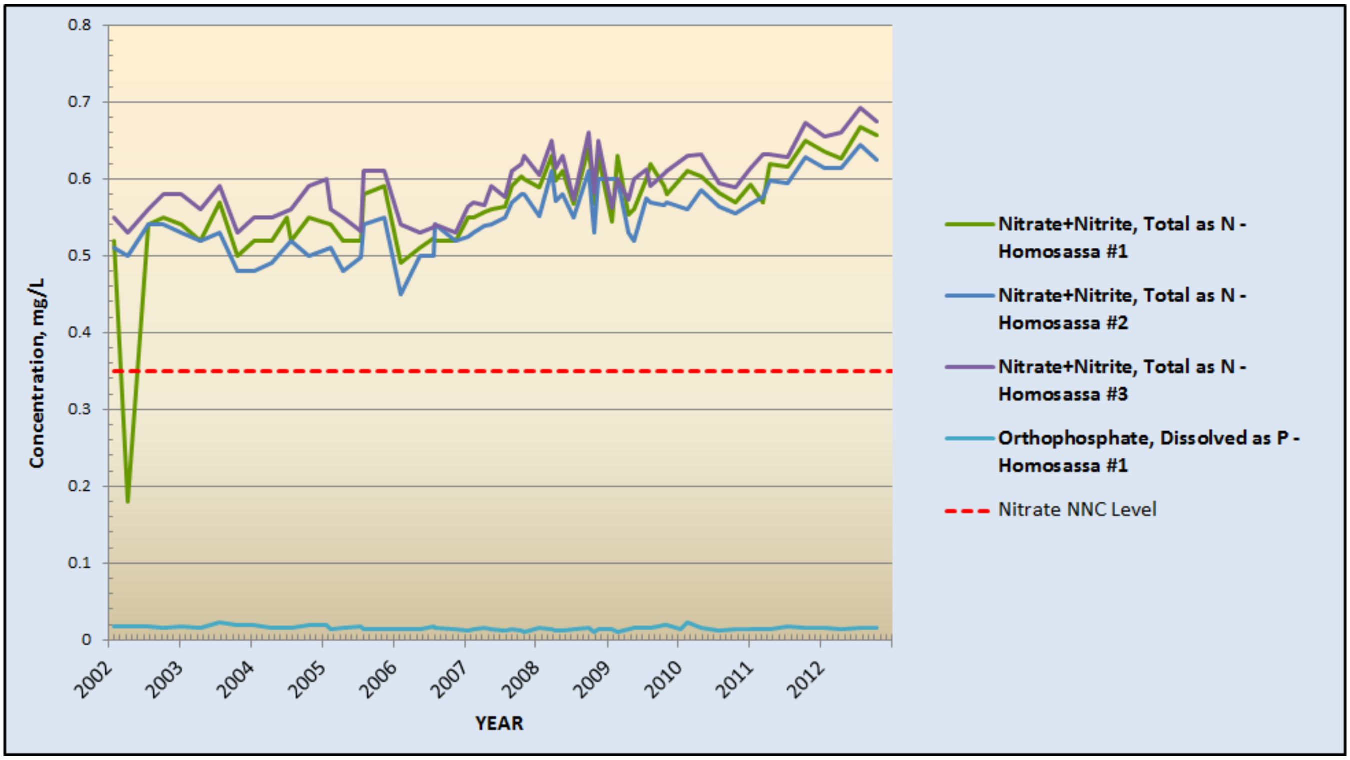


Figure 2.15. Nitrate and orthophosphate trends in Homosassa Main #1, #2, and #3 Springs, 2002–12

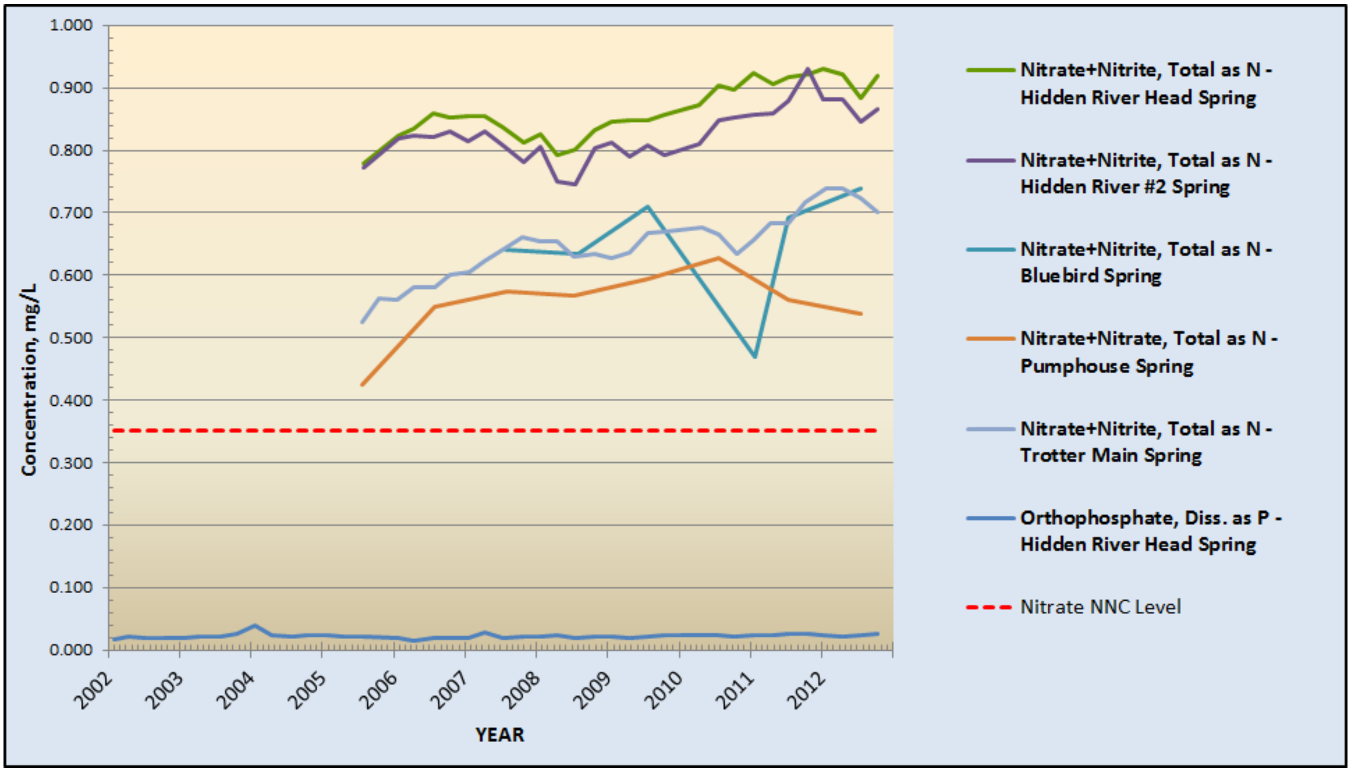


Figure 2.16. Nitrate and orthophosphate trends in Hidden River Springs, Bluebird Springs, Trotter Main Spring, and Pumphouse Spring, 2002–12

Table 2.6a. Summary of selected water quality results for Homosassa Main #1 Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2002–12	mg/L	60	0.600	0.569	0.647	0.646
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	63	0.015	0.015	0.015	0.016

Table 2.6b. Summary of selected water quality results for Homosassa Main #2 Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2002–12	mg/L	58	0.550	0.550	0.625	0.620
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	62	0.015	0.015	0.017	0.018

Table 2.6c. Summary of selected water quality results for Homosassa Main #3 Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2002–12	mg/L	60	0.594	0.590	0.671	0.668
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	63	0.015	0.014	0.015	0.016

Table 2.6d. Summary of selected water quality results for Pumphouse Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2002–12	mg/L	8	0.555	0.564	N/A	N/A
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	13	0.018	0.018	N/A	N/A

Table 2.6e. Summary of selected water quality results for Trotter Main Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2005–12	mg/L	29	0.646	0.053	0.726	0.731
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	44	0.020	0.020	0.021	0.021

Table 2.6f. Summary of selected water quality results for Bluebird Springs

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2007–12	mg/L	6	0.600	0.666	N/A	N/A
Macronutrients	Orthophosphate, Diss (as P)	2007–12	mg/L	6	0.022	0.021	N/A	N/A

Table 2.6g. Summary of selected water quality results for Hidden River Head Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2005–12	mg/L	28	0.900	0.855	0.914	0.921
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	43	0.022	0.022	0.024	0.024

Table 2.6h. Summary of selected water quality results for Hidden River #2 Spring

Data from the Department and SWFWMD (STORET, WMIS)

Indicator Type	Analyte	Period of Record	Units	Number of Samples	Period of Record Mean	Period of Record Median	2012 Mean (last 4 quarters)	2012 Median (last 4 quarters)
Macronutrients	Nitrate+Nitrite, Total (as N)	2005–12	mg/L	28	0.800	0.821	0.869	0.874
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	43	0.025	0.024	0.026	0.026

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criterion 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)**

The impaired waters listed in this report are Class III marine waterbodies (with designated uses of recreation, propagation, and 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 have been demonstrated to adversely affect flora or fauna.

3.2 Applicable Water Quality Standards and Numeric Water Quality Targets

3.2.1 Nutrients

The narrative nutrient water quality criterion for the protection of Class III waters, as established by Subsection 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.

For the impaired waters addressed in this TMDL report, benthic macroalgae mats and epiphytic algae growing on macrophytes were shown to be a significant problem. Algal growth causes a variety of ecological impairments, including, but not limited to, the smothering of habitat, 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 stream. Macroalgal mats can produce human health problems, foul beaches, inhibit navigation, and reduce the aesthetic value of clear springs or spring runs.

Research on Florida springs, including Homosassa, has provided evidence that algal growth responds to the introduction of phosphorus and nitrate in spring water (Stevenson *et al.* 2007). In the Homosassa–Trotter–Pumphouse Springs Group as well as Bluebird Springs and Hidden River Springs, elevated nitrogen is the nutrient of concern because phosphorus is at natural background. As nitrate is the dominant form of nitrogen in these systems based on concentration, the nutrient linked to the excessive algal growth in WBIDs 1345G, 1348A, and 1348E is nitrate nitrogen.

Chapter 5 discusses the nitrate impairment and the setting of the TMDL target concentration of nitrate. These TMDL target concentrations for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs will be submitted to the EPA for approval as site-specific (Hierarchy 1) interpretations of the narrative nutrient criterion for these waterbodies as stated in Rule 62-302.531, F.A.C.

3.2.2 Outstanding Florida Water Designation

The Outstanding Florida Water (OFW) criterion in Rule 62-302.700, F.A.C., allows no degradation in water quality for special waters, which include the Homosassa riverine system. Homosassa Springs State Wildlife Park was designated as an OFW in 1990, meaning that it is worthy of special protection because of its natural attributes. The Homosassa River system—including Halls River; Turtle, Otter, Battle, and Price Creeks; and other tributaries to the Homosassa River but excluding artificial waterbodies—was designated as an OFW on January 5, 1993.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Population and Land Use in the Contributing Area for Impaired Springs

4.1.1 Population

In 1840 a military expedition started the first modern settlement in the vicinity of the Homosassa River. In 1851 David Yulee developed a plantation on Tiger Tail Island near the Homosassa River. The plantation grew citrus and sugar cane. Remains of the sugar mill can be visited at the Yulee Sugar Mill ruins near the community of Homosassa (also known as "Old Homosassa").

Today, the total population of Citrus County is 139,271, according to the U.S. Census Bureau's 2013 Census. **Figure 4.1** shows population growth in Citrus County from 1960 to 2013. There are 59,491 households (HH) and 77,904 housing units (HU) in Citrus County and 84,196 HU in Hernando County. Citrus County contains 242 people per square mile of land and 106 HU per square mile, while Hernando County contains 106 people per square mile of land and 51 HU per square mile. A little over 19% of the contributing area for Homosassa Spring is in residential land uses, and the most populated areas are in Citrus County close to the spring, mainly lying between U.S. Highways 19 and 41 (**Figure 4.2**).

The largest incorporated area in Citrus County is Inverness, which was incorporated in 1917. The original subdivision within Inverness, Inverness Heights, was platted in 1958 by Mr. Norvell Cullen Bryant. In 1924, Mr. Bruce Hoover founded the Homosassa Development Company. The company purchased the land around the springs and surrounding acreage, which later became the community of Homosassa Springs. This was the early beginnings of significant residential growth around the tourist attraction known as "Nature's Fishbowl" and what is now Ellie Schiller Homosassa Springs State Park.

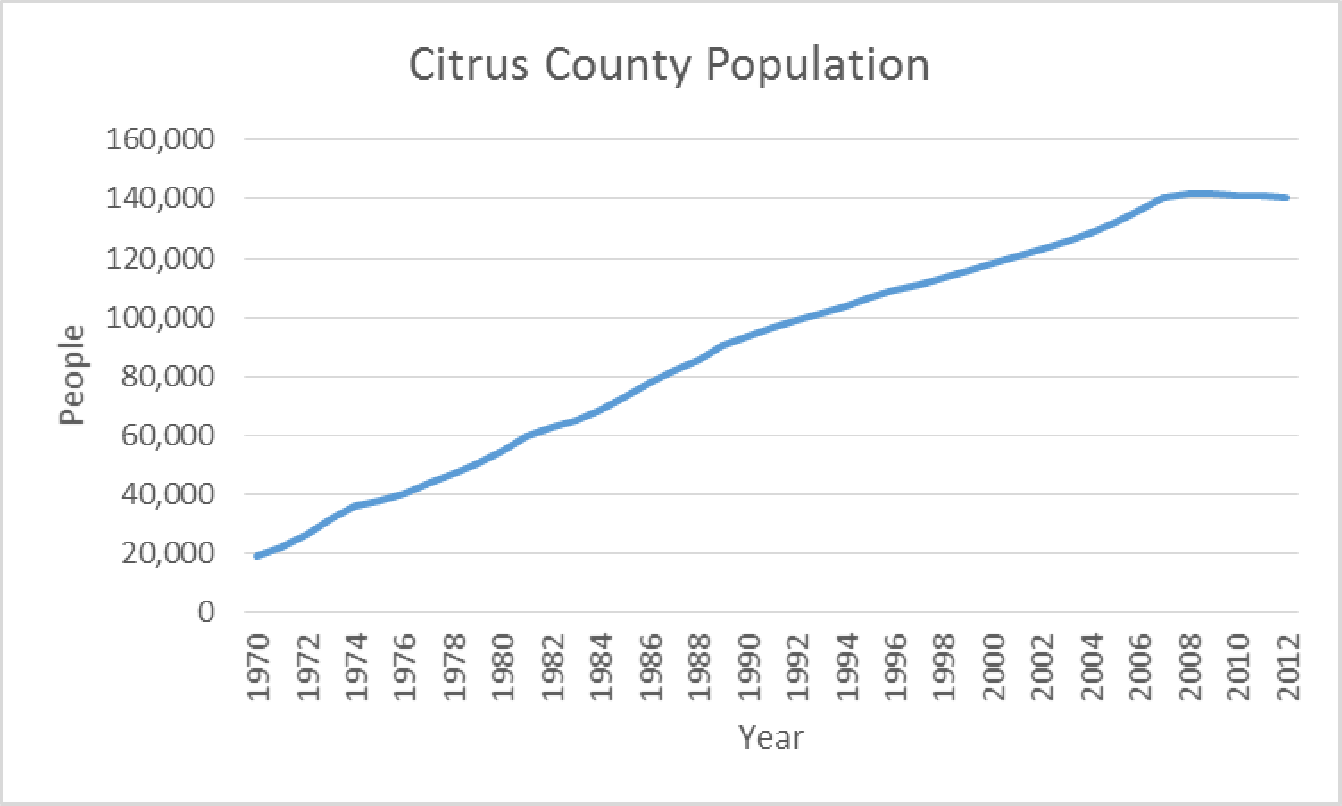


Figure 4.1. Citrus County population growth, 1970–2012 (University of Florida Bureau of Economic and Business Research 2014)

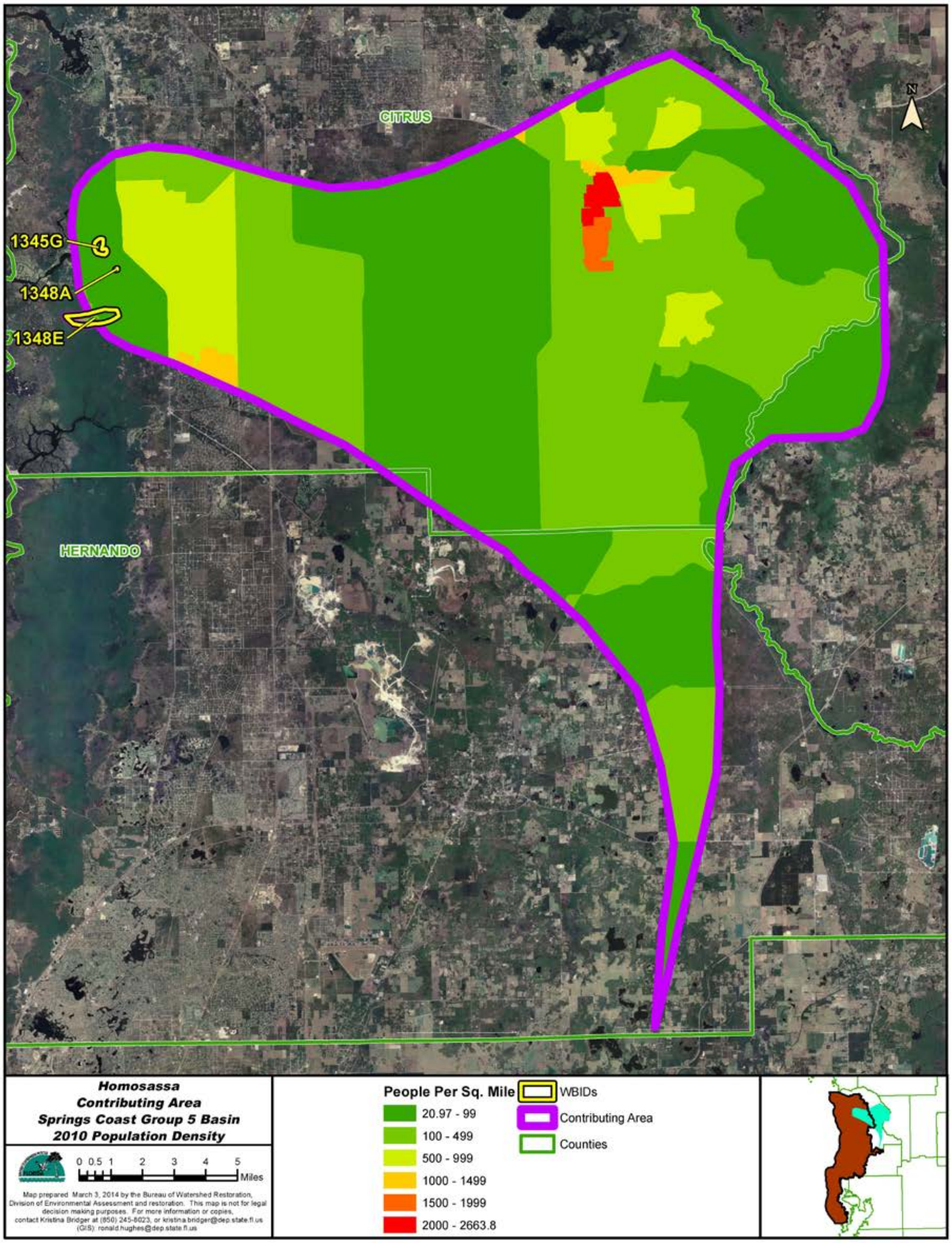


Figure 4.2. **Population density for the spring contributing area in Citrus, Hernando and Sumter Counties (based on 2011 Census data)**

4.1.2 Land Uses

Land use information for the Homosassa Springs Group's contributing area was obtained from the 2011 SWFWMD land use Geographic Information System (GIS) coverage, which is the most recent land use data available. **Table 4.2** and **Figure 4.3** show the breakdown of the various land use and land cover categories from the GIS data. In 2011, forest, urban land uses, and wetland areas covered most of the contributing area, covering 42%, 24%, and 18%, respectively. Agricultural areas were fourth, covering 13% of the contributing area for the Homosassa Springs Group. A significant forested area in the springs' contributing area is the nearly 50,000-acre Citrus Wildlife Management Area, managed by the Florida Fish and Wildlife Conservation Commission and located just west of Inverness.

Urbanized areas increased from 56 square miles (mi^2) in 1988 to 70 mi^2 in 2011. Conversely, agricultural areas decreased from 48 mi^2 in 1988 to 38 mi^2 in 2011. In this same period, forest/rural open areas also decreased from 126 mi^2 to 116 mi^2 in 1988 and 2009, respectively. In 2011, replanting efforts increased forested areas from 116 mi^2 in 2009 to 121 mi^2 in 2011. **Table 4.1** shows the land use categories for the Homosassa Springs contributing area by decade. Anthropogenic sources of nitrate in the contributing area include fertilizers (urban and agricultural) and waste (human and animal). In addition, a legacy nitrate load may exist in the soil and aquifer as a result of past agricultural activities.

Table 4.1. Classification of land use categories for the spring contributing area by decade

Land Use	Code	1988 (mi^2)	2009 (mi^2)	2011 (mi^2)
Urban and Built-Up	1000	56	69	70
Agriculture	2000	48	44	38
Forest/Rural Open	4000	126	116	121
Wetlands	6000	51	51	51

Table 4.2. Percentages of major land uses in the spring contributing area in 2011

- = Empty cell/no data

Code	Land Use	Square Miles	Acreage	% of Contributing Area
1100	Low-Density Residential	45	28,643	15.57%
1200	Medium-Density Residential	13	8,099	4.5%
1300	High-Density Residential	2	1,074	0.69%
1400	Commercial	2	1,493	0.69%
1500	Light Industrial	0	192	0%
1600	Extractive/Quarries/Mines	1	801	0.35%
1700	Institutional	1	848	0.35%
1800	Recreational (Golf Courses, Parks, Marinas, etc.)	1	670	0.35%
1900	Open Land	5	2,937	1.73%
2000	Agriculture	38	24,412	13.15%
3000	Rangeland	2	664	0.7%
4000	Forest/Rural Open	121	77,661	41.86%
5000	Water	5	3,441	1.73%
6000	Wetlands	51	32,517	17.65%
8000	Communication and Transportation	3	1,221	0.7%
-	**Total**	**289**	**185,200**	**100%**

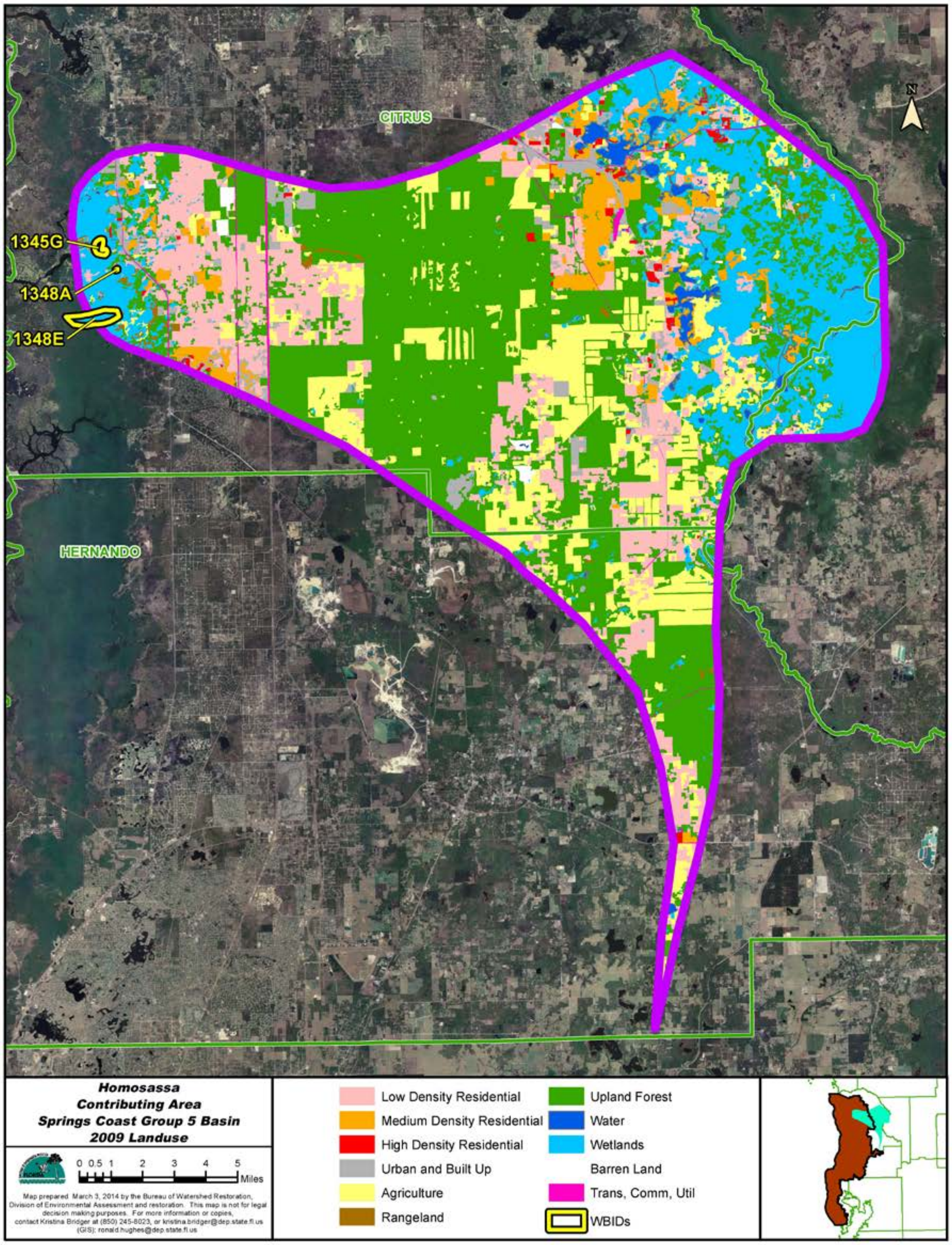


Figure 4.3. Land uses in the spring contributing area in 2011

4.2 Pollutant Source Categories

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of nutrients in the watershed and the magnitude of pollutant loading contributed by each of these sources. 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) that discharge directly to surface waters and are covered by a National Pollutant Discharge Elimination System (NPDES) permit are examples of traditional point sources. In contrast, the term "nonpoint sources" refers to intermittent, rainfall-driven, diffuse sources of pollution associated with everyday human activities and those sources that do not directly discharge to an impaired surface water, including runoff from urban land uses, wastewater treatment sites, stormwater drainage wells, agriculture, silviculture, mining, discharges from onsite treatment and disposal systems (OSTDS, or septic systems), and atmospheric deposition. All pollutant sources that discharge to ground water, including wastewater application sites, are also classified as nonpoint sources.

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 NPDES Program. These nonpoint sources include certain urban stormwater discharges to surface water, such as those from local government master drainage systems, construction sites with land disturbance over one acre, and a wide variety of industries (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 methodologies used to estimate nonpoint source loads do 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.

4.3 Potential Sources of Nitrate in the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs Contributing Area

While nitrate occurs naturally in the environment through nitrogen fixation, bacterial processes, and lightning, the elevated and increasing levels of nitrate in the springs from may come from a variety of anthropogenic sources. These may include permitted domestic wastewater treatment sites; OSTDS; fertilizer applied to residential landscaping and lawns, golf courses, and agricultural operations; pet and livestock waste; and atmospheric deposition. While not a nitrate source *per se*, stormwater runoff is an important pathway for nitrate to reach an impaired waterbody.

4.3.1 Point Sources

Domestic Wastewater

Domestic wastewater application sites can produce a significant load of nitrogen in spring areas. **Figure 4.4** shows the locations of the 26 domestic wastewater treatment facilities and one septage application site in the contributing area if the impaired springs. **Table 4.3** lists the facilities and their permit numbers. None of the domestic WWTFs have NPDES-permitted discharges to surface water; thus by definition they are not considered point sources of pollution. Rather, they are included in the nonpoint source contribution discussion in a subsequent chapter.

These domestic WWTFs discharge treated effluent to ground water via spray irrigation, rapid infiltration basins (RIBs), drainfields, and percolation ponds, and in some cases treated effluent is reused as irrigation water on golf courses and public areas. There is only one large WWTF located in the springs contributing area. **Table 4.3** provides summary information for the larger domestic facilities in the springs contributing area that have permitted discharges of 0.1 million gallons per day (MGD) or greater. The contributing area also includes an FDOH-permitted land application site that receives septage. Summary information for this site is also provided in **Table 4.3.**

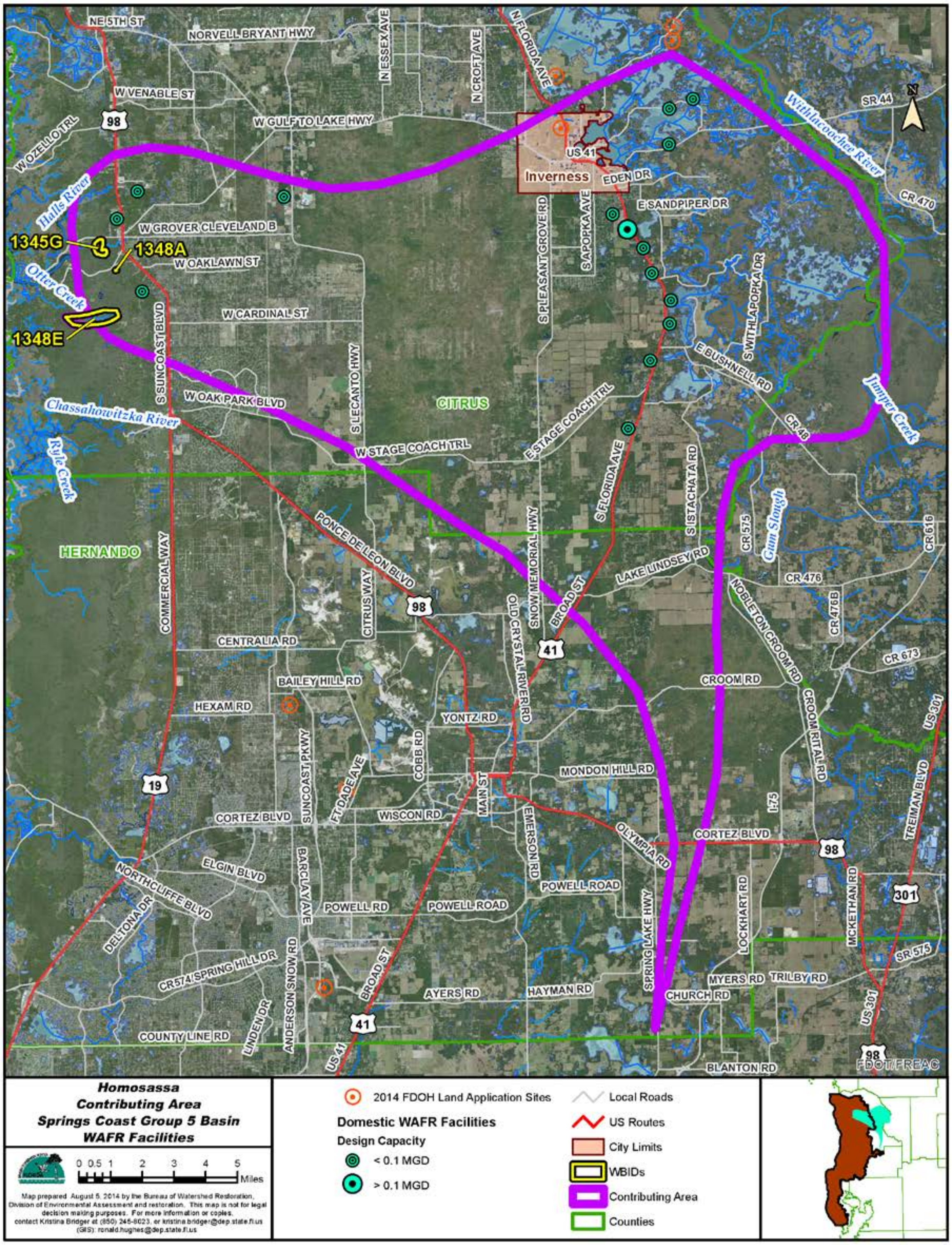


Figure 4.4. Domestic wastewater facilities in the spring contributing area

Table 4.3. Domestic wastewater facilities and RMFs in the spring contributing area

N/A = Not applicable

WAFR ID Number	Facility ID Number	Facility Name	Facility Type	NPDES	Design Capacity (MGD)	County
11847	FLA011847	Inverness, City of - WWTF	Domestic Wastewater Program	No	1.5000	Citrus
11901	FLA011901	Bell Villa MHP	Domestic Wastewater Program	No	0.0125	Citrus
11883	FLA011883	Stonebrook MHP WWTF	Domestic Wastewater Program	No	0.0351	Citrus
11907	FLA011907	Evanridge MHP	Domestic Wastewater Program	No	0.0200	Citrus
11902	FLA011902	Palm Terrace Village WWTF	Domestic Wastewater Program	No	0.0200	Citrus
11900	FLA011900	Royal Oaks Manor	Domestic Wastewater Program	No	0.0710	Citrus
11927	FLA011927	Tarawood Adult Community	Domestic Wastewater Program	No	0.0200	Citrus
11904	FLA011904	Oasis MHP WWTF	Domestic Wastewater Program	No	0.0075	Citrus
11853	FLA011853	Aunt Vera's Antique Store	Domestic Wastewater Program	No	0.0150	Citrus
11884	FLA011884	Floral Oaks Apartments WWTF	Domestic Wastewater Program	No	0.0100	Citrus
11880	FLA011880	Stoneridge Landing	Domestic Wastewater Program	No	0.0300	Citrus
11839	FLA011839	Floral City Elementary School WWTF	Domestic Wastewater Program	No	0.0060	Citrus
11879	FLA011879	Oak Pond Mobile Home Estates	Domestic Wastewater Program	No	0.0100	Citrus
11898	FLA011898	Harbor Lights Mobil Home Resort WWTF	Domestic Wastewater Program	No	0.0100	Citrus
11891	FLA011891	Singing Forest WWTF	Domestic Wastewater Program	No	0.0250	Citrus
11864	FLA011864	Moonrise Resort	Domestic Wastewater Program	No	0.0130	Citrus
11893	FLA011893	Point O Woods	Domestic Wastewater Program	No	0.0580	Citrus
N/A	09-QL-00140	Chet's Septic	Commercial Residual Septic Application	No	2,500 gallons per year	Citrus

Municipal Separate Storm Sewer Systems

A municipal separate storm sewer system (MS4) under the federal NPDES Program is a publicly owned conveyance or system of conveyances (*i.e.*, ditches, curbs, catch basins, underground pipes, etc.) that is designed or used for collecting or conveying stormwater and that discharges directly to surface waters of the state. Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs are located within the service area of a local government currently holding an MS4 permit. MS4 entities may discharge nutrients to waterbodies in response to storm events. The NPDES stormwater collection systems in the Homosassa Springs contributing area are maintained by Citrus County (Co-permittee: FLR04E141), city of Inverness (Co-permittee: FLR04E144), Hernando County (FLR04E040), and FDOT District 7 (FLR04E017 – Hernando) and (FLR04E142 - Citrus) (see **Figure 4.5**). Wasteload allocations (WLAs) may be assigned to MS4 entities if their discharges affect impaired surface waters. Wasteload allocations (WLAs) may be assigned to MS4 entities if their discharges affect impaired surface waters. The potential involvement of MS4 entities in this area may not be limited to the typical discharges of urban stormwater to surface water

Wildlife Park Water Quality Assessment

Ellie Schiller Homosassa Springs Wildlife State Park straddles a small spring-fed run, which flows south through the Black Bear, Water Fowl, Otter, Alligator, and Hippopotamus habitats before discharging into the Homosassa River about 100 yards (96 meters) below the Homosassa Main Spring vents (**Figure 4.6**). At the same time that the TMDL is being developed, the Department is performing a water quality assessment to develop a better understanding of the potential influence of the wildlife park on water quality in the Homosassa River (Maddox and Wade 2014). The results of the assessment will be further examined during the BMAP development process.

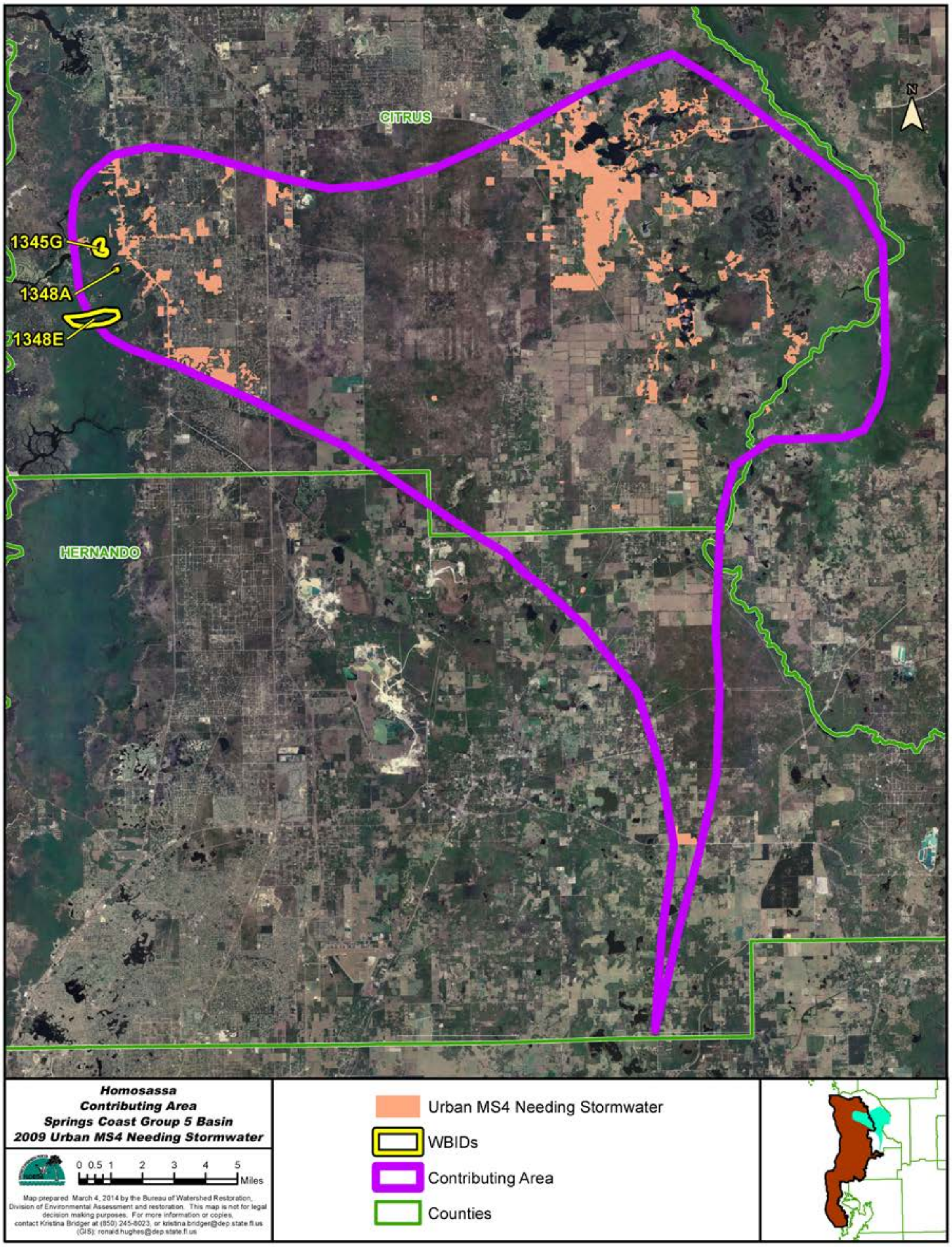


Figure 4.5. MS4 permit boundaries in the contributing area

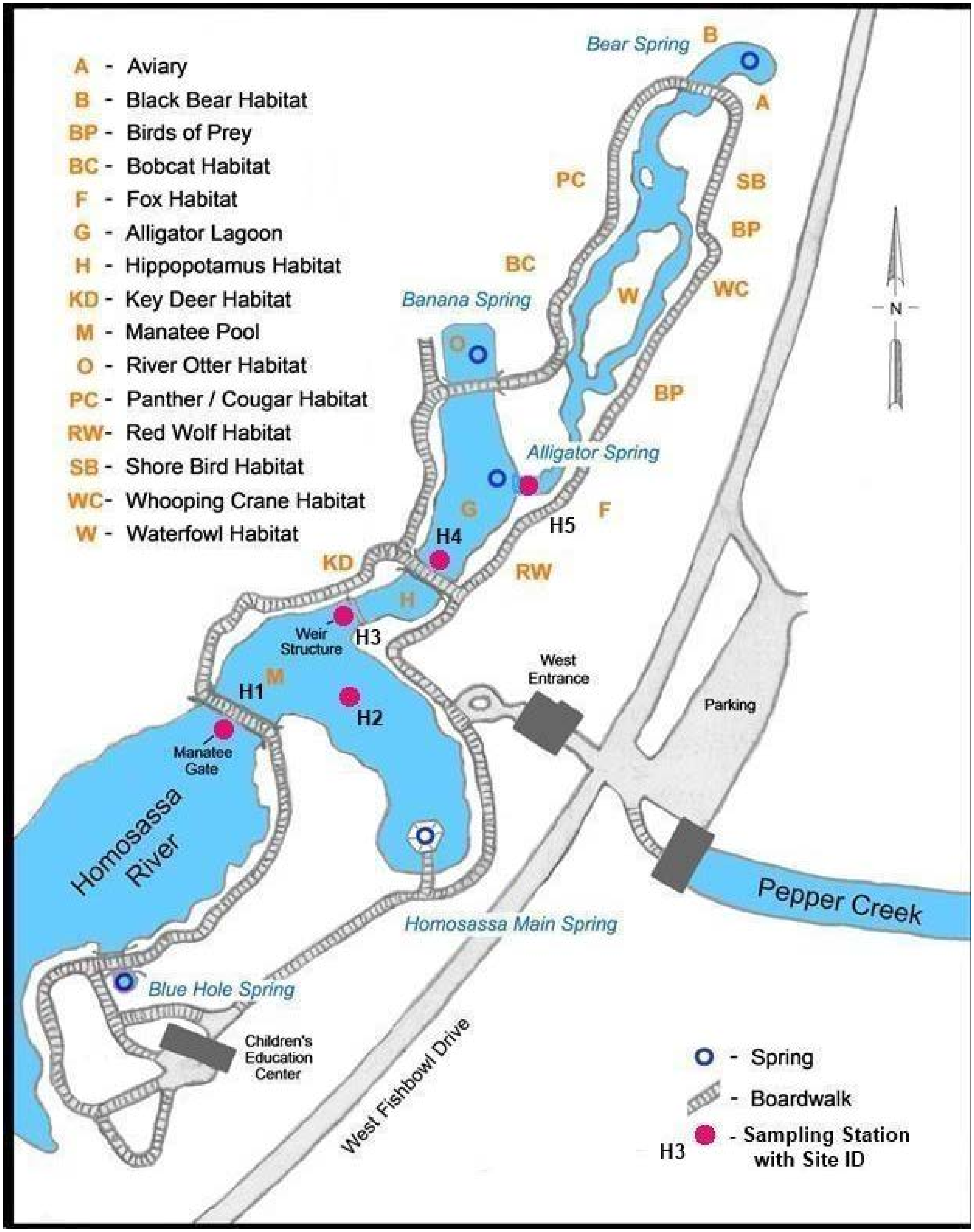


Figure 4.6. **Sketch map of the Homosassa Wildlife Park area, showing the locations of spring vents, habitat areas, and water quality/discharge sampling stations**

4.3.2 Nonpoint Sources

OSTDS

OSTDS are used to dispose of domestic waste 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 nitrogen concentrations in effluent from OSTDS are considerably higher than those in effluent from typical domestic WWTFs, 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 2010). 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 2010).

On average, the TN concentration in the effluent from a typical OSTDS is 57.7 mg/L (Hazen and Sawyer 2009), although this concentration is reduced further as the effluent is discharged to the drainfield and percolates to ground water. Under a low-density residential setting, nitrogen loadings from OSTDS may not be significant, but under a higher density setting, one could expect the nitrogen input to be approximately 129 pounds per acre per year (lb/ac/yr) (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. There has been a growing concern over the abundance and continuing use of septic tanks as the primary sanitary sewer disposal method within the contributing areas of springs, particularly those in higher density areas close to the springs.

Data for septic tanks are based on the FDOH statewide inventory of OSTDS (Hall and Clancy 2009). According to the FDOH parcel coverage, the Homosassa Springs Group contributing area contains approximately 8,300 OSTDS (**Figure 4.7**).

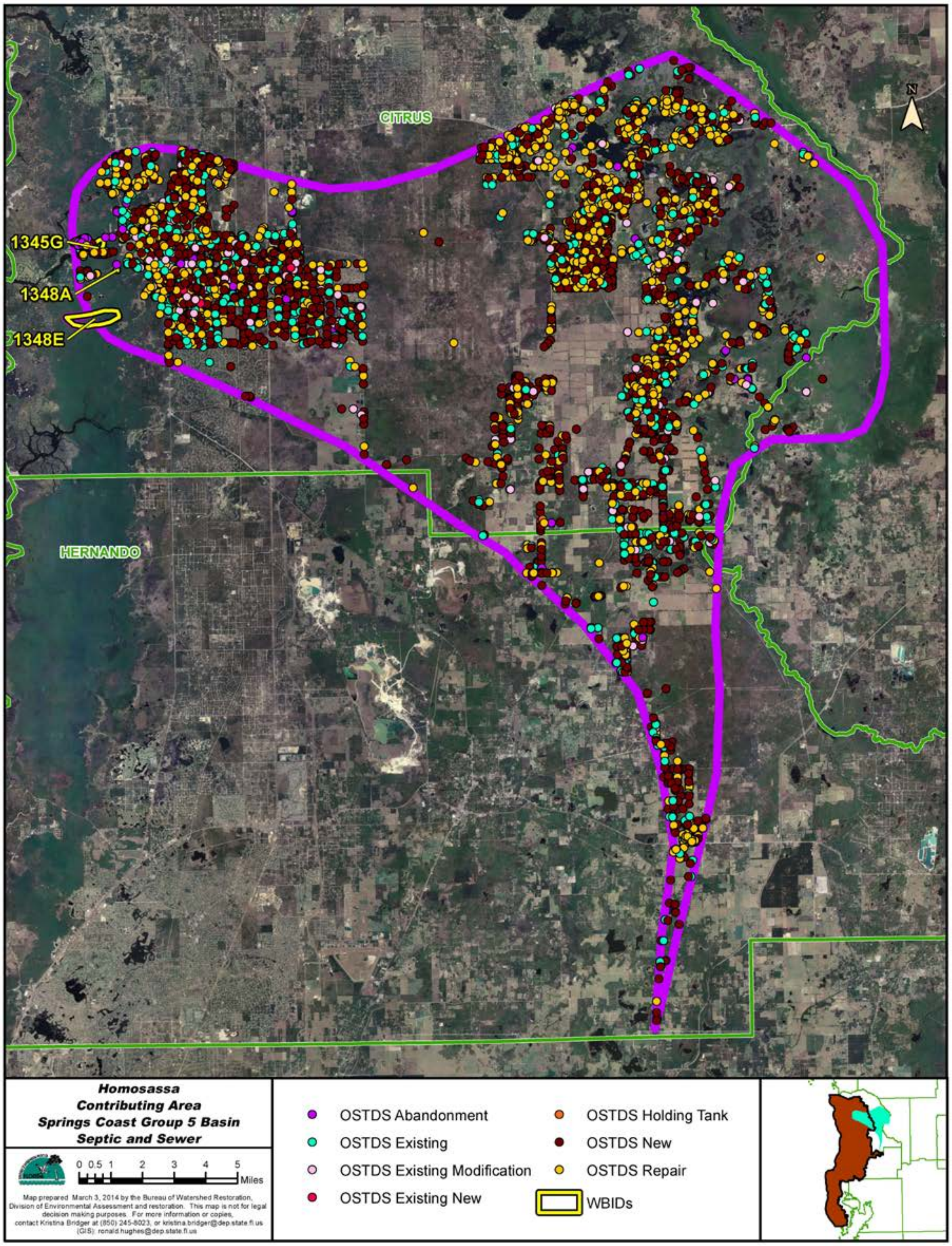


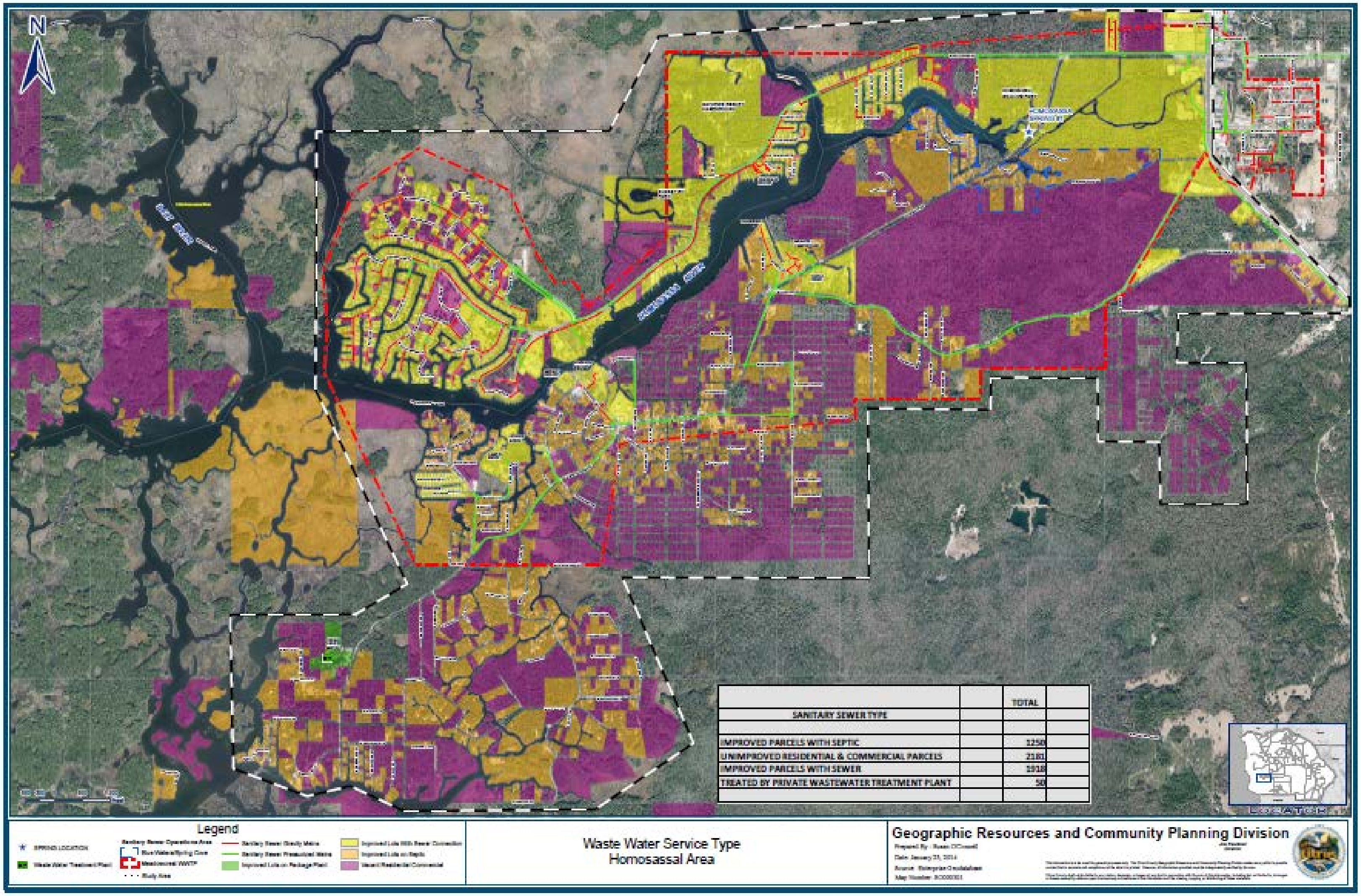
Figure 4.7. Density of OSTDS (septic tanks) in the spring contributing area

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 sanitary sewer overflows (SSOs), OSTDS, domestic animals, and fertilizers from home gardens, lawns, and golf courses. Approximately 24% of the total land area within the Homosassa Springs Group contributing area is designated as urban.

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 Citrus County Wastewater service type parcel coverage (Citrus County 2014). According to the Citrus County parcel coverage, approximately 1,900 parcels are connected to sewer, and 50 parcels are treated by a private wastewater treatment plant located near the Homosassa River (**Figure 4.8**).



SANITARY SEWER TYPE		TOTAL	
IMPROVED PARCELS WITH SEPTIC		1250	
UNIMPROVED RESIDENTIAL & COMMERCIAL PARCELS		2181	
IMPROVED PARCELS WITH SEWER		1918	
TREATED BY PRIVATE WASTEWATER TREATMENT PLANT		50	

Figure 4.8. Wastewater service type parcel coverage near Homosassa River provided by Citrus County

Wastewater and Fertilizer Chemical Tracers

SUCRALOSE

In January 2013, the Department sampled Bluebird, Hidden River Head, Hidden River #2, Homosassa Main #1 and #2, Pumphouse, and Trotter Main Springs for sucralose and nitrogen isotopes to help identify the sources of nitrate in the springs.

Sucralose is used as an artificial sweetener. Because it passes through water treatment systems largely intact, it has recently been used as a potential human wastewater tracer. Only one sample of sucralose has been collected to date from Bluebird, Hidden River Head, Hidden River #2, Homosassa Main #1 and #2, Pumphouse, and Trotter Main Springs. Very low detections (values between the laboratory method detection limit and the practical quantitation limit) were seen only at Pumphouse and Trotter Main Springs; at the other springs, sucralose was at concentrations below laboratory detection limits. Sucralose detections could indicate possible wastewater influences within the springshed.

NITROGEN ISOTOPES

The isotope results for these springs can be used for data interpretation. Over the years, researchers have associated isotopic ratios in ground water with a variety of sources. From those data, general delta-N-15 (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 tend not to contain nitrogen.

The nitrogen component of nitrate in ground water is composed of two stable isotopes, ^{14}N and ^{15}N, of which the vast majority of naturally occurring elemental nitrogen is ^{14}N. The difference between the two isotopes involves an extra neutron present in the nucleus of the ^{15}N isotope. The ratio of the two isotopes in the atmosphere is constant; however, the additional weight conveyed by the presence of the neutron in ^{15}N causes isotope fractionation in natural systems. Due to its lighter weight, ^{14}N is preferentially returned to the atmosphere during denitrification. Because animal and plant tissue is ^{15}N enriched, nitrogen in ground water can be traced to an organic or inorganic source. Typically, nitrate in ground water with an enrichment of over 10 parts per thousand ($^{0}/_{00}$) ^{15}N is considered representative of septic tank discharge and animal waste. Levels below 3 $^{0}/_{00}$ ^{15}N are representative of sources of nitrogen not entrained in the natural system, such as inorganic fertilizer. Levels between 3 and 10 $^{0}/_{00}$ indicate mixed inorganic and organic sources (Katz *et al.* 1999). The anthropogenic sources of inorganic nitrate include fertilizer applied to agricultural fields, residential lawns, and golf courses. Anthropogenic sources of nitrate derived from organic material include domestic wastewater and residuals, septic tank effluent, and animal waste derived from equine, poultry, and cow/calf operations.

Previous studies (Champion and Starks 2011) indicate that inorganic fertilizer is a significant source of nitrate to springs in the Springs Coast area, based on the measured ratios of the two stable isotopes of nitrogen (^{14}N and ^{15}N). Nitrogen and oxygen isotopes were analyzed from single samples collected from Bluebird, Hidden River Head, Hidden River #2, Homosassa Main #1, Homosassa Main #2, Pumphouse, and Trotter Springs in January 2013. **Figure 4.9** shows the plotted δ15N and 18O-NO3 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 fertilizer source and organic wastewater 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. The sample from Bluebird Spring may be more indicative of a greater nitrate contribution from an organic source, such as wastewater or septic tank effluent.

The high potential for fertilizer to leach through the well-drained sandy soils typical of spring areas is a major reason that inorganic fertilizer is such a prevalent source of nitrate in ground water and springs. **Table 4.4** provides the potential ranges of inorganic nitrogen use as fertilizer for the types of land uses common to the contributing area. In addition to residential lawns and landscaping, land uses with fertilizer that could potentially contribute nitrate to the impaired waters include golf courses and agriculture.

Best management practices (BMPs) and local ordinances and programs have been designed to encourage the conservative use of fertilizers and where implemented can reduce fertilizer leaching. Examples include the *Florida Golf Course BMP Manual* developed by the Department; row crop, cow-calf, equine, and container nursery BMP manuals produced by FDACS; and ordinances and programs implemented by Hernando and Pasco Counties.

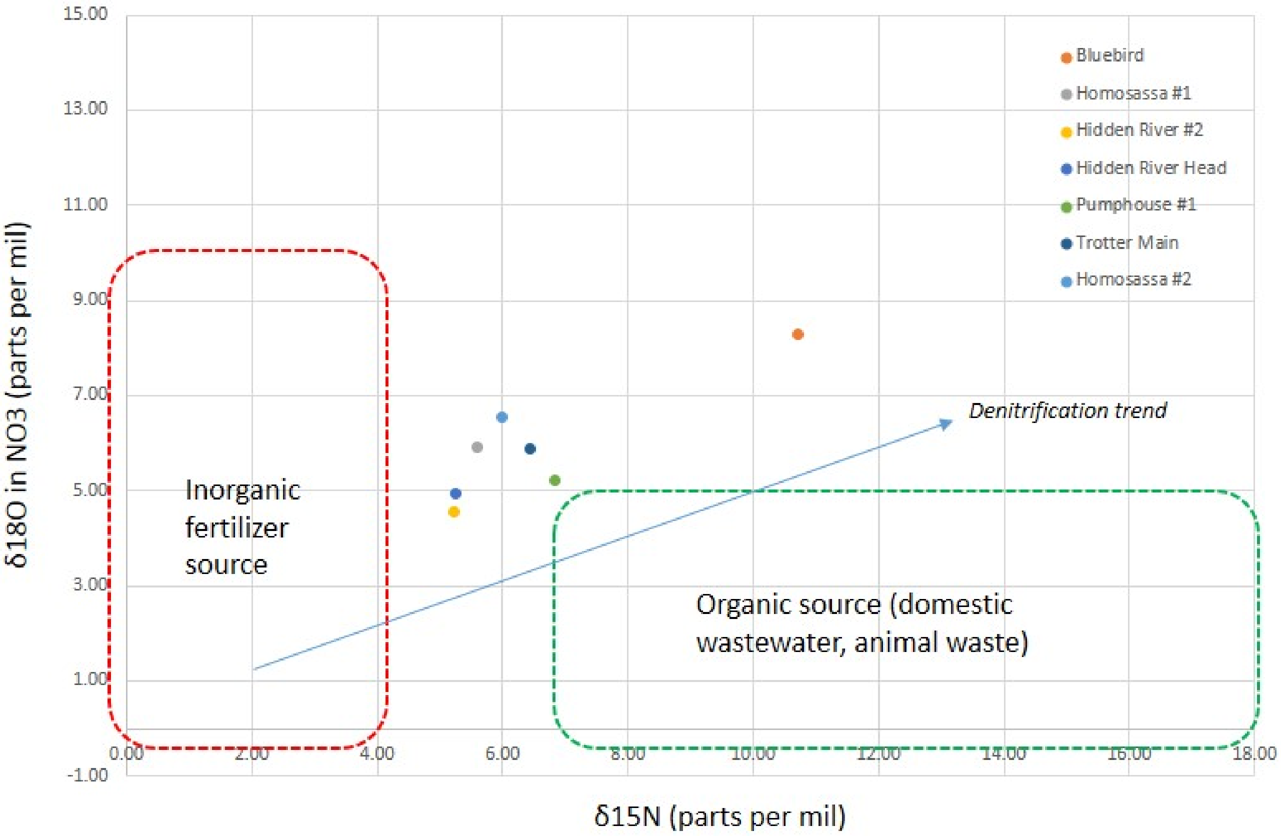


Figure 4.9. Nitrogen isotope plot for samples collected from Homosassa Springs Group springs

Atmospheric Deposition

Atmospheric deposition was also identified as an important potential nitrogen source (about 17% of the total input) (Jones *et al.* 1997). Wet nitrogen deposition from rainfall 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 (data are available at: http://nadp.sws.uiuc.edu/). Records indicate an annual average input of nitrogen from wet deposition to be 2.85 lb/ac/yr at the station from 2002 to 2012, resulting in in 264 tons of nitrogen/year contributed to the 289-square-mile Homosassa Springs Group contributing area.

Table 4.4. Potential fertilizer application ranges for selected land uses in the Homosassa Springs Group spring contributing area

Note: Potential loadings from fertilization are conservative, based on recommended agronomic rates and not actual field data.
[1] Lb/ac/yr = Pounds per acre per year

Nitrogen Source	Potential Nitrogen Application Rates Per Year (lb/ac/yr unless otherwise noted)[1]	Comments
Hayfield	320	Bahia grass; assume four cuttings (Mylavarapu *et al.* 2009)
Fertilized pasture	50–160	Bahia grass (Mylavarapu *et al.* 2009)
Container nursery, controlled- release fertilizer	17-472	Based on two to three pounds of controlled-release fertilizer per cubic yard of potting mix, ranging from pot size #1 to pot size #25 spacing (Yeager 2009; Garber *et al.* 2002)
Golf course, turf or lawn, bermudagrass–central Florida	174-261	Four to six pounds/1,000 square feet (Sartain *et al.* 2009)
Golf course, turf or lawn, St. Augustine grass–central Florida	87-131	Two to three pounds/1,000 square feet (Sartain *et al.* 2009)

Sediments

Studies have shown that an additional source of nutrients is present in sediments within the river, 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 the Homosassa River. Therefore, the Department is unable to provide estimates of nutrient loading from sediments in the TMDL analysis.

Decomposing Organic Matter

Decomposing vegetation, filamentous algal mats, and decaying aquatic organisms also release nutrients as they break down. As aquatic weeds and algae slowly decompose, a portion of nitrogen and phosphorus are released back into the water column, and some of it settles into the sediments (Sickman *et al.* 2009).

Livestock and Wildlife

Livestock and 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. 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. The actual livestock counts in the Homosassa Springs Group contributing area are not known.

4.3.3 Nitrogen Source Inventory Loading Tool

During the BMAP development process, the Department anticipates developing a nitrogen source inventory to estimate current loads of nitrogen to ground water in the Homosassa Springs Group contributing area. The Nitrogen Source Inventory and Loading Tool (NSILT) for estimating nitrogen loads uses a consistent, well-documented methodology that has been employed at other spring areas in the state. Similar estimates have been made in the past and have largely been based on land use; however, NSILT is taking this process a step further.

The nitrogen input to the land surface for anthropogenic sources is estimated based on detailed methods that are specific for each nitrogen source category. These main categories include atmospheric deposition, septic tanks, WWTFs, fertilizers (urban and agricultural), livestock waste, and any additional source category that is relevant to the specific area. After the nitrogen input is estimated, environmental attenuation is considered. This attenuation is specific for each source category and related to land application and other factors. The final step in the process is evaluating the influence of ground water recharge, which varies depending on the hydrogeology and soil characteristics. The Department's end product is a report containing a series of pie charts that illustrate the estimated percent contribution of each loading category within a BMAP area.

This process is constantly being improved upon and tailored for each specific area as new data become available. Stakeholder involvement is a critical aspect of this process and has been very helpful in NSILT development. The Department recognizes that no two BMAP areas are the same and tries to account for these differences with its estimates so that the end product is representative of the hydrogeology, anthropogenic inputs, and nitrogen attenuation within a BMAP-designated area.

Chapter 5: DETERMINATION OF LOADING CAPACITY

The Department often uses hydraulic and water quality models to simulate loading and the effects 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 TMDLs for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs.

5.1 Determination of Loading Capacity

Typically, the target loading and existing loading for a stream 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, soils, and pollutant delivery.

The predominant source of nutrient loading to the Homosassa River is ground water that is discharged at Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. The contributing area of the Homosassa River 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 the Homosassa River via ground water discharged from the spring vents. Thus, a direct relationship between surface water loadings in the watershed is not appropriate. This diffuse loading situation requires the use of an alternative approach for establishing the nutrient TMDLs.

Existing spring loading can be estimated by multiplying the measured spring flow by the measured pollutant concentrations in the spring. To estimate the pollutant loading this way, synoptic flow and concentration data measured at the outlet of each spring vent under assessment are required. Synoptic flow and concentration data for each spring vent were not available at the time of TMDL development. Therefore, the loads of nitrate could not be explicitly calculated.

Instead, the percent load reduction required to achieve the nitrate concentration target was calculated assuming the percent loading reduction would be the same as the percent concentration reduction. The percent reduction required to achieve the water quality target was calculated using the following formula:

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

5.2 Unique Nature of the Homosassa River

The Homosassa River is a tidally influenced, shallow coastal stream with a low flushing rate (or residence time). For the 1995 to 2009 benchmark period, median flushing times ranged from 6.2 to 8.9 days for the median and lowest daily flows, respectively (SWFWMD 2012). Shallow water depths allow warming and greater sunlight penetration, resulting in higher plant growth potential (Livingston 2001). In most coastal streams around the world, the combination of increased nutrients coupled with long residence time yields greater primary productivity, which in the Homosassa River is translated into increased filamentous algae and phytoplankton production.

Reductions of either nitrogen or phosphorus in the water discharging from springs, nearby stormwater flows, and nearby ground water inflows should reduce macroalgal accumulation by slowing the growth rate of macroalgae (Stevenson *et al.* 2007). Therefore, it is the purpose of this TMDL document to establish the maximum allowable nitrogen target concentration limits in water delivered to the Homosassa River by the above mechanisms, restoring the waterbody so that it meets its applicable water quality criterion for nutrients. The Department believes that reducing the growth rate of macroalgae (including *Lyngbya* and *Chaetomorpha*) through nutrient reduction will decrease filamentous algae biomass and phytoplankton productivity.

5.3 Effects of Salinity

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 and phytoplankton production in the Homosassa River. Salinity represents a primary determinant of long-term patterns in the distribution of submersed aquatic vegetation (SAV) in spring-fed systems along Florida’s Gulf Coast, including the Homosassa River (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.

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 river and spring salinities may also be tied to extended periods of lower-than-normal rainfall, sea-level rise, and ground water withdrawals. From 1920 to 2001 the estimated sea-level rise along the Florida Gulf Coast was approximately six inches (Douglas 1991; Zervas 2001).

The areas within the Homosassa River with the lowest salinity are near the springs because of their brackish discharges. Algal biomass and cover were higher near headsprings than downstream (Stevenson 2007 and Frazer *et al.* 2001). Freshwater macrophyte and macroalgae biomass decrease in response to increases in salinity and are lowest in saline environments (Hoyer *et al.* 2004).

5.4 Critical Conditions/Seasonality

Establishing the critical condition for nitrogen 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 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 inputs into ground water and discharge from the spring vents.

However, in the case of these springs, there does not appear to be any period when greater loading occurs. **Tables 5.1a** through **5.1h** summarize the monthly averages for the springs with data within the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. The nitrate concentrations in the springs do not vary greatly from month to month, based on the monthly data available.

Table 5.1a. Monthly average nitrate concentrations for Homosassa Main #1 Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	8	0.58	0.64	0.52
2	5	0.56	0.63	0.49
3	2	0.60	0.63	0.57
4	9	0.58	0.63	0.52
5	4	0.56	0.61	0.51
6	-	-	-	-
7	11	0.58	0.67	0.52
8	4	0.58	0.62	0.52
9	1	0.64	0.64	0.64
10	8	0.60	0.66	0.55
11	5	0.58	0.63	0.52
12	-	-	-	-

Table 5.1b. Monthly average nitrate concentrations for Homosassa Main #2 Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	7	0.56	0.61	0.48
2	5	0.53	0.60	0.45
3	2	0.59	0.61	0.58
4	9	0.56	0.61	0.48
5	4	0.54	0.58	0.50
6	-	-	-	-
7	10	0.56	0.65	0.50
8	4	0.56	0.57	0.54
9	1	0.61	0.61	0.61
10	8	0.58	0.63	0.50
11	5	0.56	0.60	0.52
12	-	-	-	-

Table 5.1c. Monthly average nitrate concentrations for Homosassa Main #3 Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	8	0.60	0.66	0.55
2	5	0.58	0.63	0.54
3	2	0.64	0.65	0.63
4	9	0.60	0.66	0.55
5	4	0.59	0.63	0.53
6	-	-	-	-
7	10	0.60	0.69	0.53
8	4	0.59	0.61	0.54
9	1	0.66	0.66	0.66
10	8	0.62	0.68	0.58
11	5	0.61	0.65	0.53
12	-	-	-	-

Table 5.1d. Monthly average nitrate concentrations for Pumphouse Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	3	0.57	0.69	0.49
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	8	0.56	0.63	0.42
8	1	0.57	0.57	0.57
9	-	-	-	-
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-

Table 5.1e. Monthly average nitrate concentrations for Trotter Main Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	10	0.64	0.74	0.56
2	-	-	-	-
3	-	-	-	-
4	10	0.64	0.74	0.53
5	-	-	-	-
6	-	-	-	-
7	8	0.65	0.72	0.52
8	2	0.63	0.65	0.61
9	-	-	-	-
10	10	0.65	0.72	0.56
11	-	-	-	-
12	-	-	-	-

Table 5.1f. Monthly average nitrate concentrations for Bluebird Spring, 2004–13

- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	2	0.39	0.47	0.31
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	6	0.69	0.74	0.64
8	-	-	-	-
9	-	-	-	-
10	-	-	-	-
11	-	-	-	-
12	-	-	-	-

Table 5.1g. Monthly average nitrate concentrations for Hidden River Head Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	10	0.86	0.96	0.70
2	-	-	-	-
3	-	-	-	-
4	10	0.85	0.97	0.71
5	-	-	-	-
6	-	-	-	-
7	9	0.87	0.97	0.80
8	1	0.78	0.78	0.78
9	-	-	-	-
10	9	0.87	0.92	0.81
11	-	-	-	-
12	-	-	-	-

Table 5.1h. Monthly average nitrate concentrations for Hidden River #2 Spring, 2004–13

- = Empty cell/no data

Month	Number	Mean	Maximum	Minimum
1	10	0.82	0.91	0.67
2	-	-	-	-
3	-	-	-	-
4	10	0.81	0.94	0.70
5	-	-	-	-
6	-	-	-	-
7	9	0.83	0.91	0.75
8	1	0.77	0.77	0.77
9	-	-	-	-
10	9	0.84	0.93	0.78
11	-	-	-	-
12	-	-	-	-

5.5 TMDL Development Process

5.5.1 Use of Site-Specific Information

For freshwater spring vents, the applicable numeric interpretation of the numeric nutrient criterion in Paragraph 62-301.530(47)(b), F.A.C., is 0.35 mg/L of nitrate-nitrite (NO3 + NO2) as an annual geometric mean, not to be exceeded more than once in any three consecutive calendar years. In many cases, this criterion can serve as the concentration-based TMDL target for spring waters. However, TMDLs can also serve as site-specific alternative criteria where an alternative threshold is more appropriate based on waterbody-specific information. These springs are not similar to the free-flowing freshwater springs to which the 0.35 mg/L criterion more directly applies and require an alternative threshold to address the impairment. To develop the nitrate target concentrations for Homosassa–Pumphouse-Trotter Springs Group, Bluebird Springs, and Hidden River Springs, the Department used a combination of site-specific historical documentation of algal mats, laboratory studies, and field surveys instead of a value based on the statewide criterion.

Historical Documentation of Algae

According to the *Homosassa River Water Quality Study Phase 2 Final Report* (FLD&E and Environmental Research and Design, Inc. [ER&D] 1989), “On April 7, 1988 a field inspection of the river was completed by Hans Zarbock, Chip Tolbert, and Rosanne Gibertini of FLD&E. The most predominant aquatic plant in the upper river is a filamentous blue-green alga, *Lyngbya* sp. Both nitrate and orthophosphorus, nutrient forms which are readily available to most plant species, have highest concentrations near the headwaters, but decrease steadily with increasing distance downstream.” The USGS sampled at Homosassa Springs (water quality station 112WRD 02310678) during the same period. The nitrate concentration at Homosassa Springs at that time was 0.34 mg/L.

Filamentous Algae Studies in Florida Springs

Nuisance algal growth has been observed in many springs and is associated with increases in anthropogenic activities and nutrients (Stevenson *et al.* 2007). Several studies described in this section 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 (available: 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 the Homosassa River because the river is tidally influenced, which results in a much longer residence time for nitrate in the coastal stream compared with a free-flowing freshwater stream. Also, as stated above, historical documentation revealed filamentous algae as the predominant aquatic plant in the upper river at nitrate concentrations equal to 0.34 mg/L. Therefore, a nitrate threshold lower than the statewide criterion appears to be more appropriate.

GROWTH RESPONSE OF *LYNGBYA WOLLEI* TO NITRATE ADDITIONS

In one study, Albertin (2009) used a series of recirculating stream channels (**Figure 5.1**), 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 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 5.2**).

GROWTH AND NITRATE-NITROGEN UPTAKE BY THE CYANOBACTERIUM *L. WOLLEI*

The nutrient amendment bioassay work conducted by Cowell and Dawes (2004) 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-milliliter (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 eight to 12 days after the nutrient amendment study started. This apparently suggested a time lag between a change in nitrate concentration and a *Lyngbya* response. A decrease in growth rate response was observed at nitrate concentrations equal to or less than 0.30 mg/L.

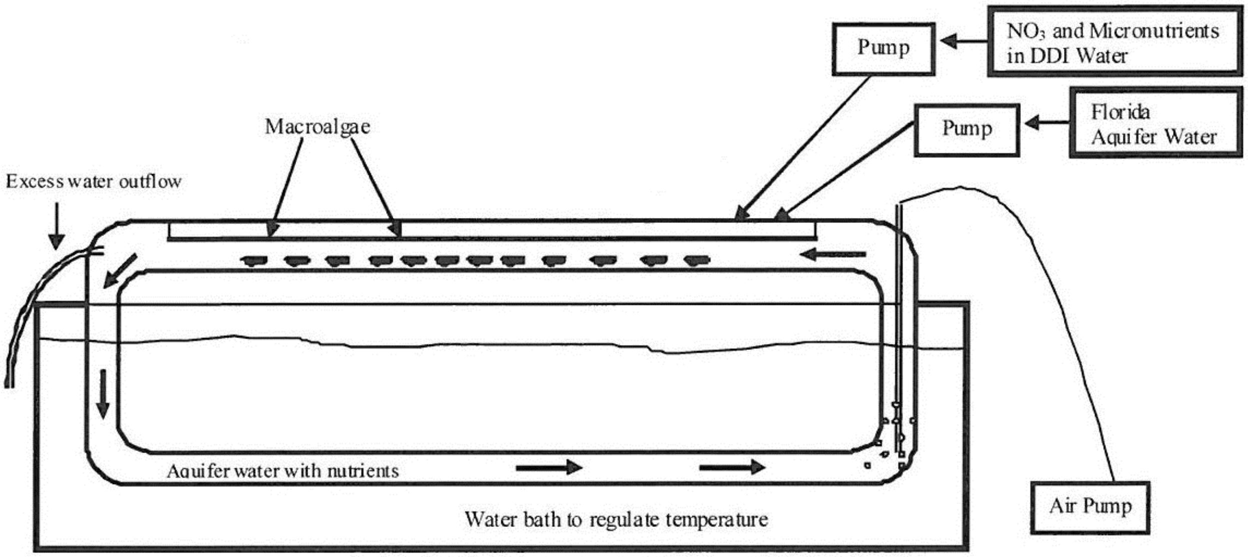


Figure 5.1. **Recirculating stream channel experimental design (Albertin 2009)**

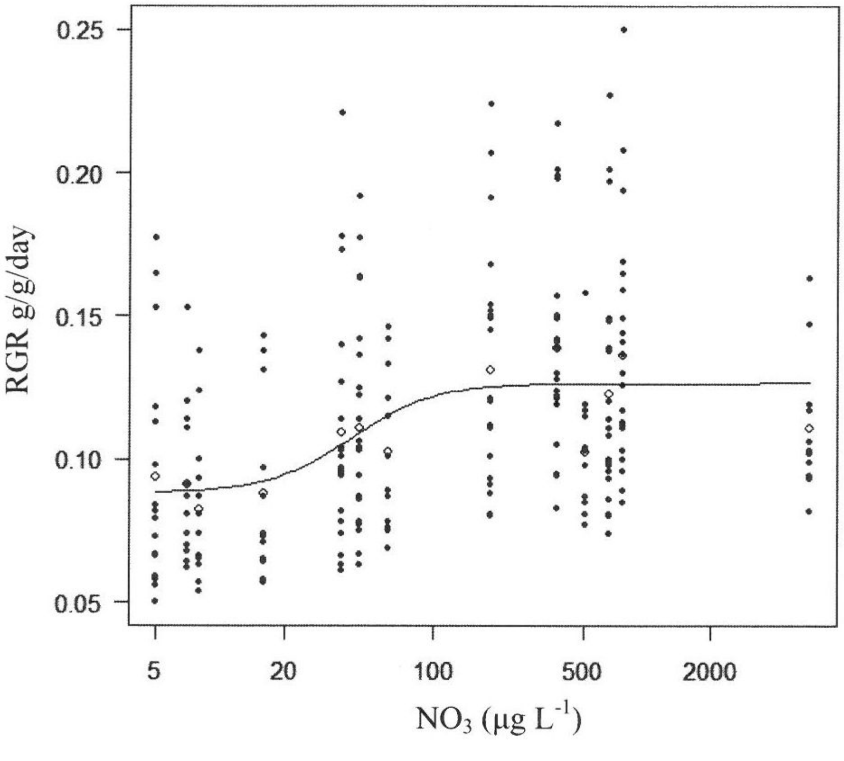


Figure 5.2. **Relative growth rates (RGR) of *L. wollei* at different nitrate concentrations in recirculating stream channels (Albertin 2009)**

EXAMINING THE ECOLOGICAL CONDITION OF ALGAE AND NUTRIENTS IN THE 2007 *FLORIDA SPRINGS REPORT*

This study evaluated algal growth response in 28 springs throughout Florida, including nearby Homosassa and Chassahowitzka Springs (**Figure 5.3**). Surveys of Florida springs conducted during this study found that almost all springs had macroscopic algae growing in them. They found that an average of 50% of the spring bottoms were covered by macroalgae and that the thickness of macroalgal mats was commonly 0.5 meters (m) and was as thick as 2 m in one spring boil. *L. wollei* and *Vaucheria* sp. were the two most common taxa of macroalgae occurring in areas with extensive growths in the studied springs; however, 23 different macroalgal taxa were observed in the spring survey.

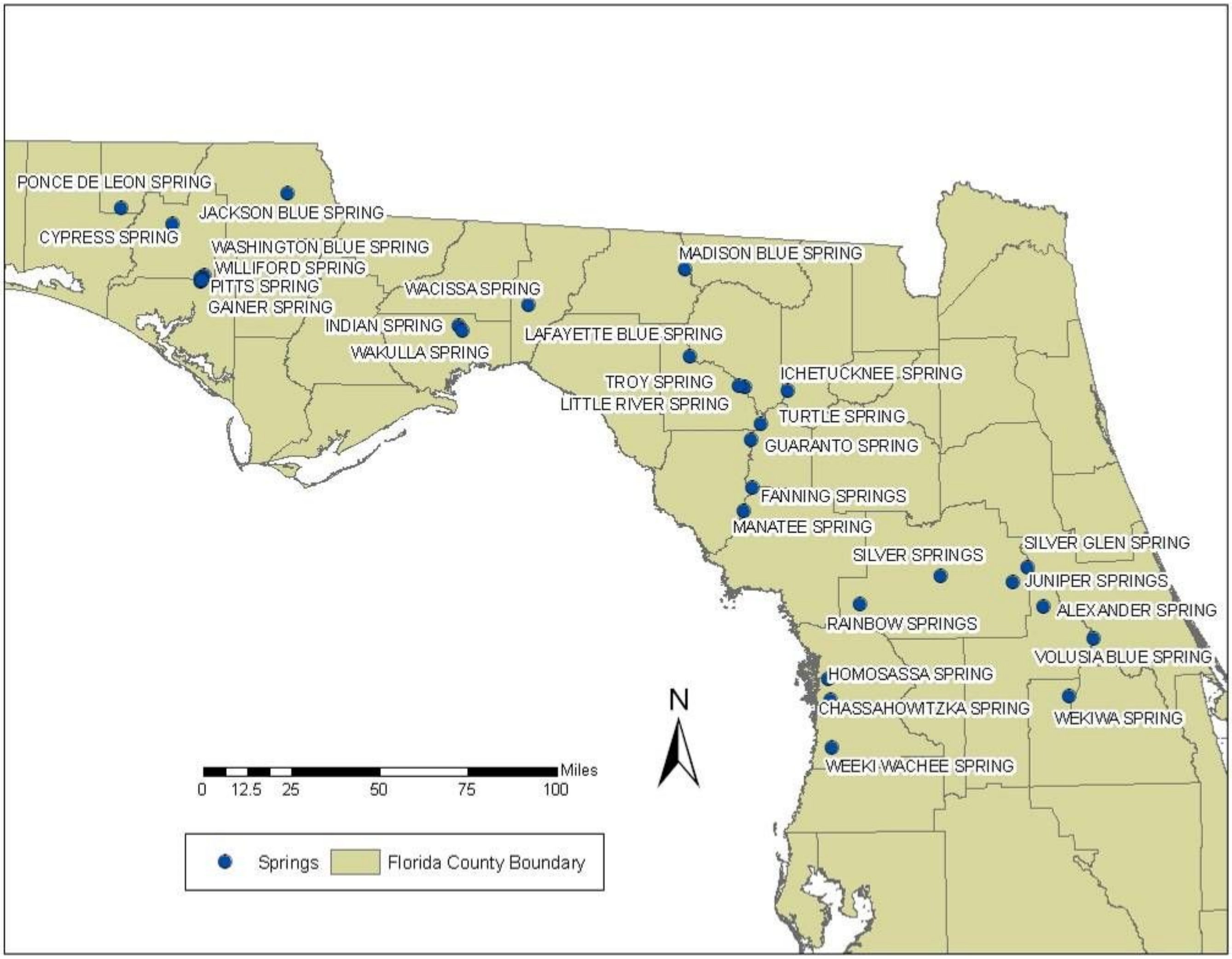


Figure 5.3. Springs included in the *Florida Springs Report* (Stevenson *et al.* 2007)

The nutrient concentration at which macroalgae growth is predicted to be elevated by 90% above which no effects of nutrient reduction would be expected is referred to as the saturating concentration. The saturating concentration was documented in a laboratory setting by Stevenson *et al.* (2007) for two 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 5.4**). 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 5.4**). 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*.

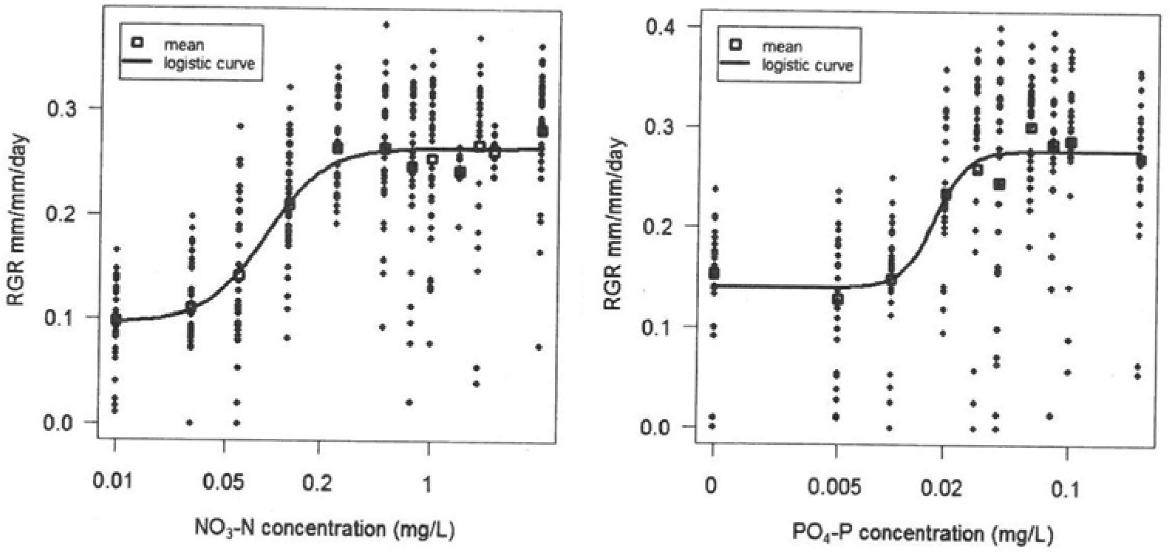


Figure 5.4. RGR of *L. wollei* at different nitrate and orthophosphate concentrations in microcentrifuge tubes (Stevenson *et al.* 2007)

Filamentous Algae in Field Surveys

From 1998 to 2000 and 2003 to 2005, the SWFWMD contracted with the University of Florida for a study to quantify the physical, chemical, and vegetative characteristics of five Gulf Coast rivers, including the Homosassa River. During the study, for each of the five rivers water chemistry and physical samples were collected during quarterly sampling events. The water chemistry sampling sites transverse the entire length of the river from the headspring to the Gulf of Mexico. Water chemistry sampling transect/sites are sequentially numbered from 1 (headspring) to 20 (Gulf of Mexico) and submersed aquatic vegetation sampling transect/sites are sequentially numbered from 1 (headspring) to 10 (mid-river). Data on SAV were collected annually during the summer for the six years to determine the species composition and coverage of plants. Macrophytes and macroalgae were sampled at 20 regularly spaced transects/sites from the headspring to mid-river. Ten SAV transects/sites corresponded to those where water chemistry was measured.

According to Frazer et al (2006), during the 2003 – 2005 sampling period, calculated nitrate loading rates in the headwater regions of the Homosassa and Chassahowitzka Rivers have increased by 56% and 43%, respectively, since the 1998 – 2000 sampling period. During both sampling periods (1998 – 2000 and 2003 – 2005) macroalgae was most abundant at the upper sampling transect/sites, though its occurrence was not restricted to the upper sampling areas for the Homosassa and Chassahowitzka Rivers (**Figure 5.5**).

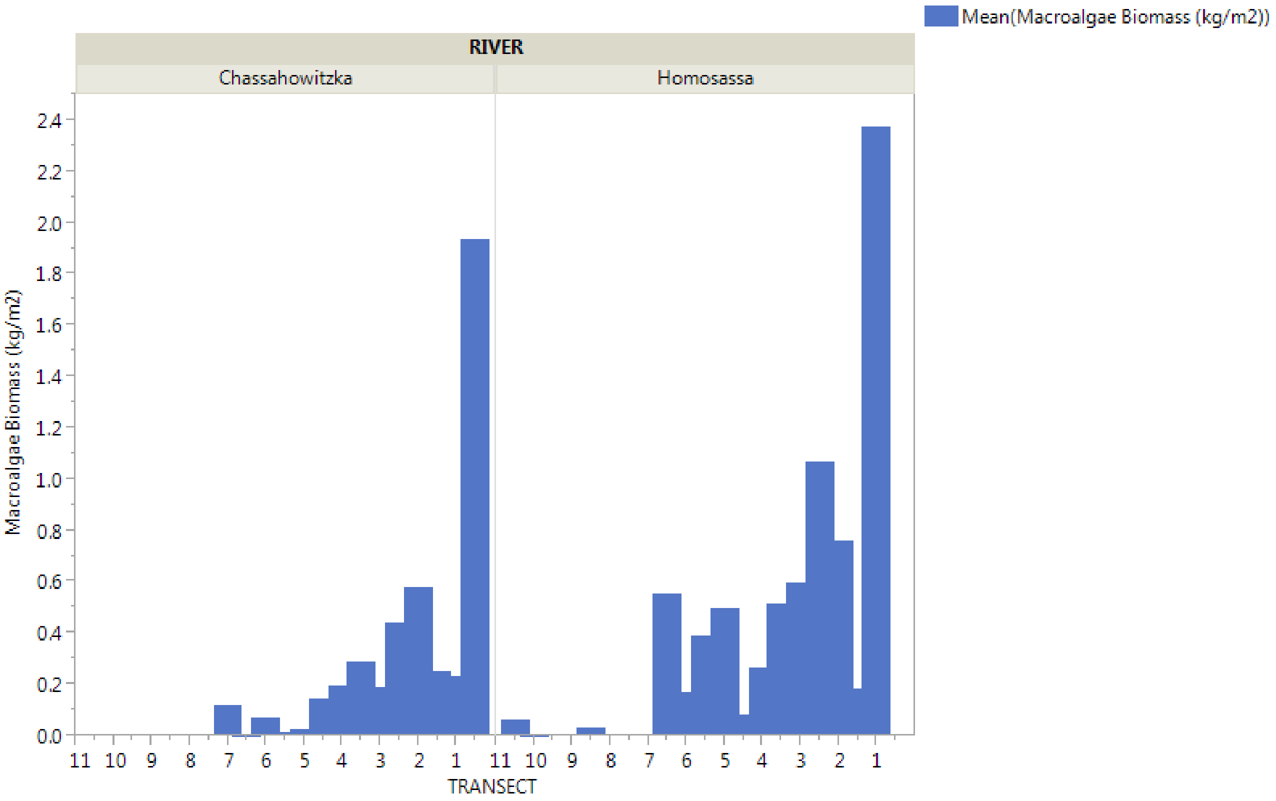


Figure 5.5. Mean macroalgae biomass and chlorophyll concentration by site for the Homosassa and Chassahowitzka Rivers, 1998–2000 and 2003–05

5.6 Setting the TMDL Water Quality Target for Nitrate

Multiple abiotic (flow, salinity, temperature, light) and biotic (nutrients and food web complexity) factors contribute to the distribution and growth of filamentous algae. Understanding the described studies and the constraints associated with each study will help develop appropriate nitrate target concentrations and reduction goals that would apply to Homosassa-–Trotter-–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs.

A site-specific alternative criteria is needed because water quality samples and field observations at Homosassa Springs in 1989 by USGS, FLD&E, and Environmental Research and Design, Inc. revealed the predominant aquatic plant to be the filamentous algae at nitrate concentrations less than the 0.34, which is less than the 0.35 mg/L numeric nutrient criterion for freshwater spring vents.

The field surveys performed by Frazer *et al.* (2001; 2006) in the Homosassa and Chassahowitzka Rivers found macroalgae was most abundant at the upper sampling transect/sites, though its occurrence was not restricted to the upper sampling areas for the Homosassa and Chassahowitzka Rivers. The combination of increased nitrate-enriched spring discharge, low salinity, and shallow water depths coupled with long residence time yielded greater primary productivity, which translated into increased filamentous algae production.

Lyngbya sp is present near the spring vents and lower salinity areas of the river system and has the most available research on algal growth response to nitrate. The laboratory 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. 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), the Homosassa River is tidally influenced, with a low flushing rate (long residence time) of approximately 6.2 days (SWFWMD 2012). 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 the Homosassa River. The effect of residence time (rate of flushing) on nitrate-enriched water discharging from the springs into a 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 and found that nitrate concentrations lower than 0 0.23 mg/L are needed to reduce the growth rate of *L. wollei*.

After carefully reviewing the above studies, the Department has selected the Stevenson *et al.* (2007) saturating nitrate concentration of 0.23 mg/L as the TMDL target concentration for the springs that discharge into the Homosassa River, which include Homosassa #1 Spring, Homosassa #2 Spring, Homosassa #3 Spring, Pumphouse Springs, Trotter Springs, Bluebird Springs, Hidden River Main Spring, and Hidden River #2 Spring. Nitrate is the most abundant form of nitrogen available in spring discharge. As discussed previously, the nitrate thresholds selected are based on algal growth studies performed in low-flushing (long residence time) conditions, which are similar to those in Homosassa River.

5.7 Setting the Annual Average Concentration for Nitrate

The Department believes that 0.23 mg/L nitrate (based on average annual concentrations) is an appropriate and conservative TMDL for the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. Annual average targets are most appropriate because algal growth does not respond to instantaneous changes in nutrient concentration. Therefore, a short-term exceedance of the target concentration may not produce negative or positive biological or ecological effects.

The nitrate concentrations in the springs are constant and do not vary greatly from season to season based on the quarterly data available. Therefore, annual arithmetic average concentrations were calculated for each year based on monitoring data collected during the Cycle 2 verified period (January 1, 2004–June 30, 2011) plus more recent data (2012–13). Data for each month are not available for springs because many of the smaller springs are sampled annually every July, and the larger springs are sampled four times a year. Homosassa #1 Spring, Homosassa #2 Spring, Homosassa #3 Spring, Hidden River Main Spring, Hidden River #2 Spring, and Trotter Springs are typically sampled four times a year (January, April, July, and October). Bluebird Springs and Pumphouse Springs are sampled annually in July. This schedule is the part of the SWFWMD routine spring sampling. The Department performed supplementary water quality sampling.

To ensure that the annual average concentrations would meet the concentration target even under the worst-case scenario, the highest annual average nitrate concentrations were used to calculate the percent reductions required to achieve the nitrate targets. This approach adds to the margin of safety of these TMDLs.

For Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs, the percent reductions required to meet their TMDLs were calculated using the annual values for nitrate averaged over the most recent verified period (January 1, 2004–June 30, 2011) plus more recent data (2011–13). The maximum annual average for each WBID was then considered in calculating a target for the percent reduction (**Tables 5.2a** through **5.2h**).

Table 5.2a. Yearly average nitrate concentrations for Homosassa Main #1 Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Average	Maximum	Minimum
2004	5	0.53	0.55	0.52
2005	5	0.55	0.59	0.52
2006	5	0.51	0.52	0.49
2007	8	0.57	0.60	0.55
2008	8	0.60	0.64	0.57
2009	8	0.58	0.63	0.54
2010	4	0.59	0.61	0.57
2011	5	0.61	0.65	0.57
2012	**4**	**0.65**	**0.67**	**0.63**
2013	5	0.63	0.64	0.61

Table 5.2b. Yearly average nitrate concentrations for Homosassa Main #2 Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Average	Maximum	Minimum
2004	4	0.50	0.52	0.48
2005	5	0.52	0.55	0.48
2006	5	0.50	0.54	0.45
2007	8	0.55	0.58	0.52
2008	8	0.58	0.61	0.53
2009	7	0.56	0.60	0.52
2010	4	0.57	0.59	0.56
2011	5	0.59	0.63	0.57
2012	**4**	**0.62**	**0.65**	**0.61**
2013	5	0.61	0.62	0.59

Table 5.2c. Yearly average nitrate concentrations for Homosassa Main #3 Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2004	4	0.56	0.59	0.55
2005	6	0.58	0.61	0.53
2006	5	0.54	0.54	0.53
2007	8	0.59	0.63	0.56
2008	8	0.62	0.66	0.57
2009	8	0.59	0.61	0.56
2010	4	0.61	0.63	0.59
2011	5	0.64	0.67	0.61
2012	**4**	**0.67**	**0.69**	**0.66**
2013	4	0.66	0.66	0.66

Table 5.2d. Yearly average nitrate concentrations for Pumphouse Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2004	1	0.49	0.49	0.49
2005	2	0.48	0.54	0.42
2006	1	0.55	0.55	0.55
2007	1	0.57	0.57	0.57
2008	1	0.57	0.57	0.57
2009	1	0.59	0.59	0.59
2010	1	0.63	0.63	0.63
2011	1	0.56	0.56	0.56
2012	1	0.54	0.54	0.54
2013	**2**	**0.65**	**0.69**	**0.60**

Table 5.2e. Yearly average nitrate concentrations for Trotter Main Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2004	4	0.58	0.61	0.56
2005	4	0.55	0.56	0.52
2006	4	0.58	0.60	0.56
2007	4	0.63	0.66	0.60
2008	4	0.64	0.65	0.63
2009	4	0.65	0.67	0.63
2010	3	0.66	0.68	0.64
2011	4	0.68	0.72	0.66
2012	**4**	**0.73**	**0.74**	**0.70**
2013	**5**	**0.72**	**0.73**	**0.70**

Table 5.2f. Yearly average nitrate concentrations for Bluebird Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2007	1	0.64	0.64	0.64
2008	1	0.64	0.64	0.64
2009	1	0.71	0.71	0.71
2010	0	0	0	0
2011	2	0.58	0.69	0.47
2012	**1**	**0.74**	**0.74**	**0.74**
2013	2	0.52	0.73	0.31

Table 5.2g. Yearly average nitrate concentrations for Hidden River Head Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2004	4	0.76	0.81	0.70
2005	3	0.77	0.78	0.77
2006	4	0.84	0.86	0.82
2007	4	0.84	0.86	0.81
2008	4	0.81	0.83	0.79
2009	4	0.85	0.86	0.85
2010	3	0.89	0.90	0.87
2011	4	0.92	0.92	0.91
2012	4	0.91	0.93	0.88
2013	**5**	**0.95**	**0.97**	**0.92**

Table 5.2h. Yearly average nitrate concentrations for Hidden River #2 Spring, 2004–13

Note: Maximum annual average is highlighted in boldface red type.

Year	Number	Mean	Maximum	Minimum
2004	4	0.74	0.82	0.67
2005	3	0.76	0.77	0.76
2006	4	0.82	0.83	0.82
2007	4	0.81	0.83	0.78
2008	4	0.78	0.81	0.75
2009	4	0.80	0.81	0.79
2010	3	0.84	0.85	0.81
2011	4	0.88	0.93	0.86
2012	4	0.87	0.88	0.85
2013	**5**	**0.91**	**0.94**	**0.90**

5.8 Calculation of TMDL Percent Reduction

The maximum annual average nitrate concentrations were calculated from data available during the Cycle 2 verified period plus more recent data (January 1, 2004–December 31, 2013). The maximum annual average nitrate concentrations for Hidden River Main Spring and Hidden River #2 Spring occurred during 2013 and are 0.95 and 0.91 mg/L, respectively. The maximum annual average nitrate concentrations for Homosassa #1 Spring, Homosassa #2 Spring, and Homosassa #3 Spring occurred during 2012 and are 0.65, 0.62, and 0.67 mg/L, respectively. It is important to note that the maximum annual average nitrate concentrations in Homosassa #1, #2, and #3 Springs decreased by approximately

0.01 mg/L in 2013. The maximum annual average nitrate concentration for Pumphouse Spring occurred in 2013 and is 0.65 mg/L. The maximum annual average nitrate concentration for Trotter Spring occurred in 2012 and is 0.73 mg/L. At Trotter Spring the maximum annual average nitrate concentration also decreased by approximately 0.01 mg/L in 2013. The maximum annual average nitrate concentration for Bluebird Spring occurred in 2012 and is 0.74 mg/L.

These TMDL target concentrations for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs will be submitted to the EPA for approval as site-specific (Hierarchy 1) interpretations of the narrative nutrient criterion for these water bodies as stated in Rule 62-302.531, F.A.C.

To obtain percent reductions that are reasonably representative of the eight springs and will be adequately protective by using the largest datasets, the maximum annual average nitrate concentrations were used. The percent reductions required to achieve the water quality targets were calculated using the following formula:

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

Percent Reduction Calculations:

- **Homosassa #1 Spring (WBID 1345G):**

  [(0.65 mg/L – 0.23 mg/L) / 0.65 mg/L] * 100

  Equals a 65% reduction in nitrate.

- **Homosassa #2 Spring (WBID 1345G):**

  [(0.62 mg/L – 0.23 mg/L) / 0.62 mg/L] * 100

  Equals a 63% reduction in nitrate.

- **Homosassa #3 Spring (WBID 1345G):**

  [(0.67 mg/L – 0.23 mg/L) / 0.67 mg/L] * 100

  Equals a 66% reduction in nitrate.

- **Pumphouse Springs (WBID 1345G):**

  [(0.65 mg/L – 0.23 mg/L) / 0.65 mg/L] * 100

  Equals a 65% reduction in nitrate.

- **Trotter Springs (WBID 1345G):**

  [(0.73 mg/L – 0.23 mg/L) / 0.73 mg/L] * 100

  Equals a 68% reduction in nitrate.

- **Bluebird Springs (WBID 1348A):**

  [(0.74 mg/L – 0.23 mg/L) / 0.74 mg/L] * 100

  Equals a 69% reduction in nitrate.

- **Hidden River Main Spring (WBID 1348E):**

  [(0.95 mg/L – 0.23 mg/L) / 0.95 mg/L] * 100

  Equals a 76% reduction in nitrate.

- **Hidden River #2 Spring (WBID 1348E):**

  [(0.91 mg/L – 0.23 mg/L) / 0.91 mg/L] * 100

  Equals a 75% reduction in nitrate.

Reductions in nitrate concentrations of 63% to 68% in individual springs of the Homosassa-Trotter-Pumphouse Springs Group, 69% in Bluebird Springs, and 75% to 76% in Hidden River Springs are proposed because they are protective values that, when achieved, will cause filamentous algae biomass and phytoplankton productivity to decrease. Once the target concentrations are consistently achieved, each WBID will be reevaluated to determine if nitrogen continues to contribute to an imbalance of flora or fauna as a result of algal smothering. If such a condition still exists, the waterbodies will be reassessed as part of the Department's watershed assessment cycle. The TMDL target concentrations may be changed if the Department determines that further reductions in the nitrogen concentrations 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.

Chapter 6: DETERMINATION OF THE TMDL

6.1 Expression and Allocation of the TMDL

The percent load reductions were established to achieve the annual average nitrate concentrations of 0.23 mg/L for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs. While these percent reductions are the expression of the TMDLs 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 standard.

The TMDL nitrate target is 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, due to limited economic resources it is impractical to collect daily nitrate water quality data to evaluate water quality for Homosassa River and its impaired springs. Maximum monthly concentration (MMC) targets for nitrate were established using the equation below, established by the EPA (2006). In the following 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.

Z_p = p^{th} *percentage point of the standard normal distribution, at 95%* ($Z_p = 1.645$).

σ = Standard deviation.

CV = Coefficient of variance.

6.1.1 Calculation of the MMC for Nitrate

For the monthly maximum nitrate concentration, it was assumed that the average annual target concentration should be the same as the average monthly concentration. Also, assuming the target dataset will have the same CV as the existing measured dataset and allowing a 5% exceedance (EPA 2007, pp. 19 and 20), **Table 6.1** lists the monthly maximum nitrate concentrations for the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs.

It should be emphasized that these monthly maximum targets were developed for illustrative purposes. The implementation of the TMDLs will be based on the annual average concentration targets.

Table 6.1. Monthly maximums for target nitrate concentrations (mg/L)

Waterbody Name (WBID)	Standard Deviation	Long-Term Average Nitrate Target (mg/L)	CV	Monthly Maximum To Achieve Annual Average OPO4 Target
Homosassa #1 Spring (WBID 1345G)	0.0424	0.23	0.0726	0.26
Homosassa #2 Spring (WBID 1345G)	0.0438	0.23	0.0782	0.26
Homosassa #3 Spring (WBID 1345G)	0.0425	0.23	0.0701	0.26
Pumphouse Springs (WBID 1345G)	0.0527	0.23	0.0937	0.27
Trotter Springs (WBID 1345G)	0.0588	0.23	0.0916	0.27
Bluebird Springs (WBID 1348A)	0.0813	0.23	0.1276	0.28
Hidden River Main Spring (WBID 1348E)	0.0643	0.23	0.0752	0.26
Hidden River #2 Spring (WBID 1348E)	0.0545	0.23	0.0664	0.26

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed 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:

$$\mathbf{TMDL} = \sum \square \mathrm{WLAs} + \sum \square \mathrm{LAs} + \mathrm{MOS}$$

As discussed earlier, the WLA is broken out into separate subcategories for wastewater discharges (if any are ever present) and stormwater discharges regulated under the NPDES Program:

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

It should be noted that the various components of a 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 a 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 BMPs.

This approach is consistent with federal regulations (40 Code of Federal Regulations § 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 TMDLs for the Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs are expressed in terms of concentration of nitrate and represent the loading the spring and river can assimilate and maintain healthy levels of algal growth that do not contribute to an ecological imbalance (**Table 6.2**). Because no target loads were explicitly calculated in this TMDL report, the TMDLs are represented as the percent reduction required to achieve the nitrate targets. The percent reductions assigned to all the nonpoint source areas (LA) are the same as those defined for the TMDL percent reductions.

6.2 Wasteload Allocation (Point Sources)

6.2.1 NPDES Wastewater Discharges

Currently, no NPDES wastewater facilities discharge directly into the Homosassa River. Any new potential discharger is expected to comply with the Class III criterion for nutrients and with nitrate limits consistent with this TMDL. If it is determined that any of the wastewater facilities discharge into the Homosassa River, they will be subject to the assigned WLA.

Table 6.2. TMDL Components for Homosassa–Trotter–Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs

N/A = Not applicable

Waterbody (WBID)	Parameter	TMDL (mg/L)	TMDL % Reduction	Wasteload Allocation for Wastewater	Wasteload Allocation for NPDES Stormwater % Reduction	Load Allocation % Reduction	MOS
Homosassa #1 Spring (WBID 1345G)	Nitrate as Annual Average	0.23	65%	N/A	65%	65%	Implicit
Homosassa #2 Spring (WBID 1345G)	Nitrate as Annual Average	0.23	63%	N/A	63%	63%	Implicit
Homosassa #3 Spring (WBID 1345G)	Nitrate as Annual Average	0.23	66%	N/A	66%	66%	Implicit
Pumphouse Springs (WBID 1345G)	Nitrate as Annual Average	0.23	65%	N/A	65%	65%	Implicit
Trotter Springs (WBID 1345G)	Nitrate as Annual Average	0.23	68%	N/A	68%	68%	Implicit
Bluebird Springs (WBID 1348A)	Nitrate as Annual Average	0.23	69%	N/A	69%	69%	Implicit
Hidden River Main Spring (WBID 1348E)	Nitrate as Annual Average	0.23	76%	N/A	76%	76%	Implicit
Hidden River #2 Spring (WBID 1348E)	Nitrate as Annual Average	0.23	75%	N/A	75%	75%	Implicit

6.2.2 NPDES Stormwater Discharges

Table 6.2 provides the NPDES stormwater percent reductions, which represent the allowable nutrient loads that would result in ecosystem improvement. The NPDES stormwater collection systems in the Homosassa Springs contributing area are maintained by Citrus County (Co-permittee: FLR04E141), city of Inverness (Co-permittee: FLR04E144), Hernando County (FLR04E040), and FDOT District 7 (FLR04E017 – Hernando) and (FLR04E142 - Citrus). It should be noted that any future MS4 permittee is only responsible for reducing the anthropogenic loads associated with stormwater outfalls that it owns or otherwise has responsible control over, and it is not responsible for reducing other nonpoint source loads in its jurisdiction. Wasteload allocations (WLAs) may be assigned to MS4 entities if their discharges affect impaired surface waters. The potential involvement of MS4 entities in this area may not be limited to the typical discharges of urban stormwater to surface water

6.3 Load Allocation (Nonpoint Sources)

Reductions in nitrate concentrations of 63% to 68% in Homosassa–Trotter–Pumphouse Springs Group, 69% in Bluebird Springs, and 75% to 76% in Hidden River Springs are needed from the nonpoint source areas contributing to these impaired springs. The target annual average nitrate concentrations and the percent reductions represent estimates of the maximum reductions required to meet the targets. It may be possible to meet the targets before achieving the percent reductions. It should be noted that the LA could also include loading from stormwater discharges regulated by the Department and the water management district that are not part of the NPDES Stormwater Program (see **Appendix A**).

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 concentration within the eight-year data period (2004–13) was used instead of the average of the annual averages. In addition, when estimating the required percent reduction to achieve the water quality target, the highest long-term monthly average of measured nitrate concentrations was used instead of the average of the monthly averages. Both of these will make estimating the required percent load reduction more conservative and therefore add to the MOS.

Chapter 7: NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

7.1 Basin Management Action Plan

Following the adoption of these TMDLs by rule, the Department will determine the best course of action regarding their 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. A BMAP can 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.

If the Department determines that a BMAP is needed to support the implementation of these TMDLs, 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.

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 TMDLs).
- 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 TMDLs.

- 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.

References

Albertin, A.R. 2009. *Nutrient dynamics in Florida springs and relationships to algal blooms*. Ph.D. dissertation. Gainesville, FL: University of Florida.

Arthur, J.D., H.A.R. Wood, A.E. Baker, J.R. Chichon, and G.L. Raines. 2007. Development and implementation of Baysean-based aquifer vulnerability assessment in Florida. *Natural Resources Research* 16(2), 93–107.

Bishop, J.H., and D.E. Canfield. 1995. *Volunteer water quality monitoring at Crystal River, Florida (August 1992 – August 1995).* Final report submitted to the Southwest Florida Water Management District by Florida LAKEWATCH. Gainesville, FL: University of Florida, Department of Fisheries and Aquatic Sciences.

Bonn, M.A. 2004. Visitor profiles, economic impacts, and recreational aesthetic values associated with eight priority Florida springs located in the St. Johns River Water Management District. Palatka, FL: St. Johns River Water Management District.

Brewer, T. 2013a. E-mail from Toby Brewer to James Dodson. *Subject: Request for Weeki Wachee Springs economic numbers.* Florida Department of Environmental Protection.

———. 2013b. E-mail from Toby Brewer to James Dodson. *Subject: Algae records.* Florida Department of Environmental Protection.

Camp *et al.* 2012. Changes in submersed aquatic vegetation affect predation risk of a common prey fish *Lucania parva* (Cyprinodontiformes: Fundulidae) in a spring-fed coastal river. Fisheries Management and Ecology, 19, 245 – 251.

———. 2013. Replacement of rooted macrophytes by filamentous macroalgae: effects on small fishes and macroinvertebrates. Hydrobiologia, DOI 10.1007/s10750-013-1694-3.

Carr, D., K. Kolasa, D. Ellison, and R. Basso. 2013. *Minimum and guidance levels for Tooke Lake in Hernando County, Florida.* Brooksville, FL: Southwest Florida Water Management District, Resource Evaluation Section.

Champion, K.M., and R. Starks. 2001 (revised 2011). *The hydrology and water quality of select springs in Southwest Florida Water Management District.* Prepared by the Southwest Florida Water Management District, Water Quality Monitoring Program. Brooksville, FL:

Citrus County. 2014. Citrus County Wastewater Service Type Parcel Coverage for Homosassa River. GIS Section. Available at http://gis.citrus.fl.us/

Cowell, B.C., and C.J. Dawes. 2004. Growth and nitrate-nitrogen uptake by the cyanobacterium *Lyngbya sp wollei*. *Journal of Aquatic Plant Management* 42:69–71.

Douglas. 1991. Global sea level rise. Journal of Geophysical Research: Oceans (1978 – 2012), DOI 10.1029/91JC00064.

Ferguson, G.E., C.W. Lingham, S.K. Love, and R.O. Vernon. 1947. Springs of Florida. *FGS* 31: 1–197.

FitzPatrick, K. 2010 *Weeki Wachee Springs, analysis and restoration proposal.* Available: http://floridaspringsinstitute.org/Resources/Documents/Weeki_FitzPatrick.pdf.

Fitts, C. 2013. Groundwater Science. 2nd edition. Elsevier. Waltham, MA.

Florida Department of Community Affairs. 2002. *Protecting Florida's springs: Land use planning strategies and best management practices.* Tallahassee, FL: Florida Department of Environmental Protection and Florida Department of Community Affairs.

Florida Department of Environmental Protection. February 2001. *A report to the Governor and the Legislature on the allocation of Total Maximum Daily Loads in Florida.* Tallahassee, FL: Bureau of Watershed Management.

———. 2006. *Water quality status report: Springs Coast*. Tallahassee, FL: Division of Environmental Assessment and Restoration.

———. 2008a. *Water quality assessment report: Springs Coast.* Tallahassee, FL: Division of Environmental Assessment and Restoration.

———. 2008b. *Standard Operating Procedure (SOP) FS7420.* Available: http://www.dep.state.fl.us/water/sas/sop/sops.htm.

———. 2011. *Weeki Wachee Springs State Park, unit management plan.* Approved plan. Tallahassee, FL: Division of Recreation and Parks.

———. 2011b. *Florida state park system economic impact assessment for FY 2010/2011.* Tallahassee, FL: Division of Recreation and Parks.

Florida Department of Health website. 2010. Available: http://www.doh.state.fl.us/.

Florida Land Design and Engineering, Inc. 1989. *Homosassa River water quality study.* Report submitted to the Department of Technical Services, Citrus County Board of County Commissioners. Lecanto, FL.

Frazer, T.K., M.V. Hoyer, S.K. Notestein, J.A. Hale, and D.E. Canfield. 2001. Physical, chemical and vegetative characteristics of five Gulf Coast rivers. Report submitted to the Southwest Florida Water Management District. SWFWMD Contract No. 98CON000077. Gainesville, FL. University of Florida.

Frazer, T.K., S.K. Notestein, and W.E Pine, Jr. 2006. *Changes in the physical, chemical and vegetative characteristics of the Homosassa, Chassahowitzka, and Weeki Wachee Rivers.* Report submitted to the Southwest Florida Water Management District. SWFWMD Contract No. 03CON000038. Gainesville, FL: University of Florida.

Gao, X. November 15, 2007. *Nutrient TMDLs for the Wekiva River (WBIDs 2956, 2956A, and 2956C) and Rock Springs Run (WBID 2967).* TMDL report. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration.

Garber, M.P., J.M. Ruter, J.T. Midcap, and K. Bondari. October–December 2002. Survey of container nursery irrigation practices in Georgia. *HortTechnology* 12(4).

Gilbert, D. 2012. *Nutrient (biology) TMDL for the Wakulla River, WBID 1006.* TMDL report. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration.

Gulf Coast Ecosystems (GCE). 2010. Chaetomorpha sp. A Green Macroalgae. Available: http://marineplantbook.com/marinebookchaeto.htm

Hall, P., and S.J. Clancy. 2009. *The Florida statewide inventory of onsite sewage treatment and disposal systems (OSTDS): Final draft report and database.* Prepared for the Florida Department of Health, Bureau of Onsite Sewage Programs, by EarthSTEPS and GlobalMind.

Hallas, J.F., and W. Magley. September 2008. Nutrient and dissolved oxygen TMDL for the Suwannee River, Santa Fe River, Manatee Springs (3422R), Fanning Springs (3422S), Branford Spring (3422J), Ruth Spring (3422L), Troy Spring (3422T), Royal Spring (3422U), and Falmouth Spring (3422Z) . TMDL report. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration.

Hand, J. February 2009. *Florida springs assessment decision matrix.* Tallahassee, FL: Florida Department of Environmental Protection, Watershed Assessment Section.

Harrington, D., G. Maddox, and R. Hicks. February 2010. *Florida Springs Initiative Monitoring Network report and recognized sources of nitrate.* Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, Ground Water Protection Section.

Hazen and Sawyer, P.C. August 2009. Florida onsite sewage nitrogen reduction strategies study: Task A.2, Final report, Literature review of nitrogen reduction technologies for onsite sewage treatment systems. Florida Department of Health Contract CORCL.

Heffernan, J.B., D.M. Liebowitz, T.K. Frazer, J.M. Evans, and M.J. Cohen. 2010. Algal blooms and the nitrogen-enrichment hypothesis in Florida springs: Evidence, alternatives, and adaptive management. *Ecological Applications* 20(3): 816–829.

Hernando County. 2012. *Hernando County statistical abstract: FY 2012–2013.* Population and Statistics Subject Index Webpage, Table 1.09, Cities and Communities: 2010 Census.

Heyl, M.G. October 2008. *Weeki Wachee River recommended minimum flows and levels.* Southwest Florida Water Management District.

———. April 2012. *lmpact of flow on NO3+NO2-N concentration on six Florida spring discharges.* Memo to file. Southwest Florida Water Management District.

Hicks, R., D. Harrington, and G. Maddox. March 2009. Documentation to support listing of nutrient impaired springs and spring runs (Volusia Blue Spring and Volusia Blue Spring Run; DeLeon Spring; Jackson Blue Spring and Merritts Mill Pond; Silver Springs, Silver Springs Group, and Upper Silver River; Rainbow Springs Group and Rainbow Springs Group Run; and Weeki Wachee Spring and Weeki Wachee Spring Run. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, Ground Water Protection Section.

Holland, K., and R. Hicks. November 2012. *Nutrient TMDL for Silver Springs Group and Upper Silver River (WBIDs 2772A, 2772C, and 2772E).* Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, Ground Water Management Section.

———. January 2013. *Nutrient TMDL for Rainbow Springs Group and Rainbow Springs Group Run (WBIDs 1320A and 1320B).* Final report. Tallahassee, FL: Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration, Bureau of Watershed Restoration, Ground Water Management Section.

Hoyer, M.V., L. K. Mataraza, A. B. Munson, and D. E. Canfield, Jr. 1997. Water clarity in Kings Bay / Crystal River. University of Florida, IFAS. Gainesville, Florida.

———. 2004. Vegetative characteristics of three low-lying Florida coastal rivers in relation to flow, light, salinity, and nutrients. *Hydrobiologia* 528: 31–43.

Jones, G.W., S.B. Upchurch, K.M. Champion, and D.J. Dewitt. 1997. Water quality and hydrology of Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring Complexes, Citrus and Hernando Counties, Florida. Origin of increasing nitrate concentrations. Prepared for the Southwest Florida Water Management District.

Katz, B.G., H.D. Hornsby, J.K. Bohlke, and M.F. Mokray. 1999. *Sources and chronology of nitrate contamination in spring waters, Suwannee River Basin, Florida.* U.S. Geological Survey Water Resources Investigations Report 99-4252.

Knochenmus, L.A., and D.K. Yobbi. 2001. Hydrology of the coastal springs ground-water basin and adjacent parts of Pasco, Hernando, and Citrus Counties, Florida. U.S. Geological Survey Water-Resources Investigations Report 01-4230.

Maddox, G. L. and E. Wade. 2014. Ellie Schiller Homosassa Springs Wildlife State Park – Wildlife Park Water Quality Assessment, Citrus County, Florida; Florida Dept of Environmental Protection.

Miami News. June 25, 1976. Weeki Wachee is suing Deltona over pollution. Section 12A.

Murray, L., R.B. Sturgis, R.D. Bartleson, W. Severn, and W.M. Kemp. 1999. Scaling submersed plant community responses to experimental nutrient enrichment. In *Seagrasses: Monitoring, ecology, physiology, and management,* S.A. Bortone, Ed. (Boca Raton, FL: CRC Press, pp. 241–258).

Mylavarapu, R., D. Wright, G. Kidder, and C.G. Chambliss. 2009. *UF/IFAS standardized fertilization recommendations for agronomic crops.* SL129. Gainesville, FL: University of Florida, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences.

National Oceanic and Atmospheric Administration. 2013. *Online meteorological data.*

Research Data Services. 2013. Citrus County Tourism. Presented to Citrus County Tourist Development Council. Lecanto, Florida.

Roadcap, G.S., K.C. Hackley, and H.H. Hwang. 2002. *Application of nitrogen and oxygen isotopes to identify sources of nitrate.* Report to the Illinois GW Consortium, Southern Illinois University.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry, Jr., and R.W. Hull. 1977. *Springs of Florida.* Geological Bulletin No. 31, revised. Tallahassee, FL: Florida Geological Survey.

Sartain, J.B., L.T. Trenholm, E.F. Gilman, T.A. Obreza, and G. Toor. 2009. *Frequently asked questions about landscaping fertilization for Florida-friendly landscaping ordinances.* ENH1115. Gainesville, FL: University of Florida, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences.

Scott, T.M., K.M. Campbell, F.R. Rupert, J.D. Arthur, and T.M. Missimer. 2001. *Geologic map of the state of Florida.* Florida Department of Environmental Protection, Florida Geological Survey Map Series 146.

Scott, T., G.H. Means, R.C. Means, and R.P. Meegan. 2002. *First magnitude springs of Florida.* Florida Geological Survey Open File Report No. 85. Tallahassee, FL: Florida Department of Environmental Protection, Florida Geological Survey.

Scott, T.M., G.H. Means, R.P. Meegan, R.C. Means, and S.B. Upchurch. 2004. *Springs of Florida.* Bulletin No. 66. Tallahassee, FL: Florida Department of Environmental Protection, Florida Geological Survey.

Scruggs, L. 2013. *Economic impact assessment—Florida State Park system.* Tallahassee, FL: Florida Department of Environmental Protection, Florida Park Service, Office of Park Planning.

Sepulveda, N. 2002. Simulation of ground-water flow in the intermediate and Floridan aquifer systems in peninsular Florida. U.S. Geological Survey Water-Resources Investigations Report 02-4009.

Sickman *et al.* 2009. A Comparison of Internal and External Supply of Nutrients to Algal mats in Two First Magnitude Springs in Florida. J. Aquat. Plant Management, 47: 135-144.

Stevenson, R.J., A. Pinowska, and Y.K. Yang. 2004. *Ecological condition of algae and nutrients in Florida springs.* Tallahassee, FL: Florida Department of Environmental Protection.

Stevenson, R.J., A. Pinowska, A. Albertin, and J.O. Sickman. 2007. *Ecological condition of algae and nutrients in Florida springs: The synthesis report.* Submitted to the Florida Department of Environmental Protection.

Southwest Florida Water Management District. 1991. Resource evaluation of the Weekiwachee riverine system proposed water management land acquisition.

———. 1994. Weeki Wachee River diagnostic/feasibility study. Section V, Submerged aquatic vegetation.

______. July 2000. Crystal River/Kings Bay Surface Water Improvement and Management (SWIM) Plan.

______. May 2001. The hydrology and water quality of select springs in the Southwest Florida Water Management District. Prepared by the Water Quality Monitoring Program.

———. 2012. Recommended Minimum Flows for the Homosassa River System. Brooksville, FL.

Tennille. 2014. Email from Kimberlee Tennille to James Dodson, May 22, 2014

Terrell and Canfield. 1996. Terrell, J.B. and D.E. Canfield. 1996. Evaluation of the effects of nutrient removal and the "Storm of the Century" on submersed vegetation in Kings Bay – Crystal River, Florida. *Journal of Lake and Reservoir Management* 12(3): 394–403.

Tetzlaff *et al.* 2010. Comparison of Bioenergetics Parameters from Two Spring-fed Riverine Largemouth Bass Populations. The Open Fish Science Journal, 3: 87-100.

University of Florida Bureau of Economic and Business Research. 2014. *Florida estimates of* population 2013.

Upchurch, S.B., and F.W. Lawrence, 1984. Impact of ground-water chemistry on sinkhole development along a retreating scarp. In B.F. Beck (ed.), Sinkholes: Their Geology, Engineering & Environmental Impact. Rotterdam, A.A. Balkema, pp. 23-28.U.S. Census Bureau website. 2010. Available: http://www.census.gov/.

U.S. District Court. August 2, 1974. United States of America vs. John R. Underwood, W.G. Underwood, and R.W. Underwood, Jr., Case Number 70-389-CIV-T-K.

U.S. Environmental Protection Agency. November 2006. Memorandum establishing TMDL "daily" loads in light of the decision by the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et al., No.05-5015 (D.C. Cir. 2006) and implications for NPDES permits. Washington, DC.

———. June 2007. Options for expressing daily loads in TMDLs (The Option).

U.S. Geological Survey. 2010. Karst and the USGS: What is karst? Available: http://water.usgs.gov/ogw/karst/index

Wetland Solutions, Inc. 2010. *An ecosystem-level study of Florida's springs–Final report.* Florida Fish and Wildlife Conservation Commission Project Agreement No. 08010.

Wetterhall, W.S. 1964. *Geohydrologic reconnaissance of Pasco and Southern Hernando Counties, Florida.* Florida Geological Survey Report of Investigations No. 34.

Woods Hole Group. April 2007. Final report – Natural attenuation of nitrogen in wetlands and waterbodies. East Falmouth, MA.

Yeager, T.H. 2009. *Current fertilization practices used in container nurseries.* Unpublished manuscript. Gainesville, FL: University of Florida, Institute of Food and Agricultural Sciences.

Zarbock, H. April 1988. *Homosassa River study, field inspection.* Memo to file. File #11295.04. Tampa FL: Florida Land Design & Engineering, Inc.

Zervas. 2001. Sea level variations of the United States, 1854-1999. Silver Spring, Md.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

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 Chapter 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.

Chapter 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 five 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 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 one and five 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.