SOUTHWEST DISTRICT • SPRINGS COAST BASIN

FINAL TMDL Report

Nutrient TMDLs for Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs (WBIDs 1348Z, 1348D, and 1361B)

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

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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/

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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 Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay 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 Springs Coast Basin adopted by Secretarial Order in February 2012. The TMDLs establish the allowable level of nutrient loadings to Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs 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

For assessment purposes, the Department has divided the waters of the state into water assessment polygons with a unique **w**ater**b**ody **id**entification (WBID) number for each watershed or stream reach. Beteejay Springs is WBID 1361B, Chassahowitzka Springs Group and Crab Creek Springs Group are associated with WBID 1348Z, and Chassahowitzka River–Baird Creek (which includes Baird Springs and Ruth Spring) is WBID 1348D. **Figure 1.1** displays the major geopolitical and hydrologic features in the estimated contributing area in Citrus and Hernando Counties. **Figure 1.2** contains a map of the three impaired WBIDs.

1.2.1 Chassahowitzka Springs Group (WBID 1348Z)

Chassahowitzka Springs Group (WBID 1348Z) consists of Chassahowitzka Main Spring, Chassahowitzka #1, and Crab Creek Spring. The Chassahowitzka Springs Group are the headwaters of the Chassahowitzka River, which flows westward six miles to the Gulf of Mexico. Chassahowitzka Springs and the Chassahowitzka River support a complex aquatic ecosystem and together are an important cultural and economic resource for the state. **Figure 1.3** shows an aerial photograph of this system.

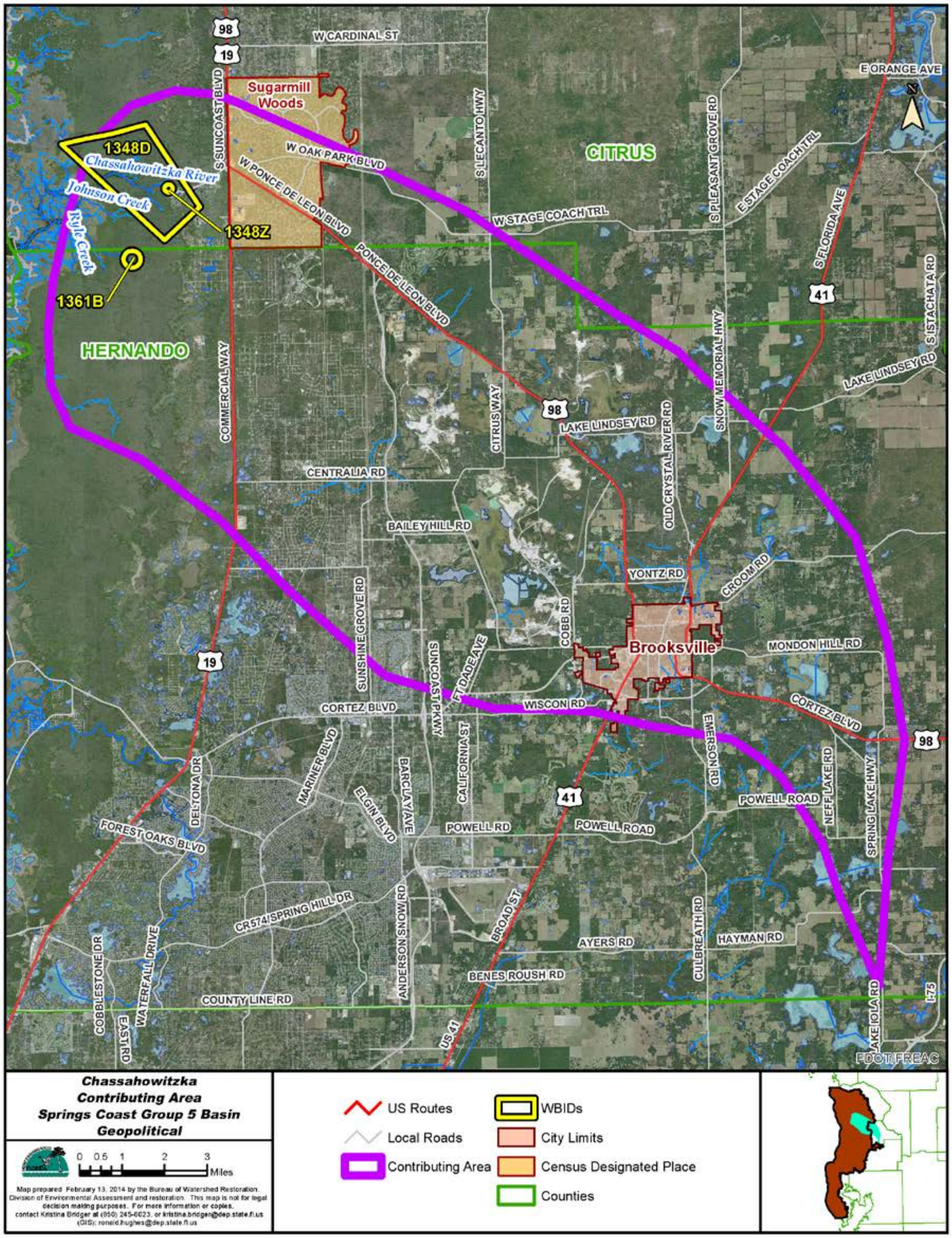

Figure 1.1. Major geopolitical and hydrologic features in the estimated contributing area in Citrus and Hernando Counties

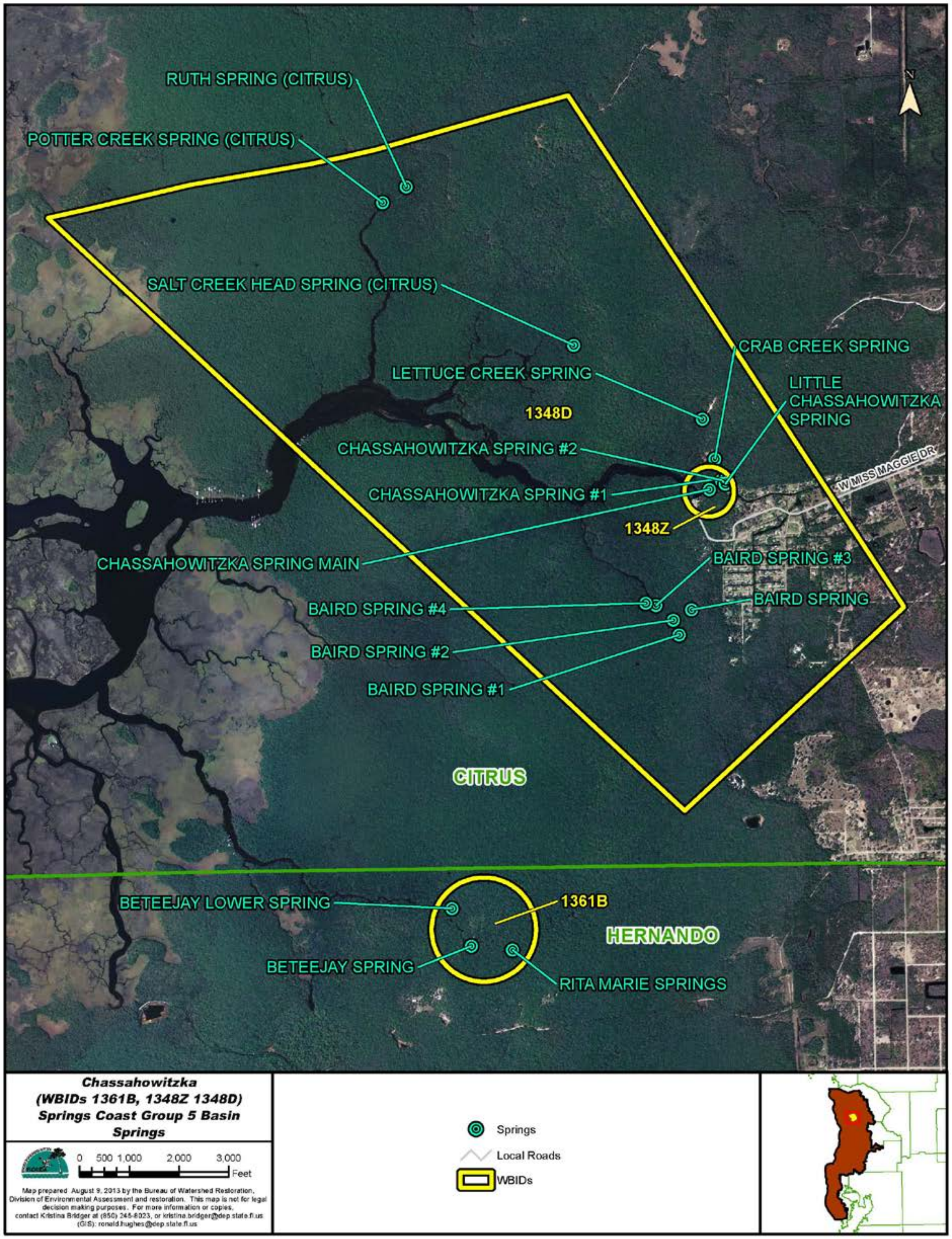

Figure 1.2. Named springs and impaired WBIDs in the Chassahowitzka Springs area

Figure 1.3. Aerial photograph of Chassahowitzka Spring and the headwaters of the Chassahowitzka River (Florida Geological Survey 2010)

Chassahowitzka Main Spring is located in Citrus County and is situated in about 20 feet of water approximately 100 feet east of the Chassahowitzka River Campground boat ramp. The main pool is circular, and about 150 feet in diameter. Chassahowitzka #1 and #2 are located in a small tributary approximately 100 feet upstream from the main spring on the Chassahowitzka River (WBID 1348D).

Crab Creek Spring is located approximately 650 feet due north of the main spring at the head of Crab Creek. Crab Creek discharges into the Chassahowitzka River a short distance downstream from Chassahowitzka Main Spring. The spring discharge produces a noticeable boil at the water surface, especially during low tide (Southwest Florida Water Management District [SWFWMD] 2011). Wetterhall (1965) describes the vent as being three feet in diameter and lying in approximately 13 feet of water. Crab Creek Spring discharges brackish water during low tide, and its water quality changes significantly over a tidal cycle (Yobbi 1992).

1.2.2 Chassahowitzka River–Baird Creek (WBID 1348D)

Chassahowitzka River–Baird Creek (WBID 1348D) consists of the upstream portion of the Chassahowitzka River, Baird Creek, Baird Springs, and Ruth Spring. It is located in southwestern Citrus County approximately six miles south of the town of Homosassa Springs. The freshwater portion of the Chassahowitzka River immediately adjoins the tidal/estuarine portion of the river. Nutrient enrichment in the estuarine segment of the Chassahowitzka River will be addressed in a future TMDL.

Baird #1 Spring is located in Citrus County approximately 0.5 miles west of Chassahowitzka Main Spring. Baird #1 Spring emanates from a fracture in the limestone that is three to five feet wide and 20 feet in length. Baird Spring forms the headwaters of Baird Creek.

Ruth Spring is located approximately 300 feet northeast of Potter Creek Spring near the head of a short spring run, and the spring emanates from a large fracture in the limestone and lies in several feet of water (SWFWMD 2011). Ruth Spring discharges brackish water during low tide, and its water quality changes significantly over a tidal cycle (Yobbi 1992).

1.2.3 Beteejay Springs (WBID 1361B)

Beteejay Springs Group (WBID 1361B) is located on private property in Hernando County approximately one mile southwest of Baird Spring. Beteejay Springs Group includes Beteejay Spring, Beteejay Lower Spring, and Rita Marie Spring. The Beteejay Spring vent is within several feet of water, and the spring pool is approximately 100 feet in diameter. Beteejay Springs Group is the headwaters of Crawford Creek.

1.3 Geological Setting and Contributing Area

In physiographic terms, the Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs Group are located in a karst plain region, where the landforms and surface water features were shaped by the dissolution of shallow underlying limestone. 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.

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 squifer (UFA) (Knochenmus and Yobbi 2001). Based on an analysis of ground water elevation maps called potentiometric surface maps, the SWFWMD created a generalized springshed boundary for the Chassahowitzka Springs Group, which also serves as the capture area for all the springs contributing to the Chassahowitzka River (Jones *et al.* 1997). Delineation based on potentiometric surface maps provides a good general description of springshed boundaries 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 the impaired waters, the Department considered the springshed as well as the combined surface watershed of the impaired receiving waters. The estimated combined contributing area of water to the Chassahowitzka Springs Group, Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Springs Group as well as the Chassahowitzka River–Baird Creek includes the springshed of the springs and the surface water watershed of their associated spring runs. Together this combined contributing area encompasses an area of 190 square miles—164 square miles in Hernando County and 26 square miles in Citrus County. **Figure 1.1** shows the estimated contributing area and its major geopolitical and hydrologic features.

The geology of the Springs Coast Basin includes thick sequences of limestone exposed at or very near to (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 [TDS], 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 (a portion of which is in the eastern part of the springshed), 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 the river and its springs (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 rainwater 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).

Figure 1.4 shows the vulnerability of the Floridan aquifer in the area contributing ground water to the springs of the Chassahowitzka River system. This Hernando County portion of the map is based on the statewide Florida Aquifer Vulnerability Assessment (FAVA) model that was developed by the Florida Geological Survey using conditions such as soil characteristics, depth to ground water, recharge rate, and the prevalence of sinkhole features (Arthur *et al*. 2007). The Citrus County portion of the map is based on the same FAVA components, but at a higher resolution set of data that was used to develop the Citrus County Aquifer Vulnerability Assessment (Baker, 2009). The figure shows that most of this contributing area is vulnerable to ground water contamination compared with other regions of the state.

1.4 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 403.67, 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 these impaired waters will be followed by the development and implementation of a BMAP to reduce the levels of nutrients that contribute to the ecological imbalance in Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs Group. The restoration of these waterbodies will depend heavily on the active participation of the Department and stakeholders in the contributing area, including the United States Fish and Wildlife Service (FWS), Florida Fish and Wildlife Conservation Commission (FWC), Hernando County, Citrus County, other local governments, Chassahowitzka River Restoration Committee, 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.

The Chassahowitzka River and its springs are located in southwestern Citrus County; however, their contributing area also includes northern Hernando County. The area includes the large unincorporated community of Sugarmill Woods and extends as far as the city of Brooksville to the southeast.

The Chassahowitzka River and its springs are economically valuable to the state and local communities. A public boat ramp and nearby land are owned by the SWFWMD and have been leased to Citrus County since 1991. The nearby land is used as a campground. The Chassahowitzka River Campground and the public boat ramp are operated by Moore and Moore Management Services under agreement with Citrus County. Downstream portions of the river corridor are within the Chassahowitzka National Wildlife Refuge (NWR), which is managed by the FWS, and are the northern boundary of the Chassahowitzka Wildlife Management Area (WMA), which is managed by the FWC.

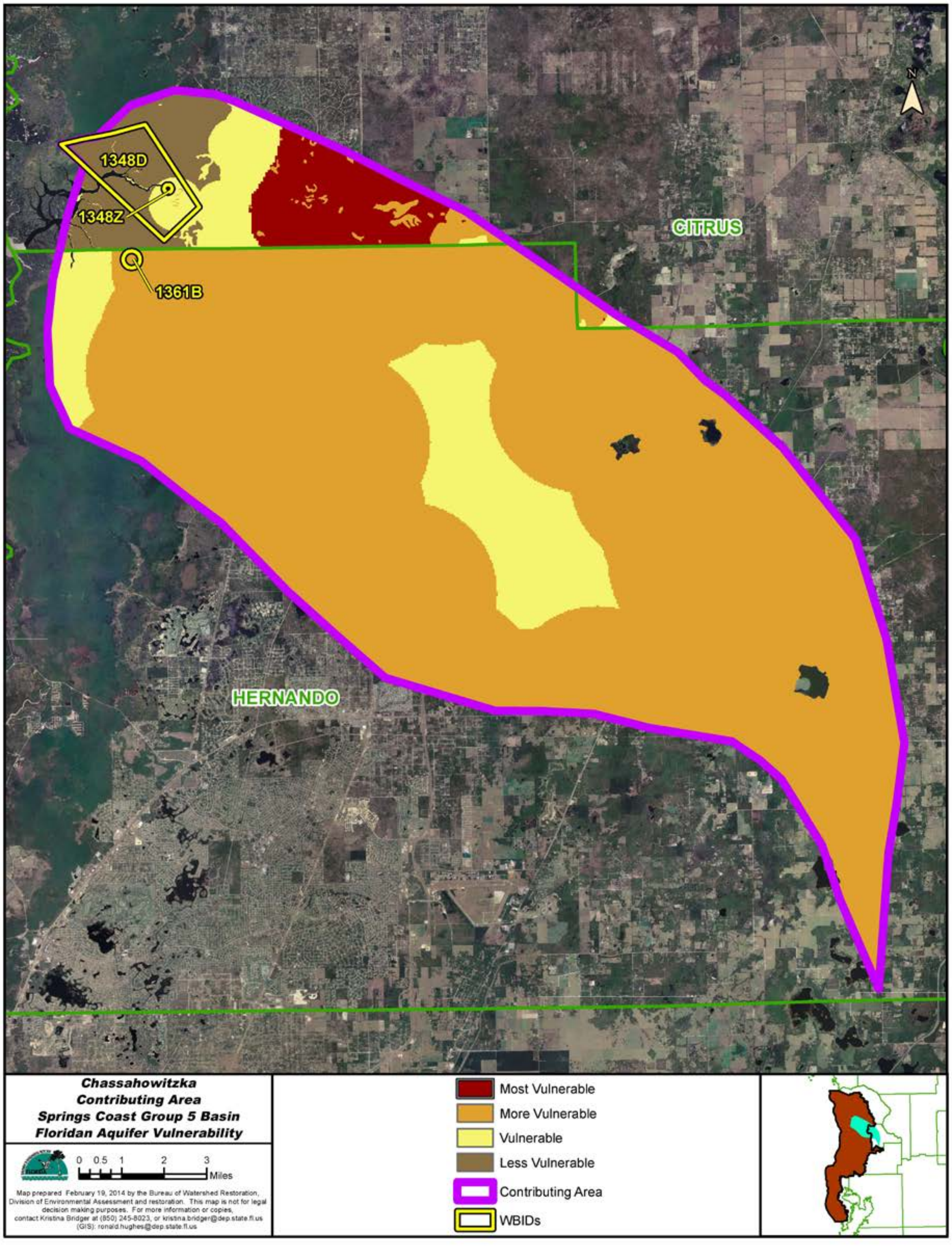

Figure 1.4. FAVA map in the contributing area for the springs of the Chassahowitzka River in Hernando County (Arthur 2007) and Citrus County (Baker 2009)

1.4.1 Chassahowitzka NWR

The Chassahowitzka NWR (**Figure 1.5**), established in 1941, comprises over 31,000 acres of saltwater bays, estuaries, and brackish marshes at the mouth of the Chassahowitzka River. The Chassahowitzka NWR is located approximately 65 miles north of St. Petersburg. A boat ramp, maintained by Citrus County, provides a launching point for boats on the Chassahowitzka River for a small fee. The refuge is located approximately three miles downstream from this boat ramp. The refuge was established primarily to protect waterfowl habitat and is home to over 250 species of birds, over 50 species of reptiles and amphibians, and at least 25 different species of mammals, including the endangered West Indian manatee.

1.4.2 Chassahowitzka WMA

In 1985 land for the Chassahowitzka WMA (**Figure 1.6**) was purchased from the Lykes Brothers and the Turner Corporation as part of Florida's Conservation and Recreation Lands (CARL) Program. In 1988, another 150 acres was added to compensate for the loss of red-cockaded woodpecker habitat in Marion County. In 1996, the first portion of the Weeki Wachee tract was purchased. The Seville and Annutteliga Hammock tracts east of Highway 19 were purchased in 1998 and provide an upland buffer for coastal lands as well as a geographic link to the Withlacoochee State Forest. In 2000, the FWC approved the purchase of an additional 720 acres. Bordered on the west by the Chassahowitzka NWR, the 34,597-acre Chassahowitzka WMA is part of a nearly unbroken crescent of protected public lands stretching 200 miles from Pasco County to the Apalachicola River. Nature enthusiasts can hunt deer and small game or hike along trails through rare sandhill and scrub communities.

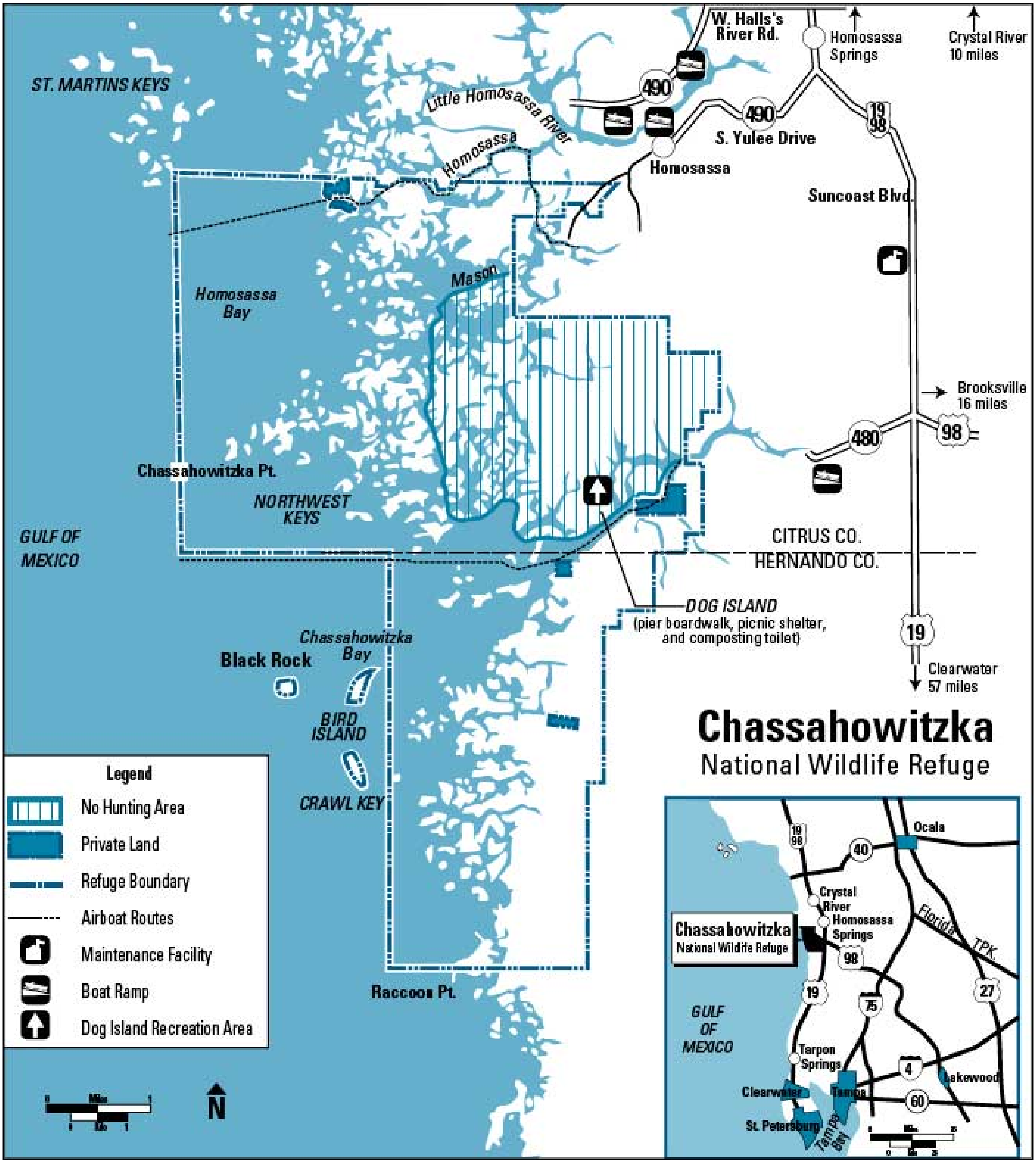

Figure 1.5. Map of the Chassahowitzka NWR (provided by FWS)

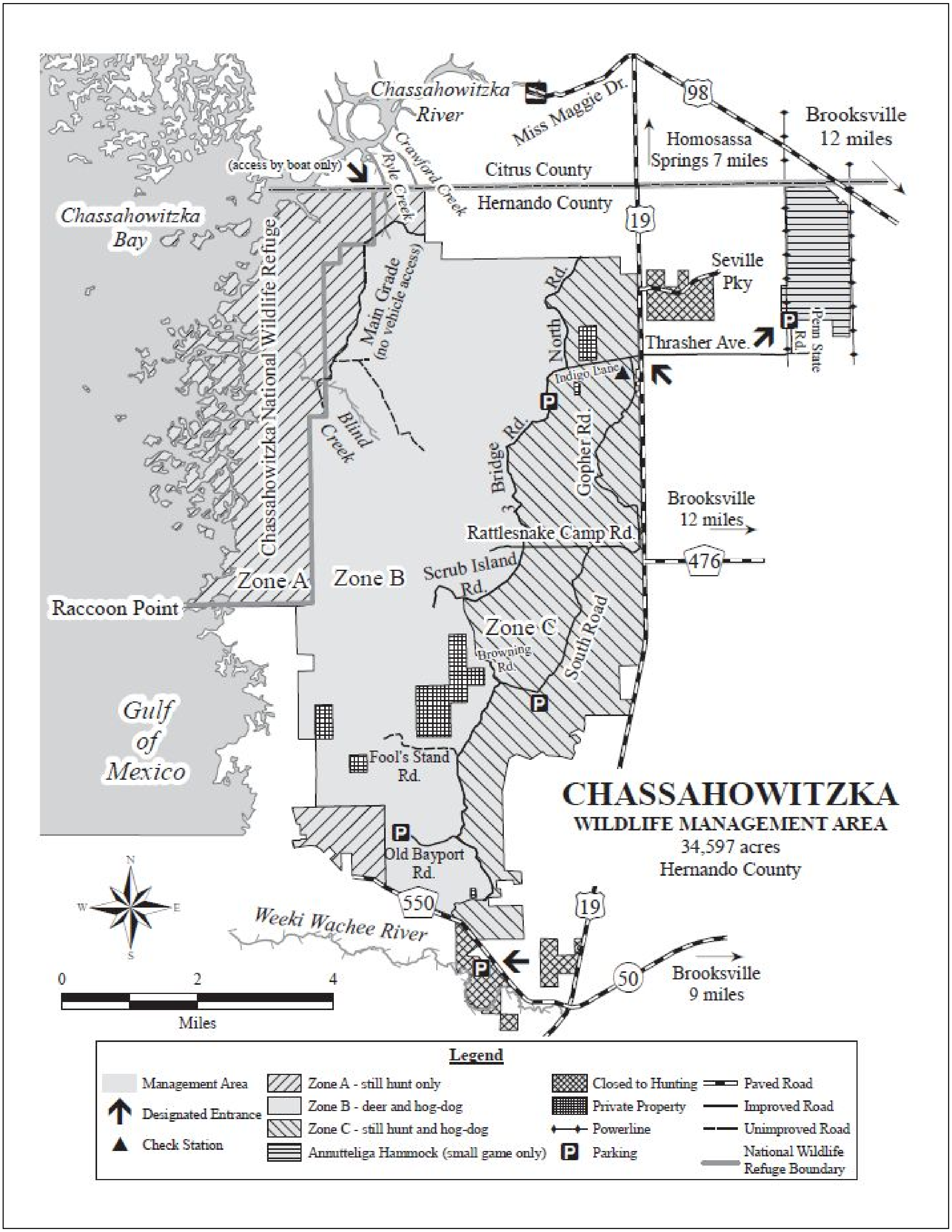

Figure 1.6. Map of the Chassahowitzka WMA (provided by FWC)

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 Rule 62-303, Florida Administrative Code (F.A.C.) (Identification of Impaired Surface Waters Rule, or IWR), in April 2001. The IWR was modified in 2006 and 2007.

2.2. Information on Verified Impairment

Rule 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, and other sources to evaluate impairment status of the springs in the Springs Coast Basin based on nitrate concentrations and evidence of ecological imbalance. 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
1348Z	Chassahowitzka Springs Group Crab Creek Spring	Nutrients (Algal Mats)
1348D	Chassahowitzka River–Baird Creek Baird Springs Ruth Spring	Nutrients (Algal Mats)
1361B	Beteejay Springs	Nutrients (Algal Mats)

2.3 Nutrients

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 previous and ongoing research on many Florida springs have led to a greater understanding of 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 these impaired waters 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 Algae and Diatoms

Evidence of an increasing trend in algal coverage and algal smothering, specifically *Lyngbya* sp., has been documented at Chassahowitzka Springs. Also, an increasing trend in algal coverage and algal smothering, especially the filamenous algae *Chaetomorpha* sp. (commonly known as horsehair algae), has been documented in Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Springs Group. In addition, overgrowth of the diatom *Fragilaria* cf *capucina* has been documented at Crab Creek Spring and Baird Spring.

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 the mats are floating, wind and water currents can move them 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 Department has not been able to obtain documentation of exactly when the algal overgrowth began in these impaired waters. The earliest mention of diatoms in the Chassahowitzka Springs area was in Whitford (1956), which describes an abundance of algal flora, including a mention that the diatom *Cyclotella meneghiniana* was also abundant in algal mats. Both Whitford (1956) and Wetterhall (1965) mentioned the presence of algal growth, but there was no mention of an imbalance due to overgrowth of algae.

The response of algae to nutrient enrichment in these impaired waters 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), 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) and Frazer *et al.* (2006) documented these conditions between 1998 and 2005 in the Chassahowitzka River as well as two other spring-run river systems in the Springs Coast region: Weeki Wachee and Homosassa (for which a TMDL is also being developed).

Recent photographs, taken within the past five years, document the conditions within the aquatic community in Chassahowitzka Springs, Crab Creek Spring, Baird Springs, and Beteejay Springs (**Figures 2.1** through **2.5**).

Figure 2.1. Algae at Chassahowitzka #1 Spring, October 2008 (photo by G. Maddox, Department)

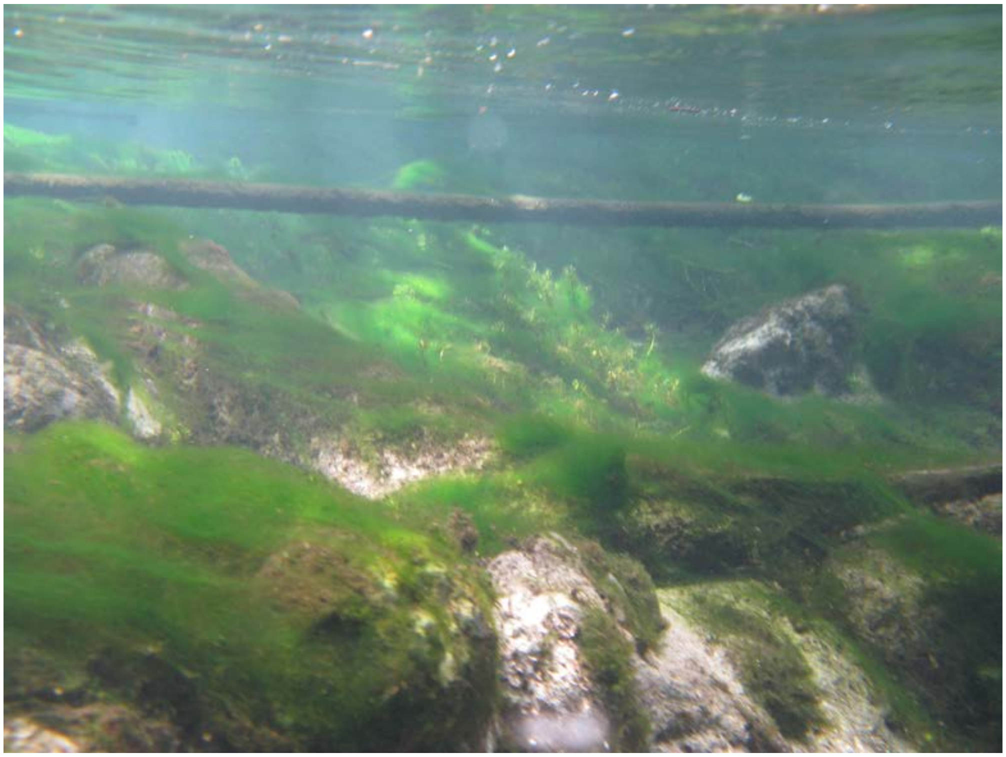

Figure 2.2. Algal growth in Chassahowitzka Main Spring, September 2008 (photo by G. Maddox, Department)

Figure 2.3. Diatoms at Crab Creek Spring, October 2008 (photo by G. Maddox, Department)

Figure 2.4. Aerial photo of filamentous algae at Crab Creek Spring Run, 2012 (photo by Florida Geological Survey)

Figure 2.5. Horse hair algae, Beteejay Spring Run, March 2011 (photo by G. Maddox, 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 for largemouth bass (*Micropterus salmoides*) populations, the weight-at-age and length-at-age were higher in a patchy heterogeneous distribution of submersed aquatic vegetation (SAV) than SAV limited to primarily filamentous algae.

2.4.3 Other Ecological Issues

A small amount of the natural land cover around these impaired waters has been extensively altered. The spring pool and adjacent areas underwent significant development with the construction of residential homes. Also, residential land development has occurred along Baird Creek.

Filamentous algal mats have the potential to trap particles, causing the development and accumulation of muck sediments. Accumulated muck sediments and algal growth in the spring pool were removed from the Chassahowitzka headsprings by a SWFWMD dredging project. The project began in May 2013 and was completed in October 2013 (SWFWMD 2014). Suction pumps were used to remove excess sediment in the spring basin, and a number of archaeological artifacts, dating from 12,000 years ago to the present, were discovered in the process. This project was an important first step in the restoration of a diverse spring ecosystem, and additional phases are being planned for the future (SWFWMD 2014).

2.5 Monitoring Sites and Sampling

Historical water quality data for the impaired springs and the Chassahowitzka River are limited, but they do provide a glimpse of current versus "background" water quality. Data providers within the Chassahowitzka River contributing area are the SWFWMD, Department, United States Geological Survey (USGS), and LakeWatch (a volunteer monitoring program funded by the University of Florida). Biological and water quality data have been collected from various locations around the springs and in the river. The Florida Storage and Retrieval (STORET), 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 (**Figure 2.6**). The Chassahowitzka River is sampled every month, and the springs are sampled four times a year (January, April, July, and October). This schedule is the part of the SWFWMD routine water quality sampling program.

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 Chassahowitzka Springs Group and Crab Creek Spring. **Figure 2.8** shows the same information for Chassahowitzka River–Baird Creek, Baird Springs, and Ruth Spring, and **Figure 2.9** contains information on Beteejay 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, to June 30, 2011) plus more recent data (2012–13), and are the result of sampling done by the SWFWMD, USGS, LakeWatch, and Department.

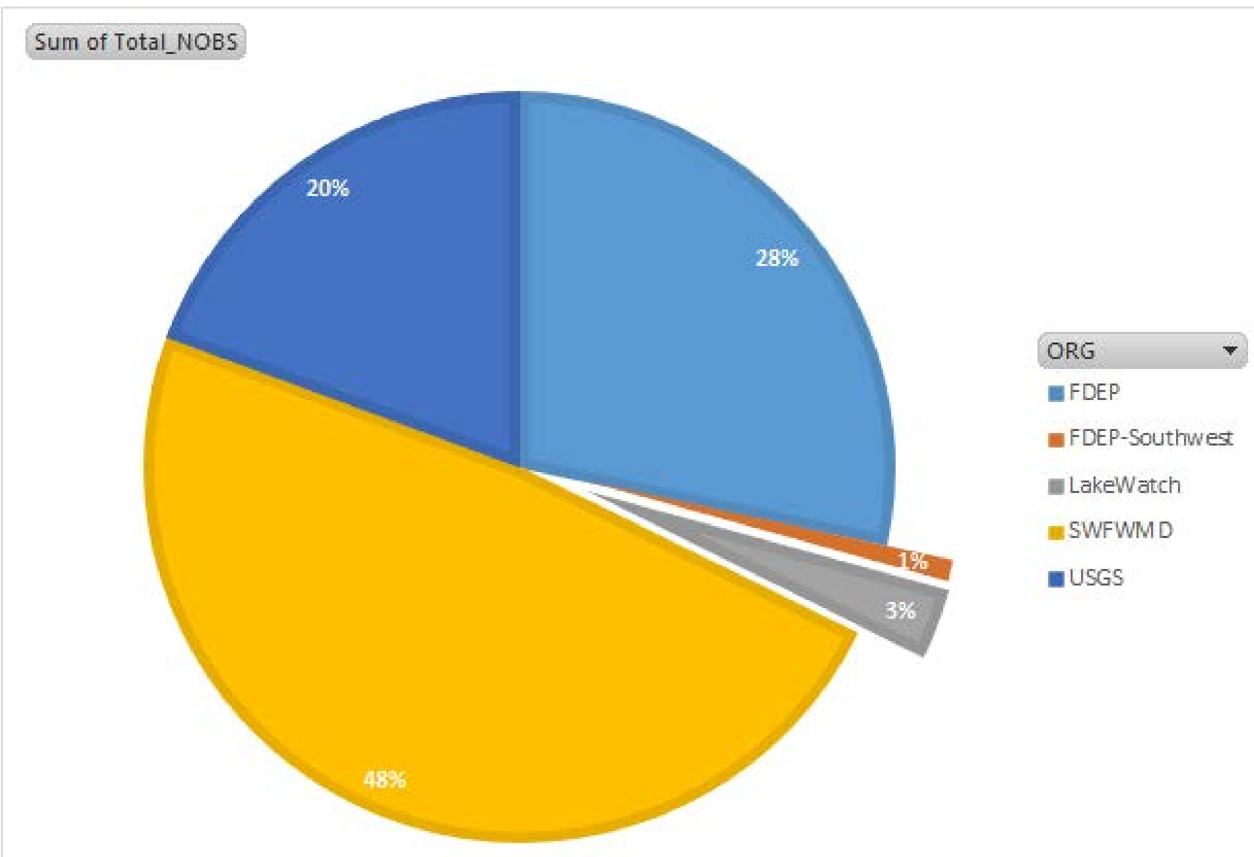

Figure 2.6. Water quality and biological data providers within the Chassahowitzka River contributing area

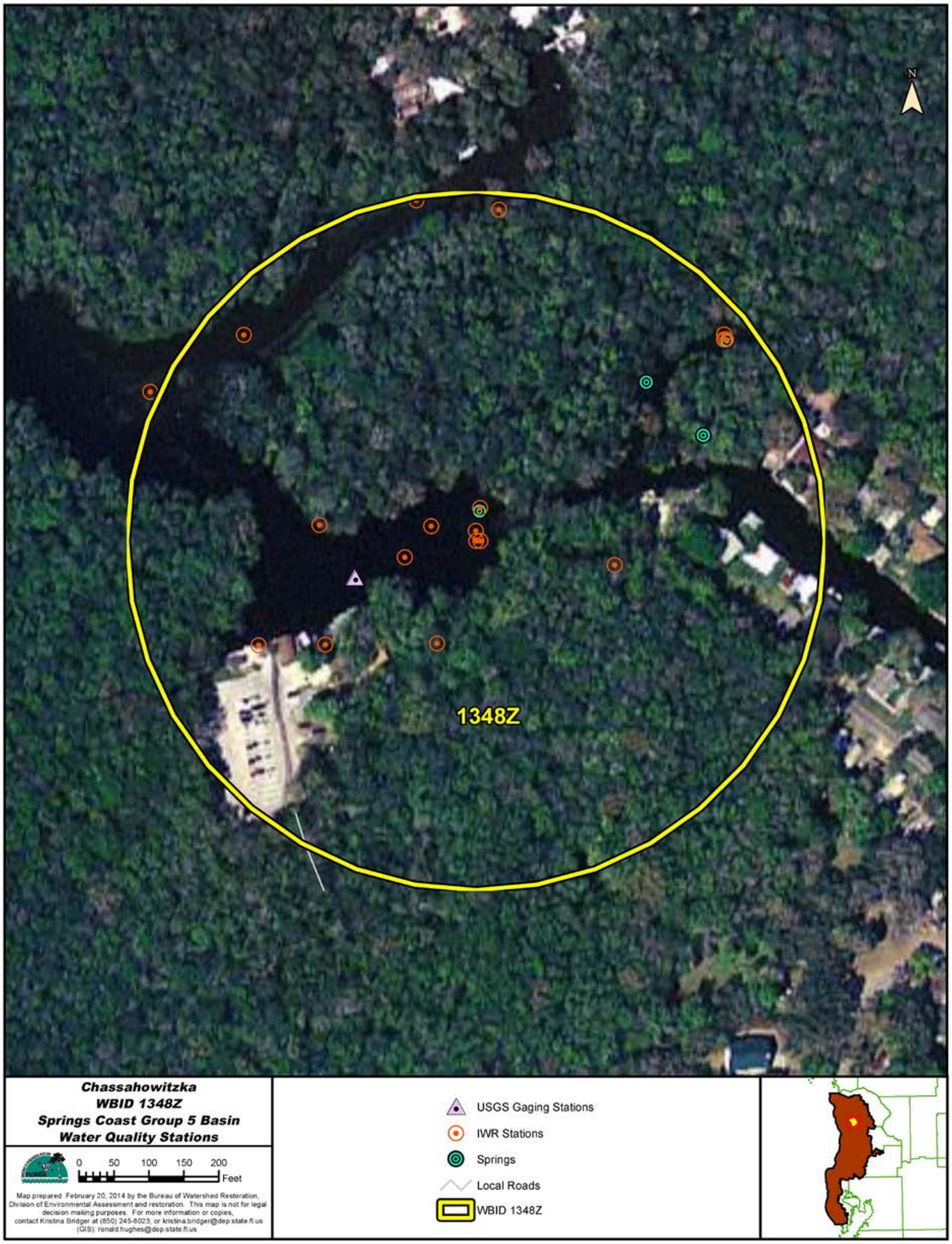

Figure 2.7. Water monitoring sites associated with impaired Chassahowitzka Springs Group and Crab Creek Spring (WBID 1348Z) (based on Department dataset)

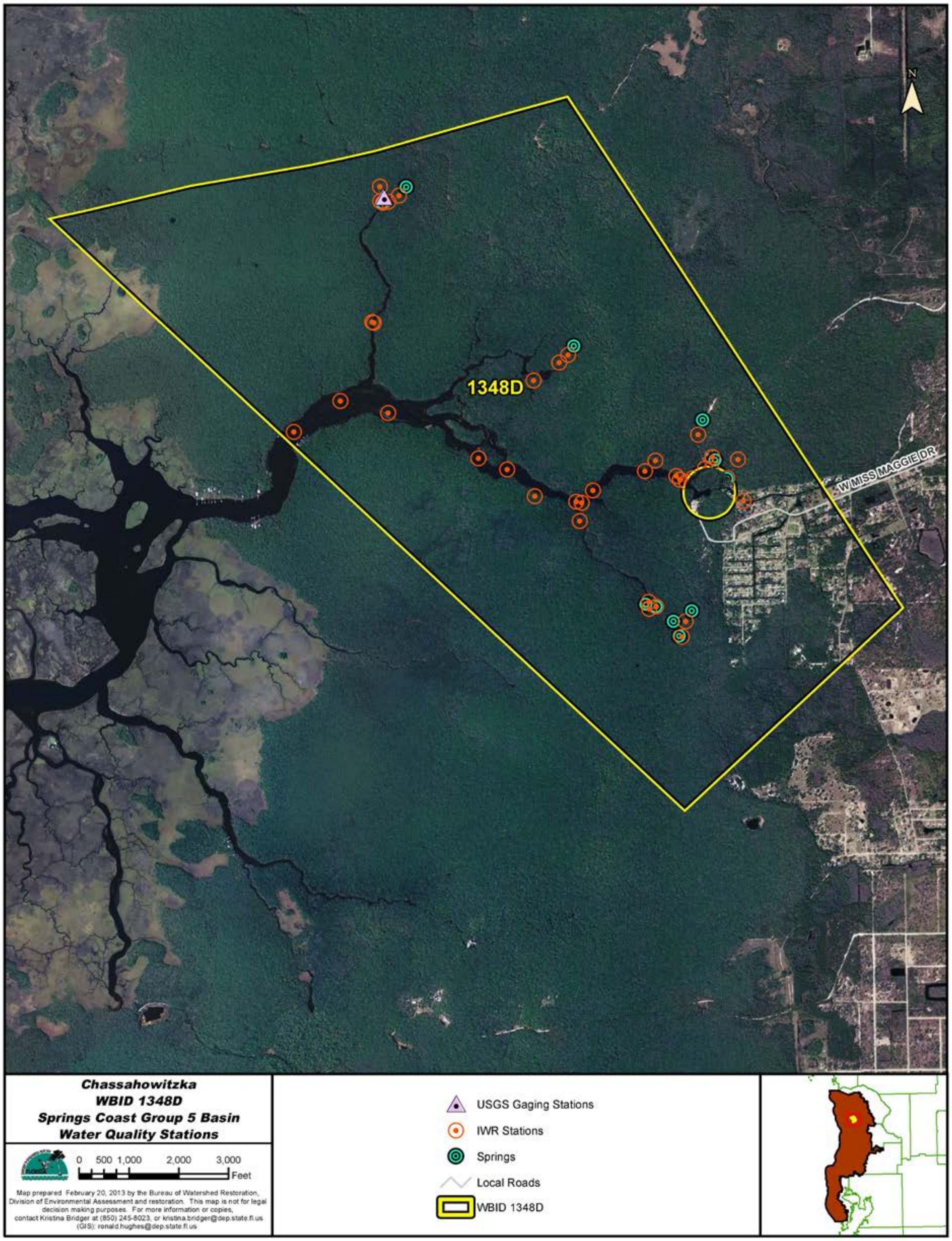

Figure 2.8. **Water monitoring sites associated with impaired Chassahowitzka–Baird Creek, Baird Springs, and Ruth Spring (WBID 1348D) (based on Department dataset)**

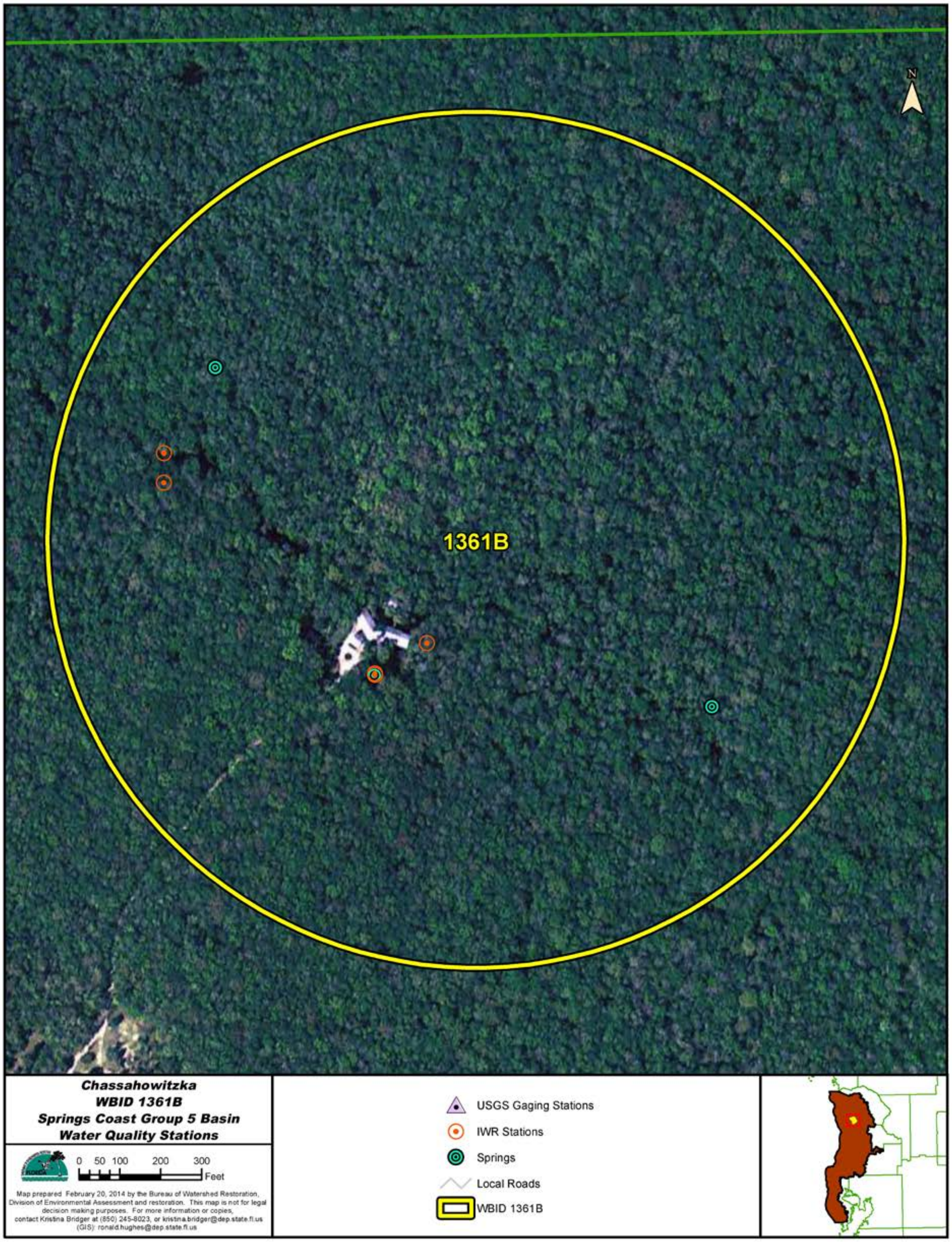

Figure 2.9. Water monitoring sites associated with impaired Beteejay Springs (WBID 1361B) (based on Department dataset)

2.6 Rainfall and Temperature Data

The climate in the Chassahowitzka 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 amounts for Hernando County were used to reflect precipitation in the Chassahowitzka springshed because most of the springshed lies in Hernando County (SWFWMD 2014). Rainfall and temperature data were reviewed for the 30-year period of record from January 1984 through December 2013 (**Table 2.2**). Annual rainfall amounts average approximately 51.19 inches per year (in/yr), with an average air temperature of about 71.1° F. (National Oceanic and Atmospheric Administration [NOAA] 2014).

Figure 2.10 shows the 30-year historical rainfall trend measured for Hernando County. Over the 30-year period, the lowest annual rainfall of 34.20 inches occurred in 2000, and the highest annual rainfall of 64.45 inches occurred in 1988. Annual average rainfall from 1984 to 2013 was 51.19 inches.

Table 2.2. Temperature at Weeki Wachee (NOAA Station - 089430) and precipitation for Hernando County, January 1984–December 2013

Analysis	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
30-Year Mean–Maximum Temperature (°F.)	79.0	80.1	83.6	88.7	91.8	93.7	94.9	94.1	93.9	88.5	83.2	79.9	86.5
30-Year Mean–Minimum Temperature (°F.)	45.0	48.1	52.1	57.1	64.0	70.7	72.1	72.3	70.0	62.4	53.9	47.6	59.4
30-Year Mean–Average Temperature (°F.)	57.9	60.7	64.6	69.8	75.7	80.5	81.8	81.9	80.1	73.9	66.3	60.2	71.1
30-Year Mean–Precipitation (inches)	2.98	2.58	3.87	2.33	2.63	8.03	8.07	7.78	6.13	2.72	1.81	2.26	51.19

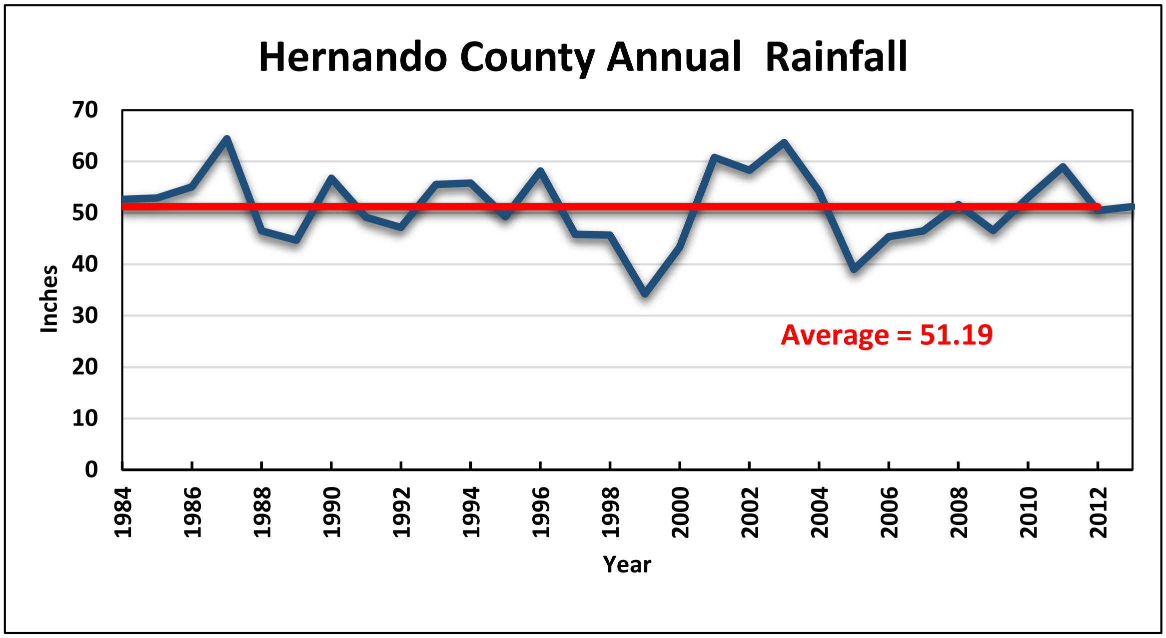

Figure 2.10. Thirty-year precipitation for Hernando County, January 1984–December 2013 (SWFWMD 2014)

2.7 Discharge Data and Residence Time

The USGS collects flow measurements for the Chassahowitzka River (#02310650). The discharge measured at the Chassahowitzka River (#02310650) includes contributions from Chassahowitzka Main Spring and Chassahowitzka #1 Spring, which also reflects flow from this first-magnitude springs group. **Figure 2.11** displays the daily mean discharge data, and **Table 2.3** shows the annual mean discharge data for the Chassahowitzka River from 1997 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 Chassahowitzka River 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 was approximately six to nine inches (Douglas 1991; Zervas, 2001).

Compared with free-flowing freshwater spring runs (flushing rates on the order of hours), tidally influenced waterbodies such as the Chassahowitzka 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 Chassahowitzka River. Residence time is the time needed to flush a pollutant, such as nitrogen or phosphorus, from a defined point within a waterbody. 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 net residence time for the Chassahowitzka River using the fraction of freshwater method (EPA 1984). Based on the long-term median flow at USGS Station #02310650 from 1997 to 2007, a flow of 63.7 cubic feet per second (cfs) equals a residence time of 155 hours or 6.5 days in the river (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 Chassahowitzka River is translated into increased filamentous algae and phytoplankton production.

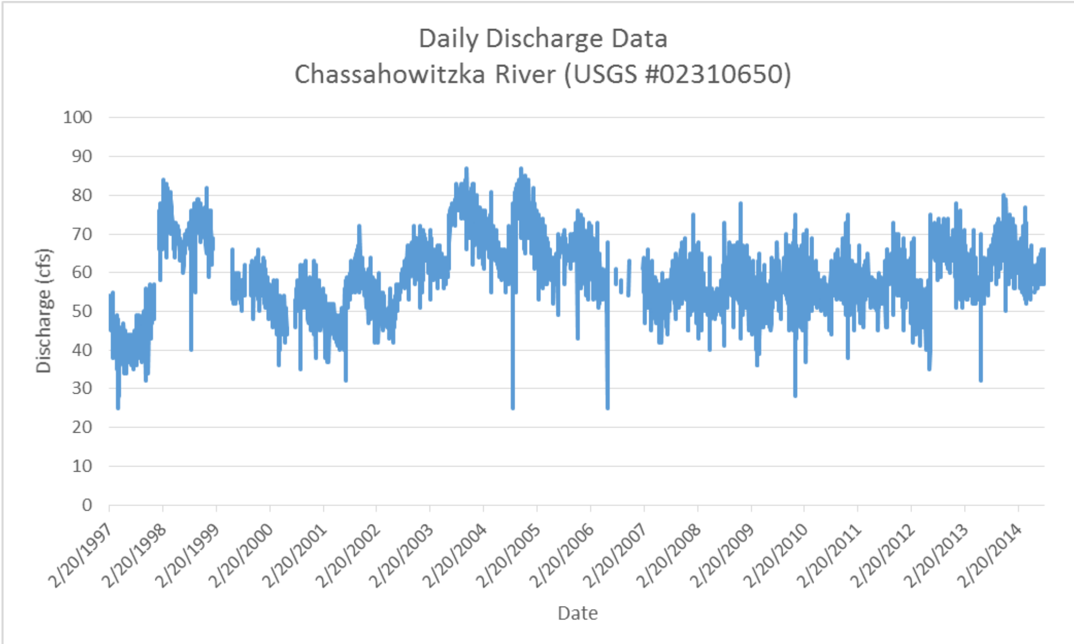

Figure 2.11. Daily mean discharge data for the Chassahowitzka River (#02310650), 1997–June 2014

Table 2.3. Annual mean discharge for the Chassahowitzka River, 1997–June 2014

* Includes USGS provisional data.

Year	Adjusted Annual Mean Discharge (cfs)
1997	43.61
1998	71.62
1999	58.73
2000	52.23
2001	52.18
2002	55.82
2003	69.89
2004	70.04
2005	66.05
2006	60.10
2007	55.41
2008	56.37
2009	55.50
2010	57.03
2011	57.33
2012	60.05
2013	61.91
2014	61.35*

2.8 Monitoring Results

2.8.1 Nitrate

Nitrogen is the nutrient most commonly causing ecological imbalances in spring systems. It is found in several forms and is ubiquitous in the environment. Seemingly low nitrogen concentrations can actually cause a significant shift in the balance of spring ecological communities, leading to the degradation of biological systems due to the overgrowth of filamentous algal mats, phytoplankton blooms, and sometimes aquatic plants (Harrington *et al.* 2010).

Total nitrogen (TN) is made up of both inorganic and organic fractions. Inorganic nitrogen components include ammonium, nitrate, and nitrite. In the Chassahowitzka River, based on the TN and nitrate data collected at surface water sampling station CV0.0 from 2005 through 2013, nitrate constitutes 37% of the TN. Therefore, the remaining nitrogen content (organic nitrogen and ammonium) in the coastal stream is approximately 63%. Various sources of organic nitrogen exist within the coastal stream, including stormwater runoff, microbial cycling, and aquatic vegetation nutrient cycling. **Figure 2.12** shows the upward trend in TN concentrations for the Chassahowitzka River. **Table 2.4a** summarizes the monitoring results for selected analytes for the river.

Nitrate (NO_3) is the form of nitrogen that occurs in the highest concentrations in ground water and springs. In comparison to surface water, the remaining nitrogen content (organic nitrogen and ammonium) 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 NO_2.

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 nitrate concentrations at the springs and wells in the contributing area (Jones *et al.* 1997), where concentrations increased 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).

Like many Florida springs, nitrate levels in all of the monitored Chassahowitzka River springs have been trending upward during the period of study (2002–12), with an approximate increase of 0.01 mg/L nitrate + nitrite (measured as N) each year.

Figure 2.13 shows the upward trend in nitrate concentrations for the six springs with sufficient data. **Tables 2.4b** through **2.4g** summarize the monitoring results for Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Springs, respectively. Reviewing the few nitrate results collected from Chassahowitzka Main Spring prior to the 2000s confirms that there has been an increasing trend over the past 66 years. In 1946, the nitrate concentration at Chassahowitzka Main Spring was measured at 0.068 mg/L, in 1962 it was 0.203 mg/L, and by the 1970s the mean value of the two samples on record was 0.209 mg/L. No nitrate samples were collected at this site during the 1980s or 1990s.

Because nitrate is the main form of nitrogen in spring water, nitrate is considered the target nutrient for Chassahowitzka Springs Group, Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Springs.

However, the nitrate in the Chassahowitzka River only constitutes 37% of the TN. Therefore, TN is considered the target nutrient for the river. **Chapter 5** discusses the nutrient impairment and the setting of the target concentration.

2.8.2 Phosphorus

Phosphorus is naturally abundant in the geologic material in much of Florida and is often naturally present in significant concentrations in both surface water and ground water. The most common form of phosphorus in geologic material is the inorganic form orthophosphate. Orthophosphate is present in limestone due to phosphorus having an affinity to bind to the calcium found in the rock formation (Fitts 2013). Only the inorganic form of phosphorus, orthophosphate, is generally found at significant concentrations in ground water and springs.

Total phosphorus (TP) includes both orthophosphate and organic forms of phosphorus. There are various sources of organic phosphorus within the coastal river, including tidal mixing with adjacent wetlands, stormwater runoff, sediment recycling, and aquatic vegetation nutrient cycling. The organic phosphorus content is normally low in spring water.

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 2.12** and **2.13; Tables 2.4a** through **2.4g)**. 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 TMDL.

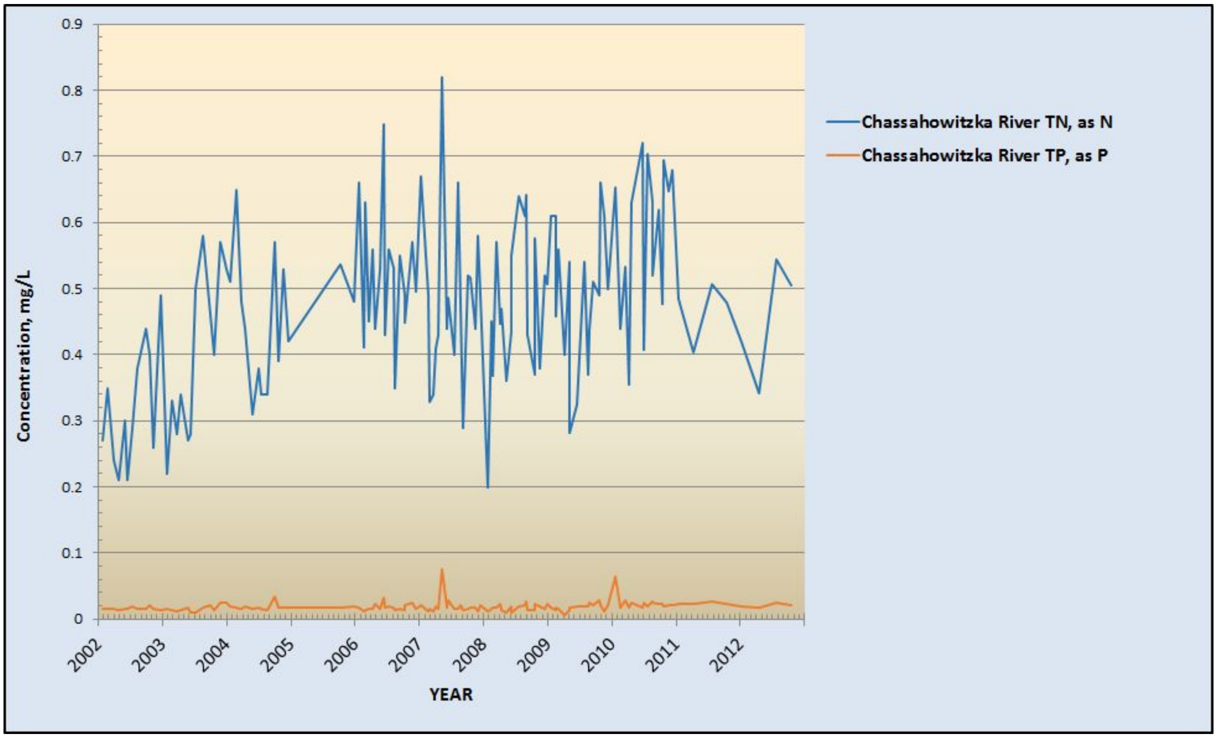

Figure 2.12. TN and TP trends in the Chassahowitzka River, 2002–12

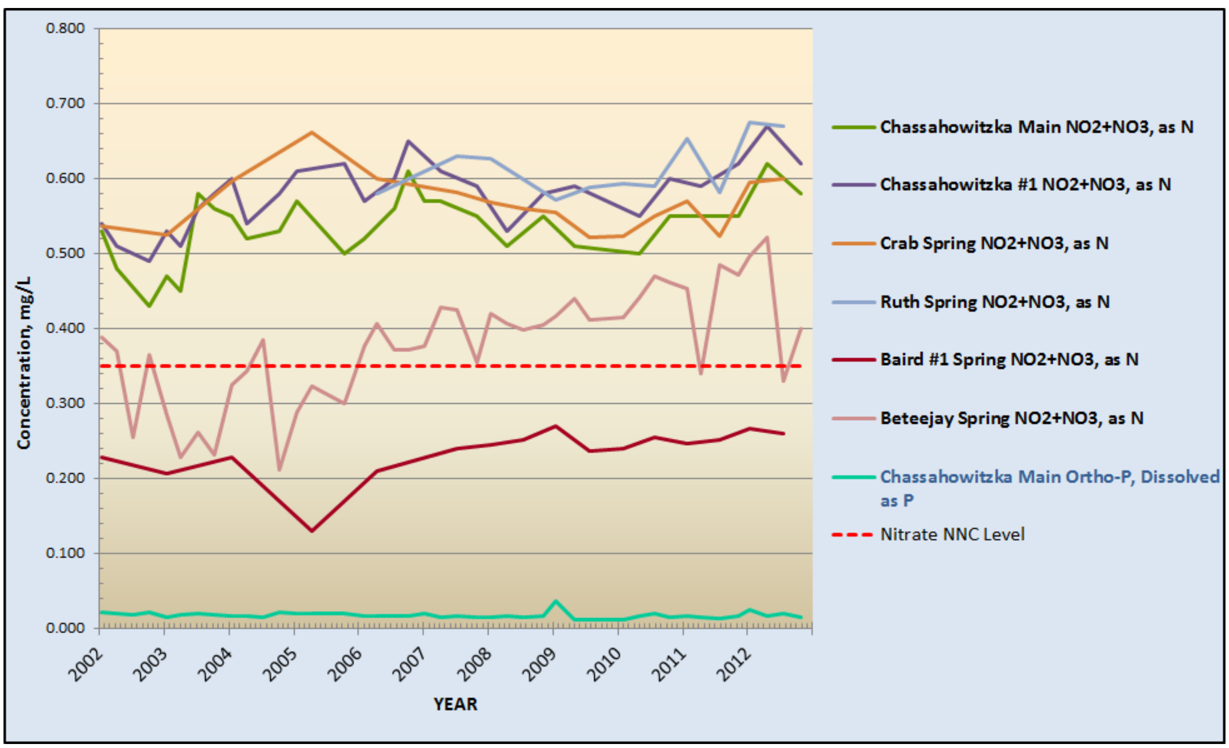

Figure 2.13. Nitrate and orthophosphate trends in Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Baird #1 Spring, Ruth Spring, and Beteejay Spring, 2002–12

Table 2.4a. Summary of selected water quality results for the Chassahowitzka River

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	TN (as N)	2002–12	mg/L	305	0.47	0.48	0.45	0.46
Macronutrients	TP (as P)	2002–12	mg/L	296	0.019	0.018	0.021	0.020

Table 2.4b. Summary of selected water quality results for Chassahowitzka 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)	2002–12	mg/L	53	0.556	0.560	0.585	0.583
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	62	0.017	0.017	0.016	0.017

Table 2.4c. Summary of selected water quality results for Chassahowitzka #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	43	0.597	0.600	0.627	0.633
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	62	0.017	0.017	0.017	0.017

Table 2.4d. Summary of selected water quality results for Baird #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	30	0.252	0.253	0.271	0.273
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	31	0.014	0.013	0.014	0.014

Table 2.4e. Summary of selected water quality results for Ruth 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	29	0.638	0.636	0.652	0.657
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	30	0.016	0.015	0.018	0.018

Table 2.4f. Summary of selected water quality results for Crab Creek 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	30	0.587	0.592	0.618	0.611
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	31	0.014	0.014	0.015	0.016

Table 2.4g. Summary of selected water quality results for Beteejay 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	43	0.375	0.384	0.437	0.449
Macronutrients	Orthophosphate, Diss (as P)	2002–12	mg/L	44	0.014	0.015	0.015	0.016

Chapter 3. DESCRIPTION OF APPLICABLE WATER QUALITY STANDARDS AND TARGETS

3.1 Classification of the Waterbody and Criteria Applicable to the TMDL

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

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

Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs (WBIDs 1348Z, 1348D, and 1361B) are Class III 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 waterbodies, 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, habitat smothering, the production of toxins that may affect biota, the reduction of oxygen levels, and an increase in diurnal swings of the 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 filamentous algae has provided evidence that algal growth responds to the introduction of phosphorus and nitrogen in water (Stevenson *et al.* 2007). Nitrate is considered the target nutrient for Chassahowitzka Springs Group, Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Springs. However, the nitrate in the Chassahowitzka River only constitutes 37% of the TN. Therefore, TN is considered the target nutrient for the upper segment of the river. Phosphorus levels for the river and its springs are at natural background and are not considered a target nutrient for the TMDL.

Chapter 5 discusses the nitrogen impairment and the setting of the TMDL target concentration of nitrogen. These TMDL target concentrations for Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay Springs Group 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 Section 62-302.700, F.A.C., allows no degradation in water quality for Special Waters, which include the Chassahowitzka riverine system. The Chassahowitzka River was designated as an OFW on January 5, 1993, meaning that it is worthy of special protection because of its natural attributes.

Chapter 4: ASSESSMENT OF SOURCES

4.1 Population and Land Use in the Springs Contributing Area

4.1.1 Population

In spring areas, elevated concentrations of nitrate in the springs often correlate with population growth. The total population of Hernando County is 172,778, and the population of Citrus County is 139,271, according to the United States Census Bureau's 2013 Census. There are 71,745 households (HH) and 84,504 housing units (HU) in Hernando County, and 59,491 HH and 77,296 HU in Citrus County. Hernando County contains 365.6 people per square mile of land and 178.8 HU per square mile, while Citrus County contains 242 people per square mile of land and 106 HU per square mile. A little over 39% of the contributing area for the springs contributing to the Chassahowitzka River is residential, and the areas of highest population are in Citrus County close to the spring, mainly lying just west of U.S. Highway 19 (Sugarmill Woods) and in Hernando County within the portion of the city of Brooksville that lies within the area (**Figures 4.1** and **4.2**).

The closest residential area to the impaired waters is unincorporated Sugarmill Woods. This residential area is considered a Census-designated place and was platted in 1972 (Sugarmill Woods Civic Association 2006). By 1980 nearly 400 homes had been built, and by 1990 there were approximately 1,600 to 1,700. In 2005 there were approximately 4,300 homes. Today, Sugarmill Woods is home to over 8,287 people (Hernando County 2012) and covers an area of 9.82 square miles, making it the most significant population center in the contributing area.

The largest incorporated community in the Chassahowitzka contributing area is the city of Brooksville in Hernando County. Brooksville was named the county seat of Hernando County in 1856. In 2010 the population of Brooksville was 7,719 persons, with 3,504 total households. Approximately 4.3 square miles within the Brooksville city limits are located in the contributing area.

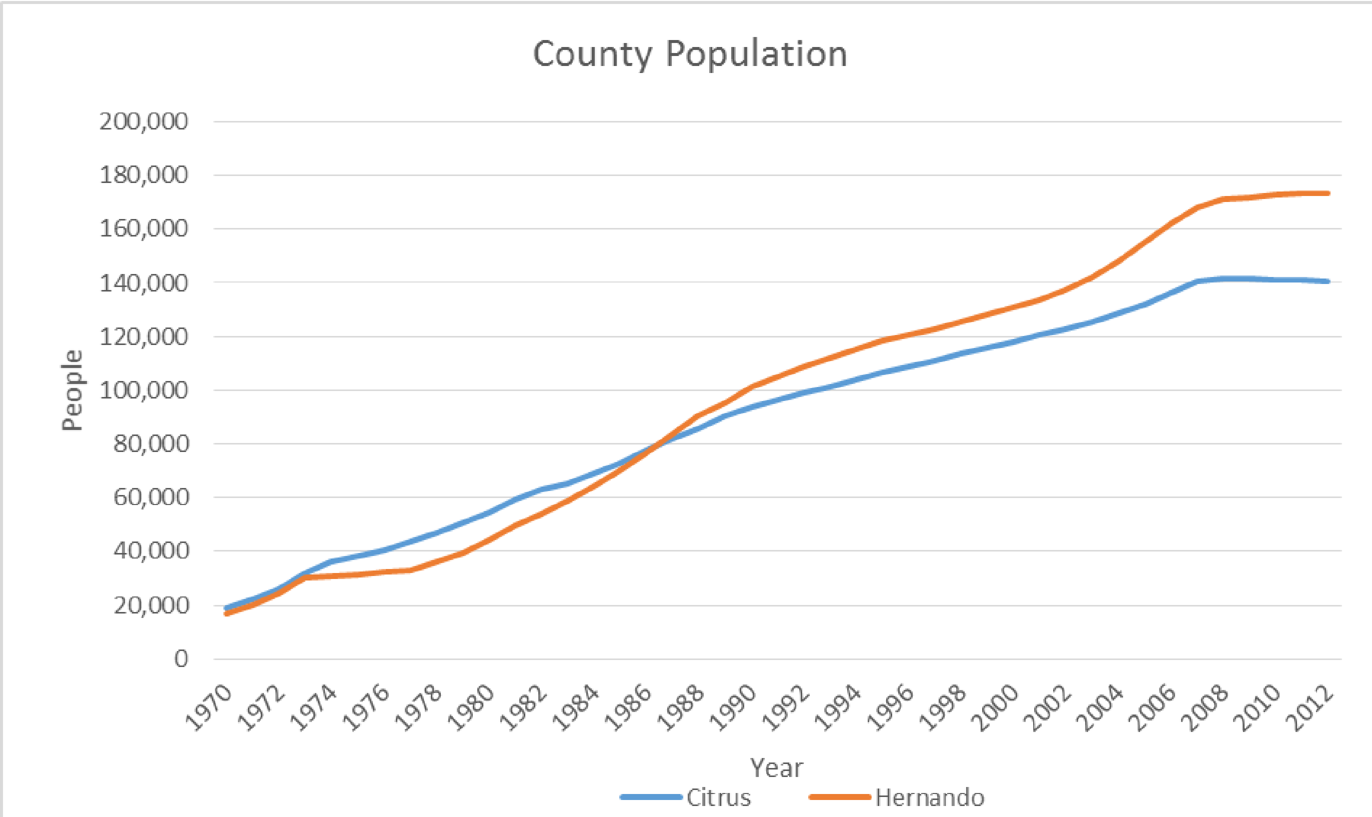

Figure 4.1. Citrus and Hernando Counties' population growth, 1970–2012 (University of Florida Bureau of Economic and Business Research 2014)

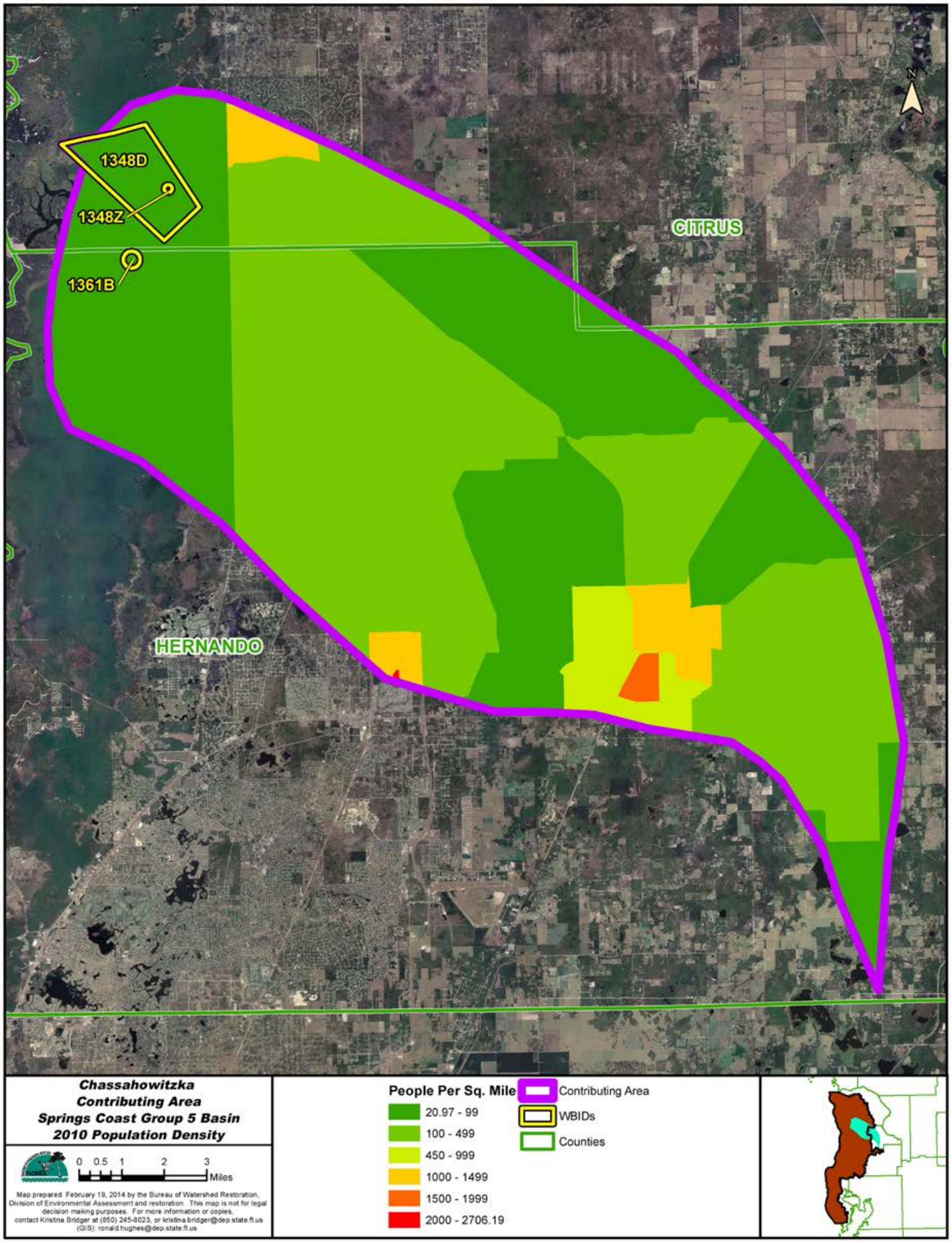

Figure 4.2. Population density for the springs contributing area in Hernando and Citrus Counties (based on 2010 Census data)

4.1.2 Land Uses

Information on the distribution of different land use categories in the 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 4.1, Figure 4.3,** and **Table 4.2** show the breakdown of the various land use categories from the GIS data. In 2011, urban, forest, and wetland areas were the predominant land uses in the contributing area, covering 37%, 30%, and 16%, respectively. Agricultural lands were fourth, with 13% of the Chassahowitzka Springs contributing area.

Nitrate concentrations in the springs increased during the period when land use transitioned from natural lands to agriculture, then to urban development. Urban land use areas increased from 55 square miles (mi^2) in 1988 to 71 mi^2 in 2011. Conversely, agricultural land use areas decreased from 35 mi^2 in 1988 to 25 mi^2 in 2011. In this same period, forest/rural open areas also decreased from 66 mi^2 to 57 mi^2 in 1988 and 2009, respectively. In 2011, the expansion of silviculture increased forested areas from 57 mi^2 in 2009 to 58 mi^2 in 2011 (~841 acres replanted). **Table 4.1** shows the land use categories for the Chassahowitzka 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 springs contributing area by decade

Land Use	Code	1988 (mi^2)	2009 (mi^2)	2011 (mi^2)
Urban and Built-up	1000	55	71	71
Agriculture	2000	35	26	25
Forest/Rural Open	4000	66	57	58
Wetlands	6000	29	30	30

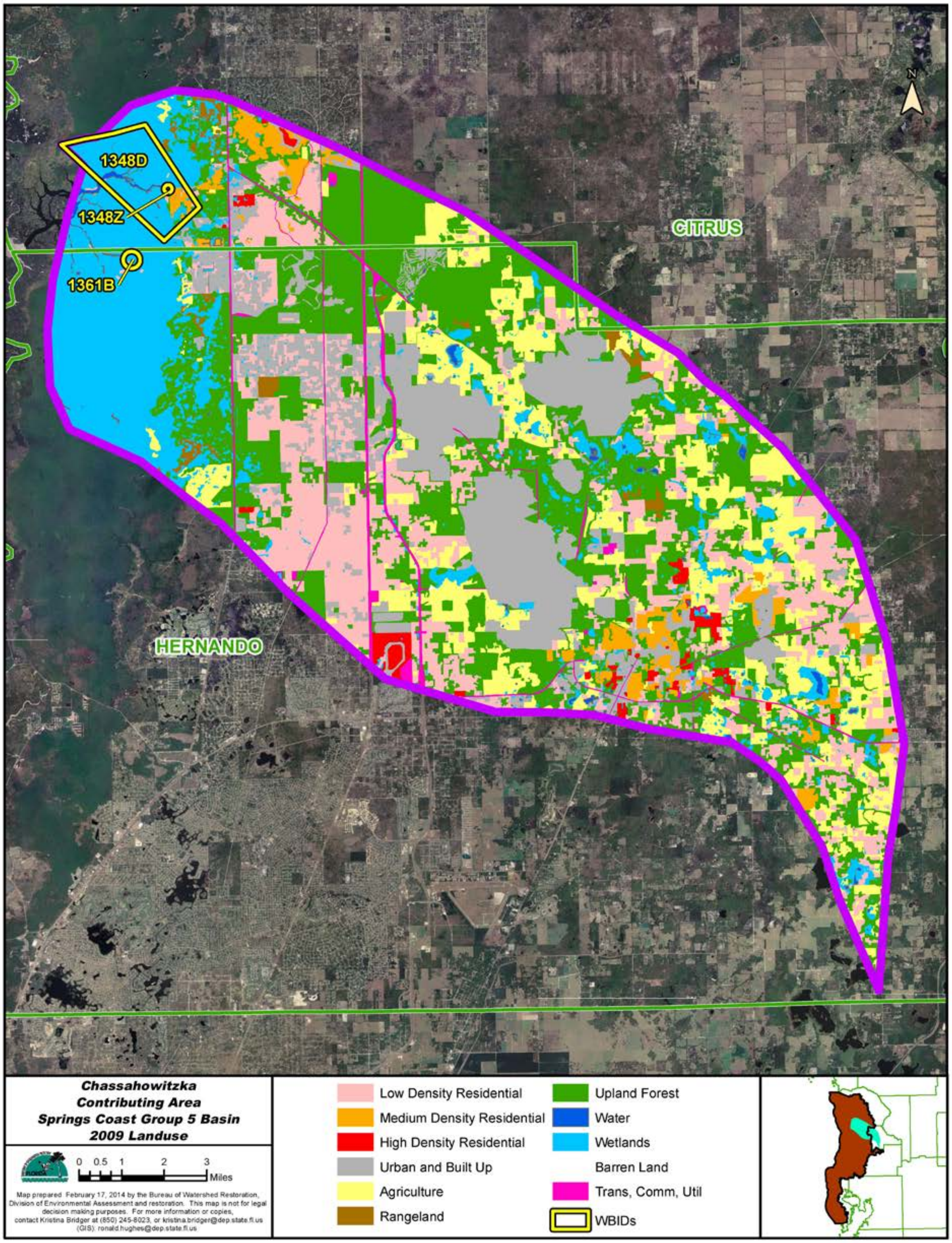

Figure 4.3. Land uses in the springs contributing area in 2011

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

- = Empty cell/no data

Code	Land Use	Square Miles	Acreage	% of Contributing Area
1000	Urban Open	0.00	0.00	0.00%
1100	Low-Density Residential	32.13	20,560.06	16.87%
1200	Medium-Density Residential	5.17	3,307.60	2.71%
1300	High-Density Residential	2.17	1,387.59	1.14%
1400	Commercial	1.41	903.15	0.74%
1500	Light Industrial	0.54	348.28	0.29%
1600	Extractive/Quarries/Mines	17.63	11,285.37	9.26%
1700	Institutional	0.95	610.03	0.50%
1800	Recreational (Golf Courses, Parks, Marinas, etc.)	1.74	1,115.72	0.92%
1900	Open Land	9.13	5,843.40	4.80%
2000	Agriculture	25.77	16,492.09	13.54%
3000+7000	Rangeland	1.69	1,084.23	0.89%
4000	Forest/Rural Open	57.04	36,508.01	29.96%
5000	Water	1.23	786.05	0.65%
6000	Wetlands	30.04	19,226.91	15.78%
8000	Communication and Transportation	3.73	2,388.46	1.96%
-	**Total**	**190.37**	**121,846.95**	**100%**

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 included certain urban stormwater discharges to surface water, such as those from local government master drainage systems, construction sites with land disturbance greater than 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 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 may come from a variety of anthropogenic sources. These include permitted domestic waste 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 Wastewater and Stormwater Sources

Domestic Wastewater

Domestic wastewater application sites can produce a significant load of nitrogen in spring areas. There are 13 permitted domestic wastewater treatment facilities in the contributing area. The contributing area also has two residual application sites permitted by the Florida Department of Health (FDOH). **Table 4.3** lists the facilities and their permit numbers. **Figure 4.4** shows the locations of the domestic wastewater facilities and FDOH-permitted residual application sites in the springs contributing area. None of the domestic WWTFs has NPDES-permitted discharges to surface water; thus by definition they are not considered point sources of pollution. They are instead included in the nonpoint source contribution discussion in a subsequent chapter.

These domestic wastewater facilities 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. **Table 4.3** includes the four largest domestic facilities in the contributing area with permitted discharges of 0.1 million gallons per day (MGD) or greater.

Table 4.3. Domestic wastewater facilities and RMFs in the vicinity of the springs contributing area

Permit Number	Facility Name	Facility Type	NPDES	Design Capacity (MGD)	County
27-QB-00024	B and F Concrete Products	Residual Application Site	No	12,960 gal per year	Hernando
27-QB-00012	Cliff's Septic Service	Residual Application Site	No	31,350 gal per year	Hernando
FLA011852	Chassahowitzka River Lodge	Domestic Wastewater Program	No	0.0100	Citrus
FLA011916	Walden Woods Mobile Home Park (MHP) WWTF	Domestic Wastewater Program	No	0.0245	Citrus
FLA012038	Weeki Wachee North MHP WWTF	Domestic Wastewater Program	No	0.0260	Hernando
FLA011903	Sugarmill Woods WWTF	Domestic Wastewater Program	No	0.7000	Citrus
FLA012062	Countryside Estates WWTF	Domestic Wastewater Program	No	0.0200	Hernando
FLA012054	Frontier Campground MHP	Domestic Wastewater Program	No	0.0200	Hernando
FLA012071	Wesleyan Village	Domestic Wastewater Program	No	0.0800	Hernando
FLA012028	Brookridge Subregional WWTF	Domestic Wastewater Program	No	0.7500	Hernando
FLA012036	Brooksville City of - Cobb Road WWTF	Domestic Wastewater Program	No	1.6000	Hernando
FLA012046	Brooksville Golf & Country Club WWTF	Domestic Wastewater Program	No	0.0105	Hernando
FLA012069	Glen Water Reclamation Facility (WRF)	Domestic Wastewater Program	No	1.0000	Hernando

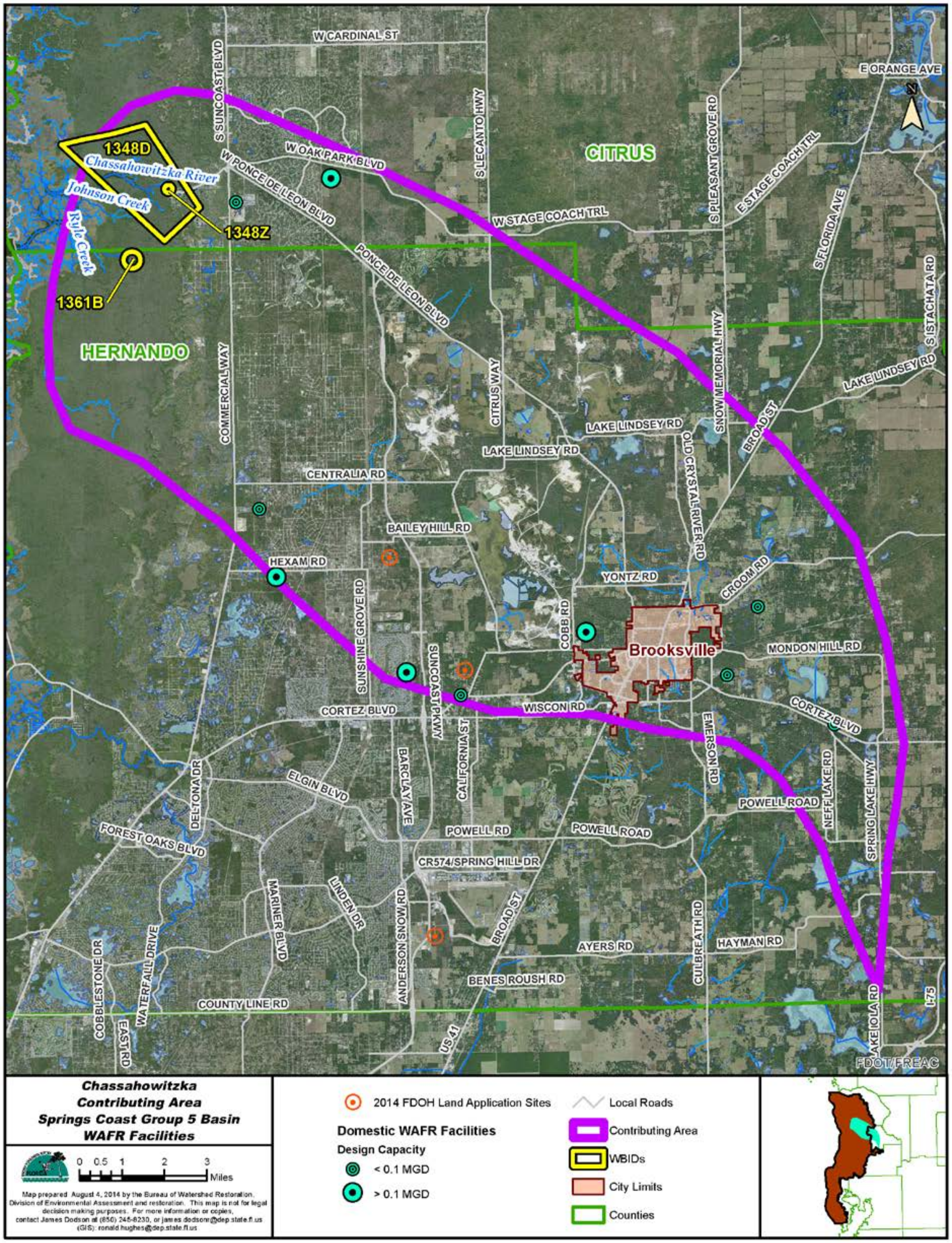

Figure 4.4. Domestic wastewater facilities in the Chassahowitzka Springs contributing area

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. The contributing area of the impaired waters include 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 springs contributing area are maintained by Citrus County (FLR04E141), Hernando County (FLR04E040), and FDOT District 7 (FLR04E017 – Hernando) and (FLR04E142 - Citrus) (**Figure 4.5**). Wasteload allocations (WLAs) may be assigned to MS4 entities under their permits 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.

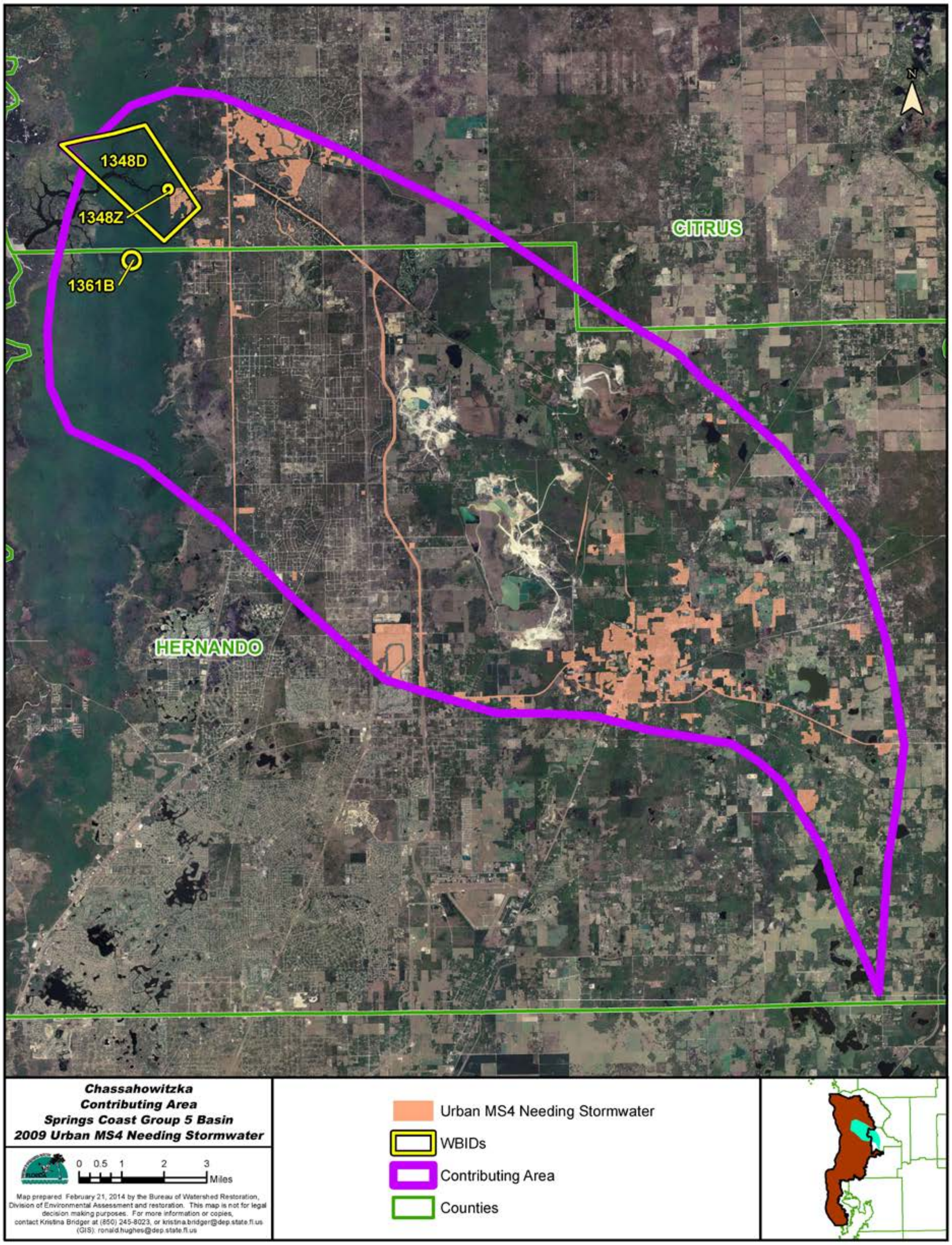

Figure 4.5. MS4 permit boundaries in the springs contributing area

Onsite Sewage Treatment and Disposal Systems

OSTDS, or septic tanks, are used for the disposal of domestic wastes at homes that are not on central sewer, often because providing central sewer is not available, cost-effective, or practical. When properly sited, designed, constructed, maintained, and operated, OSTDS provide 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 wastewater facilities, 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 leach 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 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 growing concern over the continuing use and even increase in the number of OSTDS in spring areas, particularly in more densely developed 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, approximately 3,700 OSTDS exist in the springs contributing area (**Figure 4.6**).

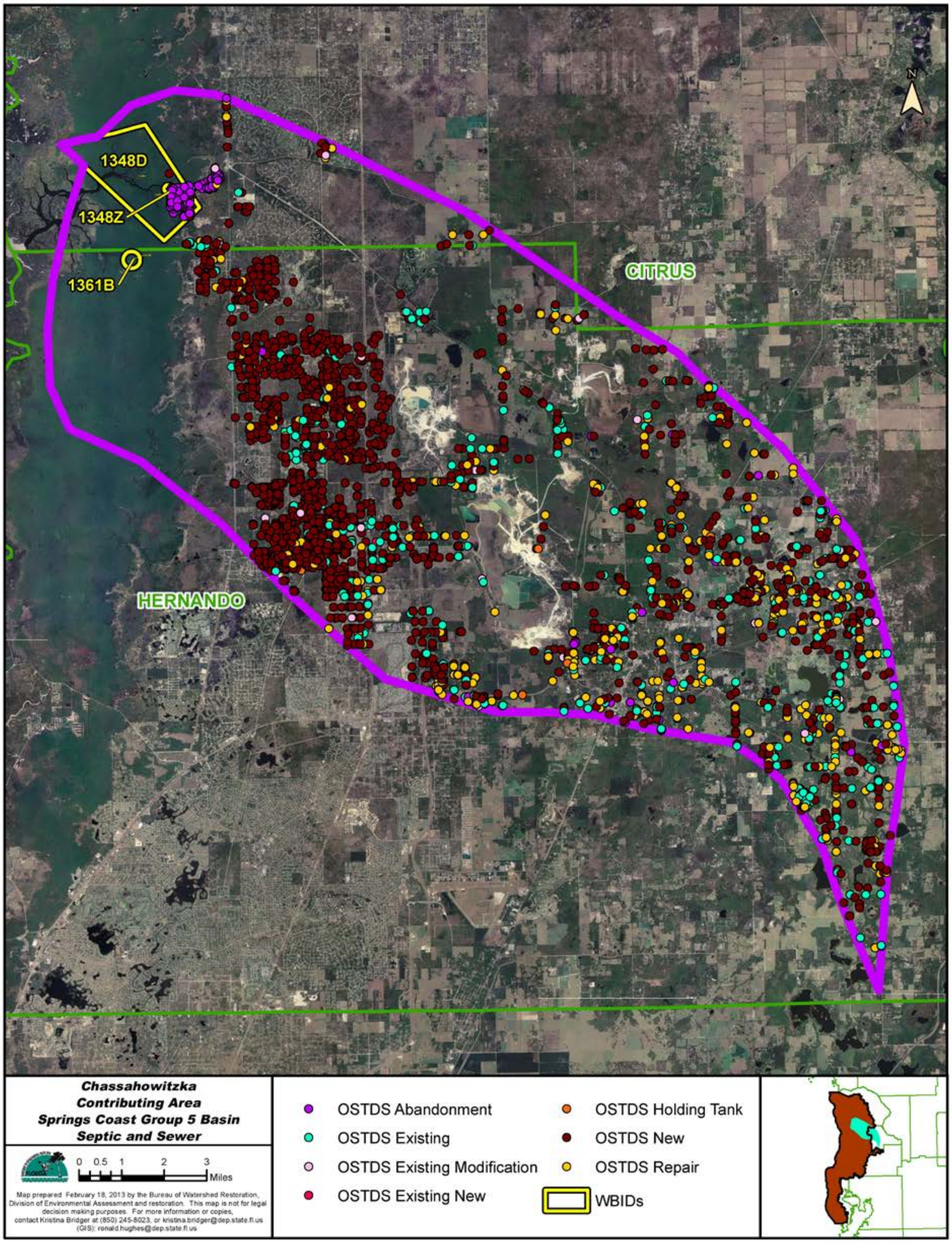

Figure 4.6. Density of OSTDS (septic tanks) in the springs contributing area

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 37% of the total land area within the Chassahowitzka Springs 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 419 parcels are connected to sewer near the Chassahowitzka River (**Figure 4.7**).

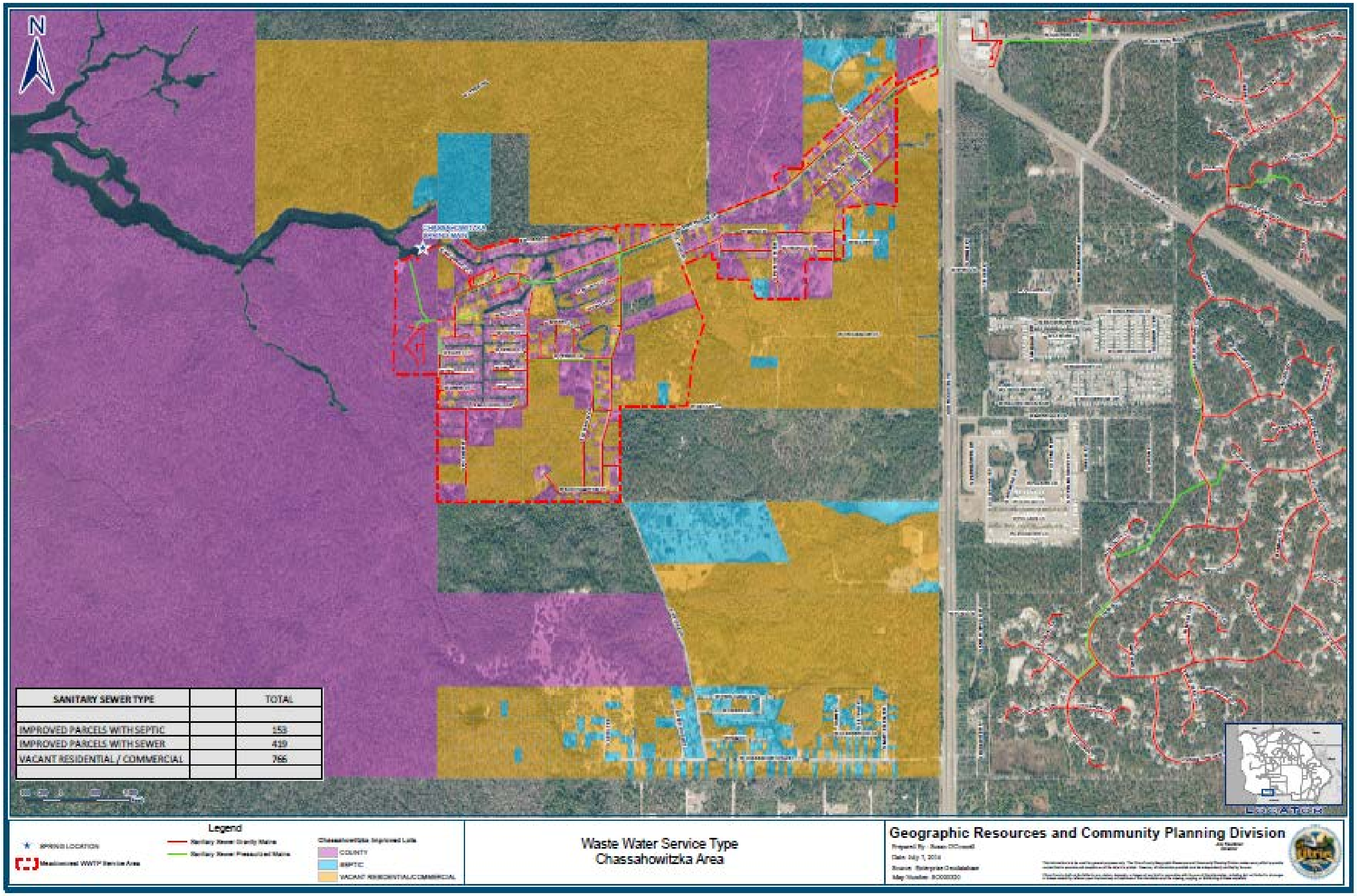

Figure 4.7. Wastewater Service Type parcel coverage near the Chassahowitzka River (provided by Citrus County)

Fertilizer Use

The high potential for fertilizer leaching 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. The 2009 land use map shows seven golf courses in the contributing area, three of which are within five miles of Chassahowitzka Spring.

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.

Table 4.4. Potential fertilizer application ranges for selected land uses in the springs contributing area

Note: Potential loadings from fertilization are conservative, based on recommended agronomic rates and not actual field data.

Nitrogen Source	Potential Nitrogen Application Rates Per Year (lb/ac/yr unless otherwise noted)[1]	Comments
Hayfield	320	Bahia grass, assume 4 cuttings (Mylavarapu *et al.* 2009)
Fertilized pasture	50–160	Bahia grass (Mylavarapu *et al.* 2009)
Container nursery, controlled-release fertilizer	17–472	Based on 2 to 3 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	4 to 6 pounds/1,000 square feet (Sartain *et al.* 2009)
Golf course, turf or lawn, St. Augustine grass–central Florida	87–131	2 to 3 pounds/1,000 square feet (Sartain *et al.* 2009)

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

NWR. 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 264 tons of nitrogen/year contributed to the 289-square-mile Homosassa Springs Group contributing area.

Wastewater and Fertilizer Chemical Tracers

Sucralose

In January 2013, the Department sampled Chassahowitzka Main Spring 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. The sampling identified a low but detectable concentration of 0.022 ug/L of sucralose in the spring water, indicating that domestic wastewater sources are influencing water quality (wastewater facility effluent and/or OSTDS).

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 2001) 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). Plotting the ratios of nitrogen isotopes versus oxygen isotopes in nitrate measured from ground water can reveal likely nitrate sources: inorganic (chemical fertilizers) or organic (wastewater, septic discharge, animal waste) (Roadcap *et al.* 2002). Nitrogen and oxygen isotopes were analyzed from single samples collected from Chassahowitzka Main Spring, Baird #3 Spring, and Baird #4 Spring in January 2013. **Figure 4.8** shows the plotted δ15N and 18ONO3 values for the spring samples compared with the general ranges for inorganic and organic sources provided by Roadcap *et al.* (2002). The results show that all values plot between the reduced, mineralized (organic) nitrogen and the organic nitrogen wastewater domains, suggesting that the nitrate from these springs may be from a mixture of inorganic (fertilizer) and organic (domestic wastewater/animal waste) sources.

Sediments

Studies have shown that an additional source of nutrients is present in sediments within the river that can be resuspended in the water column when conditions are right (Jamieson *et al.* 2005). No recent studies exist that have quantified the exact amount of nutrient loading coming from sediments in the Chassahowitzka 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, 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.

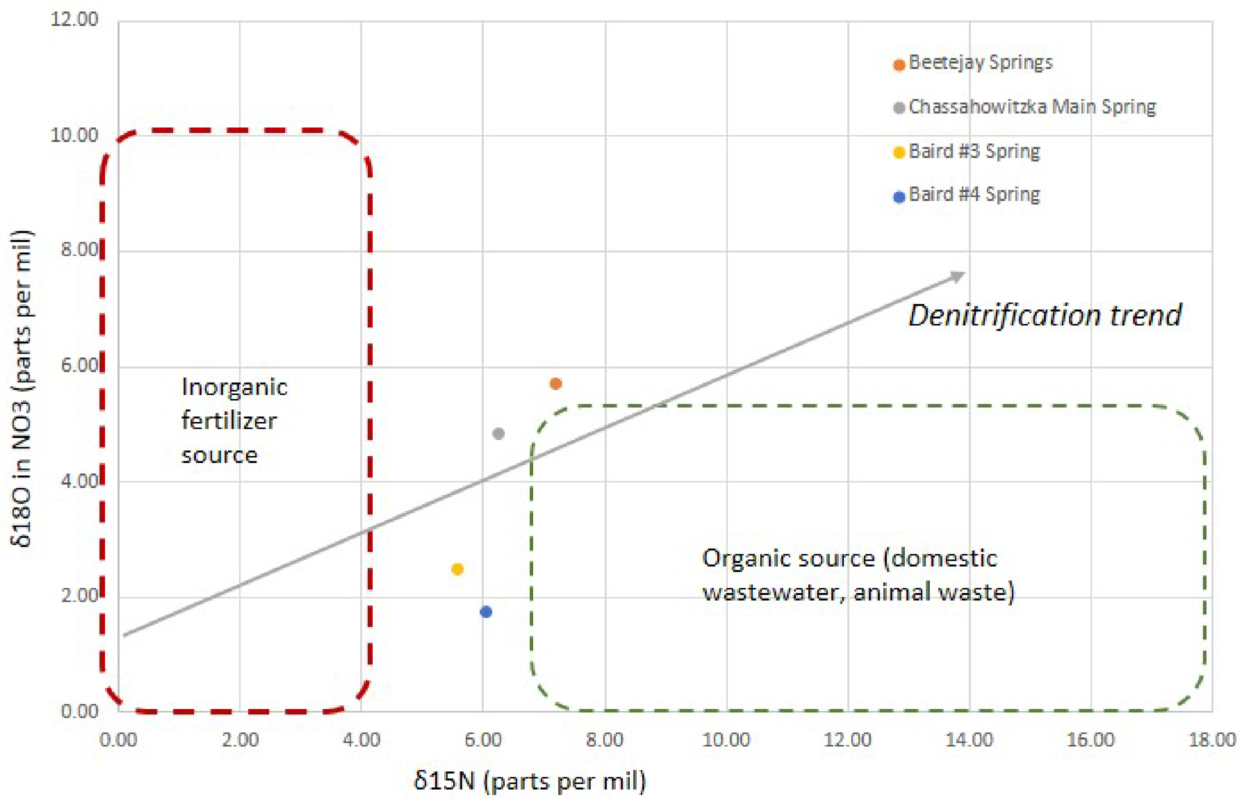

Figure 4.8. Nitrogen isotope plot for samples collected from Chassahowitzka Main, Beteejay, Baird #3, and Baird #4 Springs

4.3.2 Nitrogen Source Inventory Loading Tool (NSILT)

During the BMAP development process, the Department anticipates developing a nitrogen source inventory for the Chassahowitzka Springs Group contributing area. The Nitrogen Source Inventory and Loading Tool, or NSILT, has been developed to estimate the nitrogen loading reaching ground water within a designated BMAP area. 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 relevant to the specific study area. After estimating the nitrogen input, environmental attenuation is taken into consideration. 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- recharge, which varies depending on hydrogeology and soil characteristics. The end product is a report that contains a series of pie charts illustrating the estimated percent contribution of each loading category within a BMAP study 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 attempts 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 ASSIMILATIVE 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 TMDLs for Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River–Baird Creek, Baird Springs, Ruth Spring, and Beteejay 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 Chassahowitzka River is ground water discharged from the springs. The contributing area of the springs that are the source of the Chassahowitzka 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 ground water, which is 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 TMDL.

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 are required. These data 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 Chassahowitzka River

The Chassahowitzka River is a spring-fed ecosystem. It is a tidally influenced shallow coastal river with a low flushing rate (or residence time). The SWFWMD calculated net residence time for the Chassahowitzka River using the fraction of freshwater method (EPA 1984). Based on the long-term median flow at USGS Station #02310650 from 1997 to 2007, a flow of 63.7 cfs equals a residence time of 155 hours or 6.5 days (SWFWMD 2012). In addition, 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 coued with long residence time yields greater primary productivity, which in the Chassahowitzka River translated into increased filamentous algae and phytoplankton production.

Reductions of either nitrogen or phosphorus in the water discharging from springs, nearby stormwater, and nearby ground water inflows should reduce macroalgal accumulation because they will slow the growth rate of macroalgae (Stevenson *et al.* 2007). The phosphorus concentrations in the springs and river are at natural background. Therefore, it is the purpose of this TMDL document to establish the maximum allowable nitrate target concentration for the impaired springs and a TN target concentration for the upper segment of the Chassahowitzka River. These thresholds will be used as targets for restoration actions to meet the 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 Chassahowitzka River. Salinity represents a primary determinant of long-term patterns in the distribution of SAV in spring-fed systems along Florida's Gulf Coast, including the Chassahowitzka 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 Chassahowitzka 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.

Tables 5.1a through **5.1f** summarize the monthly averages for nitrate concentrations for Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Baird #1 Spring, Ruth Spring, and Beteejay Spring, respectively. **Table 5.1g** summarizes the monthly averages for TN concentrations for Chassahowitzka River. Based on the monthly data available, the nitrate concentrations in the springs and river are relatively consistent from month to month. In the case of these springs, there does not appear to be any period during which greater loading occurs.

Table 5.1a. Monthly average nitrate concentrations for Chassahowitzka Main Spring, 2004–13

Month	N	Mean	Maximum	Minimum
1	6	0.58	0.62	0.50
2	5	0.57	0.61	0.55
3	1	0.46	0.46	0.46
4	7	0.56	0.62	0.51
5	3	0.54	0.55	0.51

Month	N	Mean	Maximum	Minimum
6	2	0.61	0.64	0.57
7	6	0.58	0.63	0.53
8	5	0.53	0.57	0.49
9	2	0.60	0.64	0.55
10	7	0.58	0.61	0.50
11	5	0.58	0.62	0.51
12	1	0.57	0.57	0.57

Table 5.1b. Monthly average nitrate concentrations for Chassahowitzka #1 Spring, 2004–13

- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	5	0.63	0.65	0.60
2	5	0.62	0.66	0.58
3	-	-	-	-
4	6	0.60	0.64	0.54
5	3	0.60	0.62	0.59
6	1	0.61	0.61	0.61
7	5	0.62	0.65	0.58
8	4	0.60	0.63	0.58
9	1	0.62	0.62	0.62
10	6	0.62	0.65	0.55
11	4	0.61	0.67	0.53
12	-	-	-	-

Table 5.1c. Monthly average nitrate concentrations for Crab Creek Spring, 2004–13

- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	8	0.61	0.67	0.55
2	-	-	-	-
3	-	-	-	-
4	7	0.60	0.65	0.55
5	-	-	-	-
6	-	-	-	-
7	9	0.58	0.62	0.52
8	-	-	-	-
9	-	-	-	-
10	8	0.61	0.66	0.52
11	-	-	-	-
12	-	-	-	-

Table 5.1d. Monthly average nitrate concentrations for Baird #1 Spring, 2004–13

\- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	8	0.25	0.29	0.13
2	-	-	-	-
3	-	-	-	-
4	7	0.27	0.31	0.24
5	-	-	-	-
6	-	-	-	-
7	9	0.26	0.29	0.21
8	-	-	-	-
9	-	-	-	-
10	8	0.27	0.28	0.24
11	-	-	-	-
12	-	-	-	-

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

\- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	7	0.70	0.76	0.59
2	-	-	-	-
3	-	-	-	-
4	7	0.65	0.76	0.57
5	-	-	-	-
6	-	-	-	-
7	9	0.60	0.68	0.54
8	-	-	-	-
9	-	-	-	-
10	8	0.67	0.74	0.59
11	-	-	-	-
12	-	-	-	-

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

- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	9	0.40	0.50	0.29
2	1	0.38	0.38	0.38
3	-	-	-	-
4	9	0.41	0.52	0.32
5	1	0.44	0.44	0.44
6	-	-	-	-
7	9	0.41	0.48	0.33
8	-	-	-	-
9	-	-	-	-
10	8	0.35	0.46	0.21
11	3	0.29	0.47	0.01
12	-	-	-	-

Table 5.1g. Monthly average TN concentrations for the Chassahowitzka River, 2004–13

- = Empty cell/no data

Month	N	Mean	Maximum	Minimum
1	19	0.43	0.67	0.20
2	18	0.45	0.65	0.31
3	21	0.58	3.32	0.24
4	22	0.47	1.86	0.21
5	17	0.39	0.82	0.20
6	24	0.46	1.34	0.16
7	20	0.47	0.78	0.23
8	22	0.51	0.84	0.34
9	19	0.46	0.77	0.17
10	26	0.44	0.70	0.19
11	14	0.47	0.65	0.26
12	22	0.48	0.68	0.32

5.5 TMDL Development Process

5.5.1 Use of Site-Specific Information

To develop the nitrate and TN target concentrations for the springs and the upper Chassahowitzka River, 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 for nitrate. For instance, the applicable numeric criterion for freshwater spring vents in Paragraph 62-301.530(47)(b), F.A.C., is 0.35 mg/L of nitrate-nitrite (NO_3 + NO_2) 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.

Field Observations at Baird Spring

In 2008, 2013 and 2014, the Department's Ground Water Management Section (GWMS) recorded multiple field observations at Baird Spring. These revealed the predominant aquatic plant to be the filamentous algae at nitrate concentrations less than the 0.35 mg/L numeric criterion for freshwater spring vents.

Filamentous Algae Studies in Florida Springs

Nuisance algal growth has been observed in many springs and has been associated with increases in anthropogenic activities and nutrient concentrations (Stevenson *et al.* 2007). Several studies described in this section have evaluated the growth of filamentous algae 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 Chassahowitzka River because the river is tidally influenced, resulting in a much longer residence time for nitrogen in the coastal stream compared with a free-flowing freshwater stream.

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**).

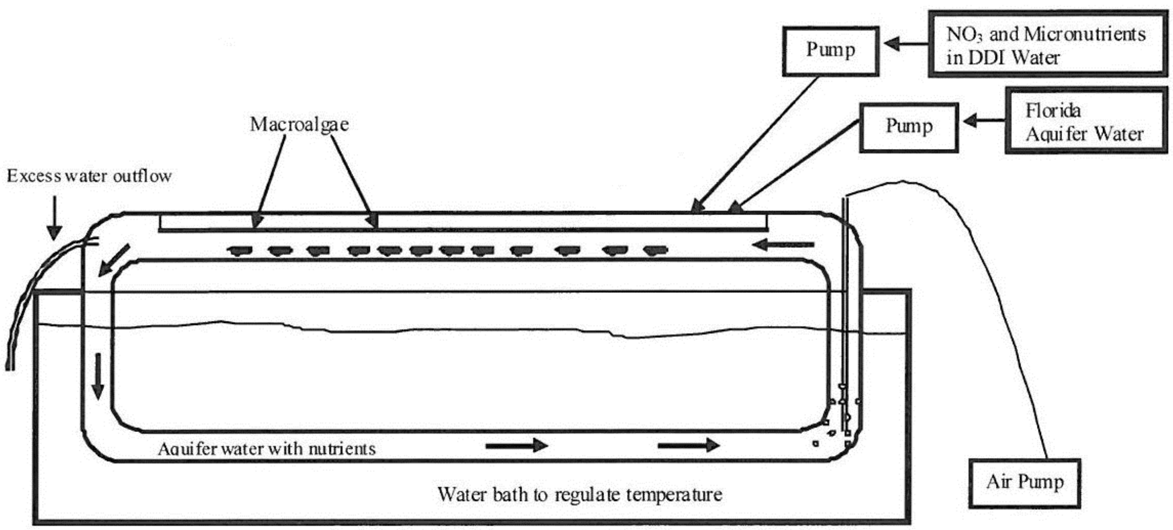

Figure 5.1. Albertin (2009) recirculating stream channel experimental design

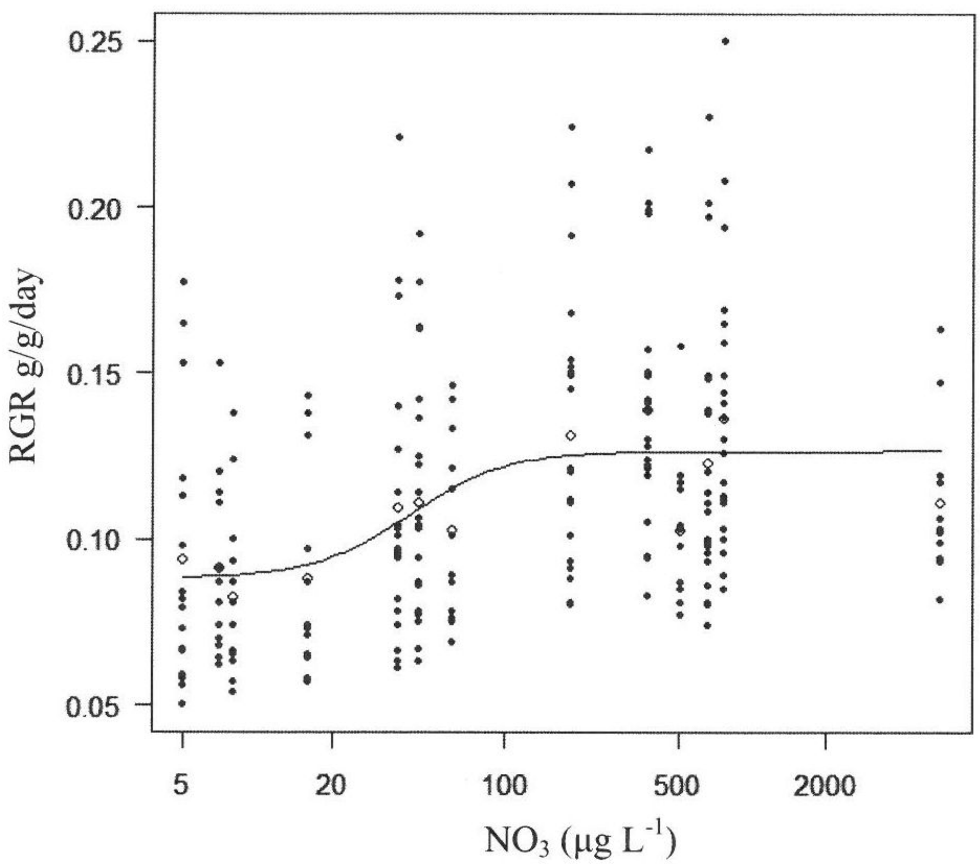

Figure 5.2. Relative growth rates (RGR) of *L. wollei* at different nitrate concentrations in recirculating stream channels (Albertin 2009)

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

The nutrient amendment bioassay work 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 response from the *Lyngbya*. A decrease in growth rate response was observed at nitrate concentrations equal to or less than 0.30 mg/L.

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

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 that occurred in areas with extensive growths in the studied springs; however, 23 different macroalgal taxa were observed in the spring survey.

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:

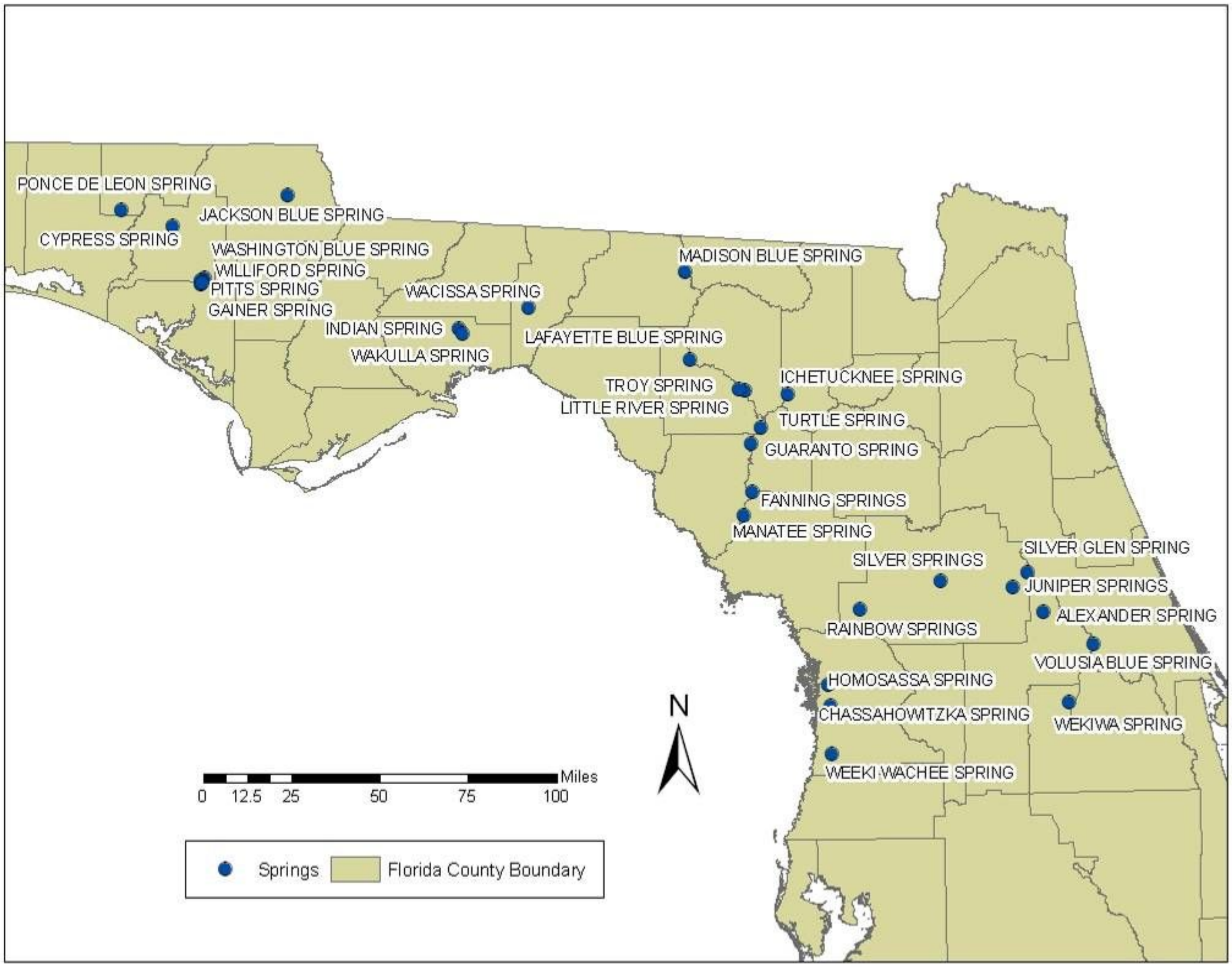

Figure 5.3. Springs included in the Florida Springs Report (Stevenson *et al.* 2007)

— 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*.

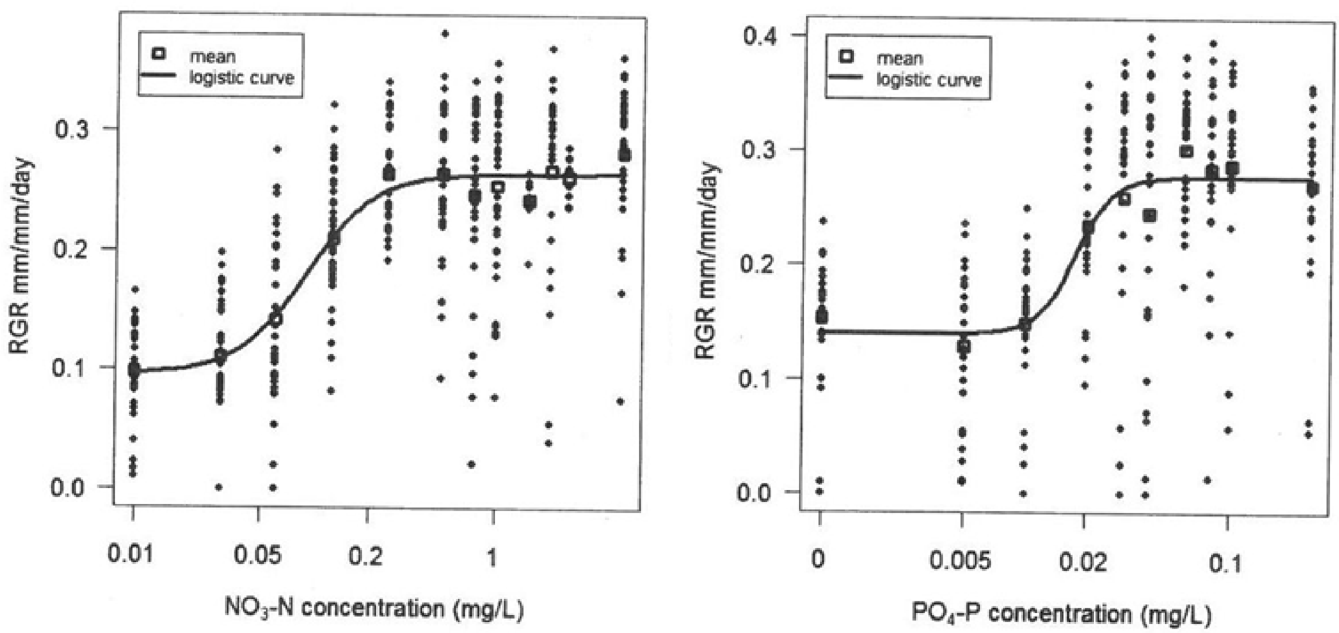

Figure 5.4. Relative growth rates (RGR) of *L. wollei* at different nitrate and orthophosphate concentrations in microcentrifuge tubes (Stevenson *et al.* 2007)

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 Chassahowitzka River. During the study, water chemistry and physical samples for each of the five rivers were collected during quarterly sampling events. The water chemistry sampling sites transversed the entire length of the river from the headspring to the Gulf of Mexico. Water chemistry sampling transect/sites were sequentially numbered from 1 (headspring) to 20 (Gulf of Mexico), and SAV sampling transect/sites were sequentially numbered from 1 (headspring) to 10 (mid-river). Macrophytes and macroalgae were sampled at 20 regularly spaced transects/sites from the headspring to mid-river. Data on SAV were collected annually during the summer for the six years to determine the species composition and coverage of plants. Ten SAV transects/sites corresponded to those where water chemistry was measured.

According to Frazer *et al.* (2006), during the 2003 to 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 to 2000 sampling period. During both sampling periods (1998–2000 and 2003–2005), macroalgae were most abundant at the upper sampling transect/sites, though their occurrence was not restricted to the upper sampling areas for the Homosassa and Chassahowitzka Rivers (**Figure 5.5**).

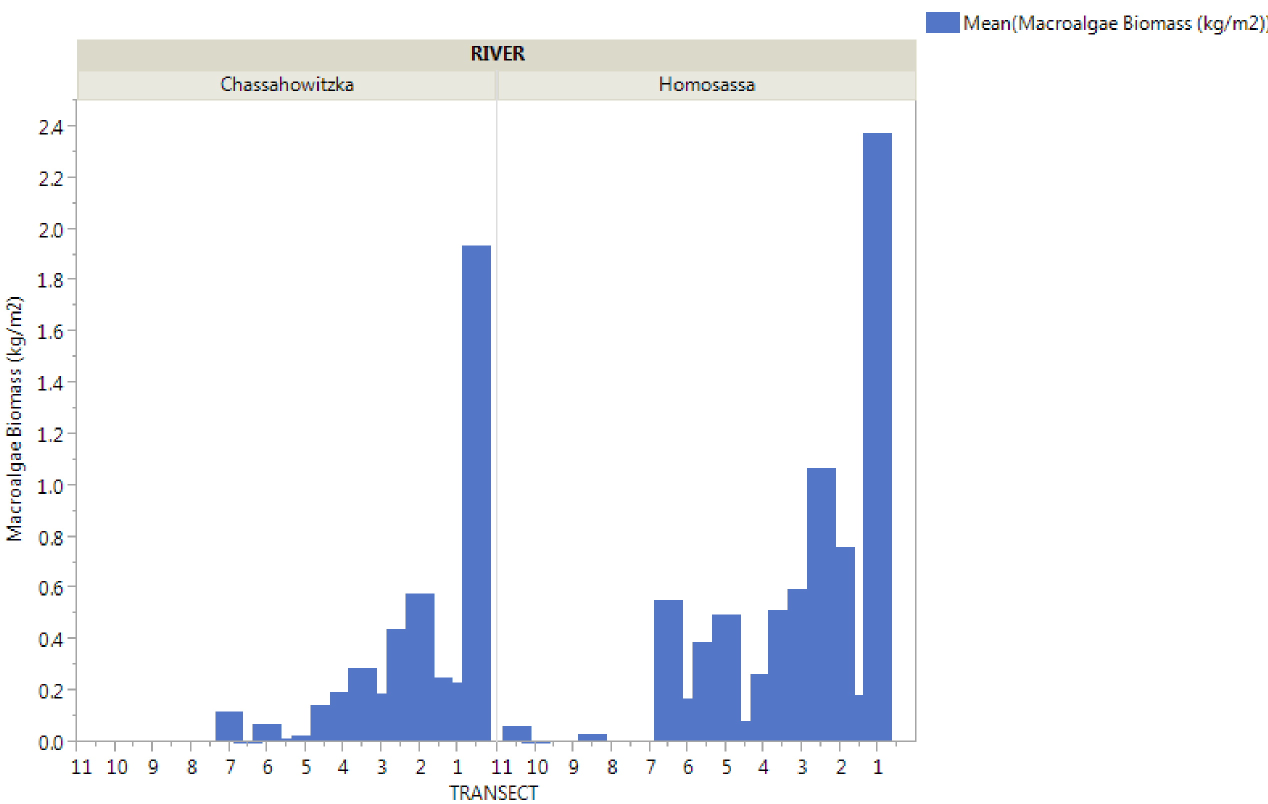

Figure 5.5. Mean macroalgae biomass and chlorophyll concentration by site for the Homosassa and Chassahowitzka Rivers, 1998–2000 and 2003–05

5.6 Setting the TMDL Water Quality Targets for TN and 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 an appropriate nitrate target concentration that would apply to the springs and an appropriate TN target concentration that would apply to the Chassahowitzka River.

A site-specific alternative criterion is needed because field observations at Baird Spring by the Department's Ground Water Management Section revealed the predominant aquatic plant to be the filamentous algae at nitrate concentrations 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 were most abundant at the upper sampling transect/sites, though their 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 Chassahowitzka 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 Chassahowitzka 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. According to Stevenson *et al.* (2007), nitrate concentrations lower than 0 0.23 mg/L are needed to reduce the growth rate of *L. wollei*.

After carefully reviewing these studies, the Department 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 Chassahowitzka River, including Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Baird #1 Spring, Ruth Spring, and Beteejay Spring. Nitrate is the most abundant form of nitrogen available in spring discharge. As discussed previously, the nitrate threshold for springs is based on algal growth studies performed in low-flushing (long residence time) conditions, which are similar to those in the Chassahowitzka River.

To estimate a corresponding nitrate target concentration that would be appropriate for the Chassahowitzka River, the nitrate concentrations for Chassahowitzka Main Spring were plotted against the nitrate concentrations for the nearby surface water sampling station CV0, located 10.4 meters downstream from the spring in the spring run.

In addition, plotting the Chassahowitzka Main Spring and surface water sampling station CV0 nitrate data over time displays the dilution and attenuation of nitrate as nitrate-enriched water migrates from the spring vent through the water column to the nearby surface water station in the river (**Figure 5.6**). Nitrate is readily available for uptake by phytoplankton and benthic organisms (Woods Hole Group 2007). Nitrate concentrations in water discharged from the springs are also decreased by dilution.

Using this methodology, a nitrate target concentration of 0.23 mg/L for Chassahowitzka Main Spring translates to a nitrate target concentration of 0.10 mg/L for the surface water sampling station CV0 using the following regression equation (**Figure 5.6)**:

CHASSAHOWITZKA RIVER CV0 = -0.2 + 1.3*CHASSAHOWITZKA MAIN SPRING

The reduction in nitrate over this distance is attributable to dilution and to biological uptake in the low-flushing main stem. The same relationship may not be representative of the relationship found in the river tributaries, but it does provide the maximum amount of protection for these other areas by being more conservative. A reduction in nitrate at CV0 is expected to be accompanied by a similar reduction in the tributaries. Therefore, the nitrate target concentration for the tributaries to the Chassahowitzka River will also be 0.10 mg/L.

However, the Chassahowitzka River (WBID 1348D) needs a TN target to address all forms of nitrogen in the river, since nitrate is not the dominant form as it is in the springs. The other forms of nitrogen (ammonium and organic nitrogen) in the river can be from other sources such as surface water inflows, or from microbial recycling of nitrate. In the Chassahowitzka River, 37% of the TN is nitrate and 63% of the TN is organic nitrogen and ammonium. A nitrate concentration of 0.10 mg/L would correspond to a TN concentration of 0.25 mg/L by using the following regression equation (**Figure 5.7**):

CHASSAHOWITZKA RIVER CV0 - TN = 0.18 + 0.72* CHASSAHOWITZKA RIVER CV0 - NO3NO2

Therefore, the Department has selected the TN concentration of 0.25 mg/L as the TMDL target concentration for the Chassahowitzka River.

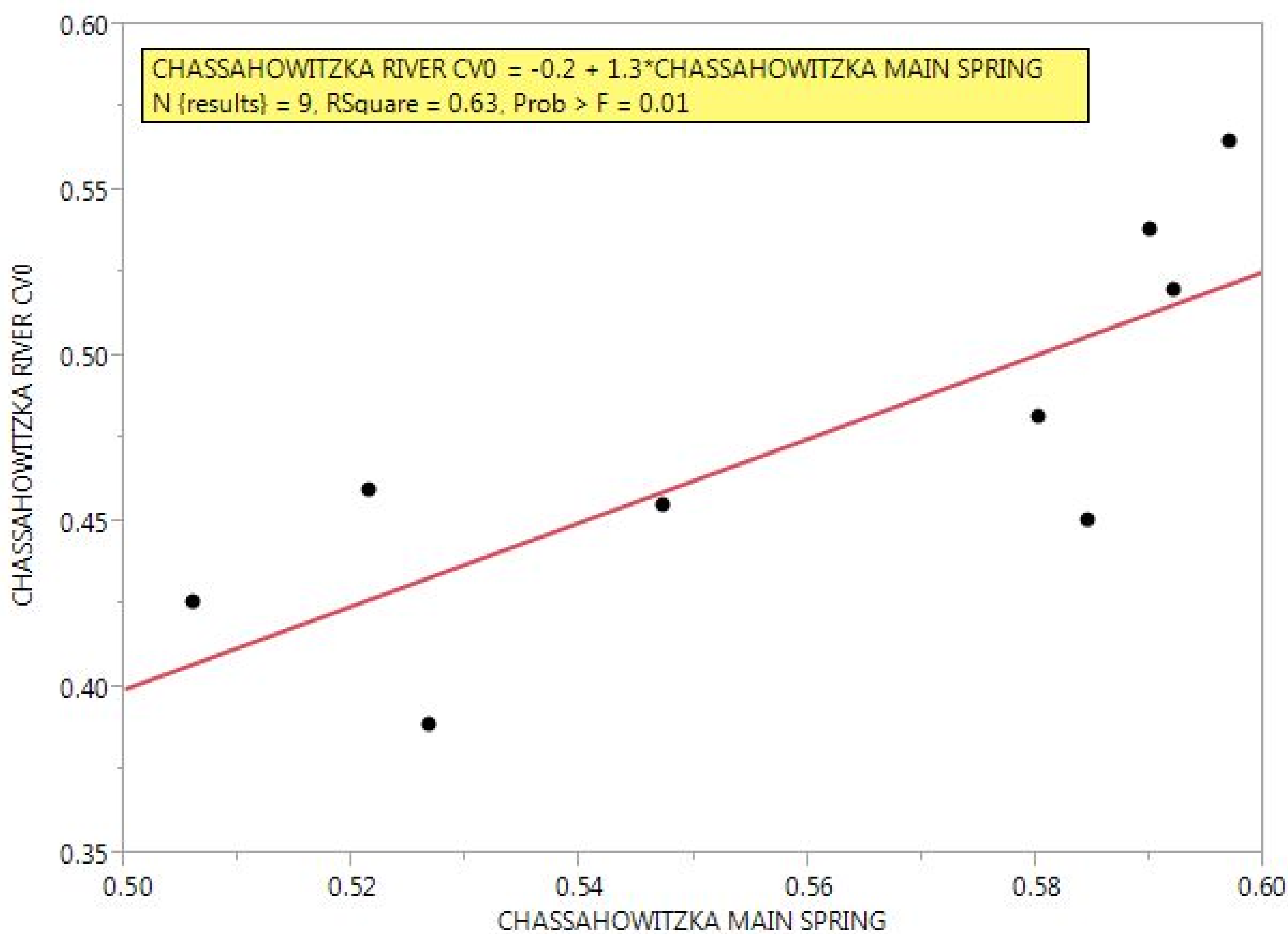

Figure 5.6. Plot corresponding Chassahowitzka Main Spring and downstream surface water sampling station CV0 nitrate concentrations (mg/L) and regression curve

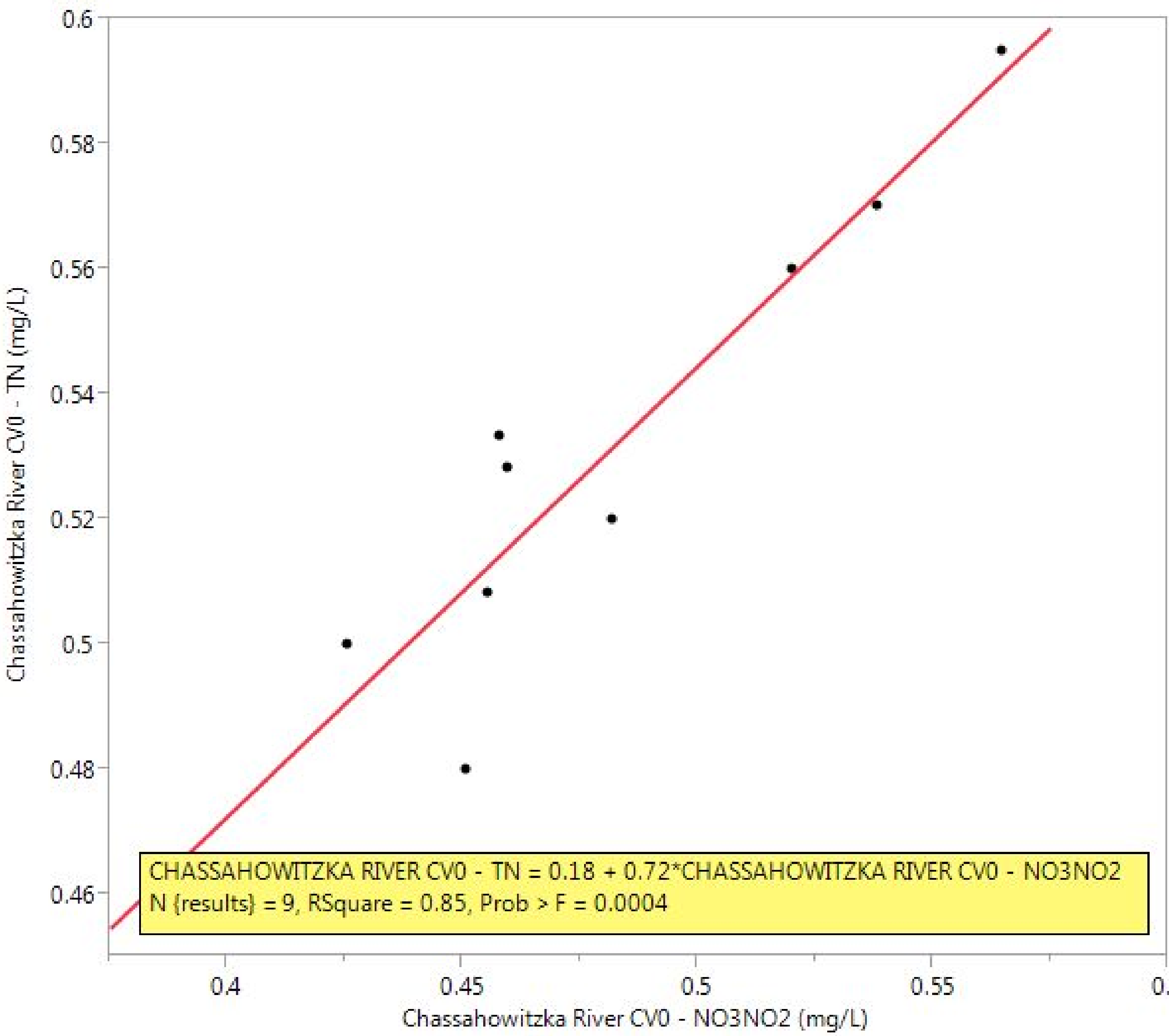

Figure 5.7. Plot for surface water sampling station CV0 corresponding TN and nitrate concentrations (mg/L) and regression curve

5.7 Setting the Annual Average Concentration for Nitrate

For the Chassahowitzka River, the annual average TN concentrations were calculated for each year (**Table 5.2a**). For Beteejay Spring, Ruth Spring, Baird #1 Spring, Crab Creek Spring, Chassahowitzka Main Spring, and Chassahowitzka #1 Spring, the annual arithmetic average nitrate concentrations were calculated for each year (**Tables 5.2b** through **5.2g**, respectively). For these impaired waters, the percent reductions required for the TMDL were calculated using the water quality values averaged for each year over the most recent nine-year period (January 1, 2004, through December 31, 2013). The longer period includes the Cycle 2 verified period (January 1, 2004, through June 30, 2011) and more recent data.

To ensure that the annual average concentrations will 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. Annual average targets are most appropriate because algal growth does not respond to instantaneous changes in nutrient concentrations. This approach adds to the margin of safety (MOS) of these TMDLs.

Due to the minimal monthly variation of the TN concentrations for Chassahowitzka River and nitrate concentrations for Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Baird #1 Spring, Ruth Spring, and Beteejay Spring, the percent reductions were established based on the data for the year with the highest annual average concentration. This will be protective for all months and add to the implicit MOS.

The nitrate concentrations in the springs and river are constant and do not vary greatly from season to season based on the monthly data available for the river and the quarterly data available for the springs. Data for each month are not available for the springs because the springs are sampled four times a year (January, April, July, and October). This schedule is the part of the SWFWMD routine spring sampling that provided the bulk of the data. Samples outside of the routine schedule were from other monitoring programs, including the Department and LakeWatch.

Table 5.2a. Yearly average TN concentrations for the Chassahowitzka River, 2004–13

Maximum annual average is shown with an asterisk and highlighted in red.
\- = Empty cell/no data

Year	N	Average	Maximum	Minimum
2004	12	0.45	0.65	0.31
2005	2	0.51	0.54	0.48
2006	17	0.52	0.75	0.35
2007	18	0.49	0.82	0.29
2008	18	0.47	0.64	0.20
2009	16	0.49	0.66	0.28
2010*	15	0.58	0.72	0.35

Year	N	Average	Maximum	Minimum
2011	4	0.47	0.51	0.40
2012	4	0.45	0.54	0.34
2013	4	0.43	0.51	0.37

Table 5.2b. Yearly average nitrate concentrations for Beteejay Spring, 2004–13

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Average	Maximum	Minimum
2004	4	0.32	0.38	0.21
2005	4	0.30	0.32	0.29
2006	4	0.38	0.41	0.37
2007	4	0.40	0.43	0.36
2008	4	0.41	0.42	0.40
2009	4	0.32	0.44	0.01
2010*	4	0.45	0.47	0.41
2011	4	0.44	0.48	0.34
2012	4	0.44	0.52	0.33
2013*	4	0.45	0.48	0.43

Table 5.2c. Yearly average nitrate concentrations for Ruth Spring, 2004–13

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	1	0.65	0.65	0.65
2005	2	0.65	0.72	0.58
2006	2	0.63	0.63	0.63
2007	3	0.58	0.59	0.57
2008	4	0.62	0.67	0.58
2009	4	0.64	0.67	0.61
2010	3	0.69	0.74	0.64
2011	4	0.68	0.73	0.62
2012	4	0.65	0.76	0.54
2013*	4	0.70	0.76	0.62

Table 5.2d. Yearly average nitrate concentrations for Baird #1 Spring, 2004–13

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	1	0.23	0.23	0.23
2005	2	0.17	0.21	0.13
2006	2	0.24	0.24	0.24
2007	4	0.25	0.27	0.24
2008	4	0.25	0.27	0.25
2009	4	0.26	0.28	0.24
2010	3	0.27	0.29	0.25
2011	4	0.28	0.29	0.26
2012	4	0.27	0.28	0.26
2013*	4	0.29	0.31	0.28

Table 5.2e. Yearly average nitrate concentrations for Crab Creek Spring, 2004 – 2013

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	1	0.60	0.60	0.60
2005	2	0.63	0.66	0.60
2006	2	0.58	0.58	0.57
2007	4	0.54	0.56	0.52
2008	4	0.56	0.60	0.52
2009	4	0.57	0.60	0.54
2010*	3	0.64	0.64	0.62
2011	4	0.62	0.64	0.59
2012	4	0.62	0.66	0.59
2013*	4	0.64	0.67	0.61

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

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	4	0.54	0.57	0.52
2005	4	0.55	0.61	0.50
2006	4	0.55	0.57	0.51
2007	4	0.52	0.55	0.50
2008	4	0.57	0.62	0.55
2009	4	0.56	0.58	0.54
2010	14	0.58	0.64	0.46
2011	4	0.59	0.62	0.53
2012	4	0.58	0.61	0.57
2013*	4	0.60	0.61	0.57

Table 5.2g. Yearly average nitrate concentrations for Chassahowitzka #1 Spring, 2004–13

Maximum annual average is shown with an asterisk and highlighted in red.

Year	N	Mean	Maximum	Minimum
2004	4	0.58	0.61	0.54
2005	4	0.61	0.65	0.57
2006	4	0.59	0.63	0.53
2007	4	0.58	0.59	0.55
2008	4	0.62	0.67	0.59
2009	4	0.62	0.63	0.60
2010*	4	0.64	0.66	0.64
2011	4	0.62	0.65	0.57
2012	4	0.63	0.64	0.61
2013*	4	0.64	0.65	0.63

5.8 Calculation of TMDL Percent Reduction

The maximum annual average TN and nitrate concentrations were calculated from data available during the Cycle 2 verified period plus more recent data (January 1, 2004, and December 31, 2013). The maximum annual average TN concentration for the Chassahowitzka River occurred during 2010 and is 0.58 mg/L. The maximum annual average nitrate concentration for Baird #1 Spring, Ruth Spring, and Chassahowitzka Main Spring occurred during 2013 and are 0.29, 0.70, and 0.60 mg/L, respectively. For Chassahowitzka #1 Spring, Crab Creek Spring, and Beteejay Spring the maximum annual average nitrate concentration occurred during 2010 and 2013. The maximum annual average nitrate concentration for Chassahowitzka #1 Spring and Crab Creek Spring was 0.64 mg/L. The maximum annual average nitrate concentration for Beteejay Spring was 0.45 mg/L.

These TMDL target concentrations for Chassahowitzka Springs Group, Crab Creek Spring, Chassahowitzka River, Baird Springs, Ruth Spring, and Beteejay Spring 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.

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:

For Chassahowitzka River (WBID 1348D):

[(0.58 mg/L – 0.25 mg/L) / 0.58 mg/L] * 100

Equals a 57% reduction in TN.

For Chassahowitzka Main Spring (WBID 1348Z):

[(0.0.60 mg/L – 0.23 mg/L) / 0.60 mg/L] * 100

Equals a 62% reduction in nitrate.

For Crab Creek Spring (WBID 1348Z):

[(0.64 mg/L – 0.23 mg/L) / 0.64 mg/L] * 100

Equals a 64% reduction in nitrate.

For Chassahowitzka #1 Spring (WBID 1348Z):

[(0.64 mg/L – 0.23 mg/L) / 0.64 mg/L] * 100

Equals a 64% reduction in nitrate.

For Baird #1 Spring (WBID 1348D):

[(0.29 mg/L – 0.23 mg/L) / 0.29 mg/L] * 100

Equals a 21% reduction in nitrate.

For Ruth Spring (WBID 1348D):

[(0.70 mg/L – 0.23 mg/L) / 0.70 mg/L] * 100

Equals a 67% reduction in nitrate.

For Beteejay Spring (WBID 1361B):

[(0.45 mg/L – 0.23 mg/L) / 0.45 mg/L] * 100

Equals a 49% reduction in nitrate.

Reductions in TN concentrations of 57% in the Chassahowitzka River and nitrate concentrations of 62% to 64% in Chassahowitzka Springs Group, 64% in Crab Creek Spring, 21% in Baird #1 Spring, 67% in Ruth Spring, and 49% in Beteejay Spring are proposed because they are protective values that, when achieved, will cause filamentous algae biomass and epiphytic 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 concentration reductions listed in **Section 5.8** should achieve the annual average nutrient target concentration for Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Chassahowitzka River, Baird Springs, Ruth Spring, and Beteejay Spring. 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 nitrogen TMDL targets are presented as annual averages instead of daily values because changes in aquatic vegetation biomass do not respond instantaneously to changes in nutrient concentrations. Murray *et al.* (1999) found that nutrient enrichment response differed for SAV on the order of months (two to two and a half months). Also, due to limited economic resources, it is impractical to collect daily nitrate water quality data to evaluate water quality for the Chassahowitzka 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:

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

$$\sigma y = \mathrm{sqrt}(\ln(CV^2 + 1))$$

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 Nitrogen

For the monthly maximum nitrogen 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 TN concentrations for Chassahowitzka River and the monthly maximum nitrate concentrations for Chassahowitzka Springs Group, Crab Creek Spring, Baird Springs, Ruth Spring, and Beteejay Spring.

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 TN and nitrate concentrations (mg/L)

Waterbody Name (WBID)	Parameter	Standard Deviation	Long-Term Average Nitrate Target (mg/L)	CV	Monthly Maximum To Achieve Annual Average Nitrogen Target
Chassahowitzka #1Spring	Nitrate	0.0238	0.23	0.0388	0.245
Chassahowitzka Main Spring	Nitrate	0.0257	0.23	0.0456	0.247
Chassahowitzka River	TN	0.0430	0.25	0.0883	0.287
Crab Creek Spring	Nitrate	0.0345	0.23	0.0577	0.253
Baird Springs	Nitrate	0.0341	0.23	0.1358	0.285
Ruth Spring	Nitrate	0.0340	0.23	0.0523	0.250
Beteejay Springs	Nitrate	0.0578	0.23	0.1485	0.290

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 Chassahowitzka Main Spring, Chassahowitzka #1 Spring, Crab Creek Spring, Chassahowitzka River, Baird Springs, Ruth Spring, and Beteejay Spring are expressed in terms of concentration of nitrogen 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.

Table 6.2. TMDL components for Chassahowitzka Springs Group, Crab Creek Spring, Chasshowitzka River–Baird Creek, Baird Springs, Ruth Spring and Beteejay Spring

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
Chassahowitzka Main Spring	Nitrate as Annual Average	0.23	62%	N/A	62%	62%	Implicit
Chassahowitzka #1 Spring	Nitrate as Annual Average	0.23	64%	N/A	64%	64%	Implicit
Crab Creek Spring	Nitrate as Annual Average	0.23	64%	N/A	64%	64%	Implicit
Chassahowitzka River-Baird Creek	TN as Annual Average	0.25	57%	N/A	57%	57%	Implicit
Baird #1 Spring	Nitrate as Annual Average	0.23	21%	N/A	21%	21%	Implicit
Ruth Spring	Nitrate as Annual Average	0.23	67%	N/A	67%	67%	Implicit
Beteejay Spring	Nitrate as Annual Average	0.23	49%	N/A	49%	49%	Implicit

6.2 Wasteload Allocation (Point Sources)

6.2.1 NPDES Wastewater Discharges

Currently, no NPDES wastewater facilities discharge directly into the Chassahowitzka 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 Chassahowitzka River, they will be subject to the assigned WLA.

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 Chassahowitzka Springs contributing area are maintained by Citrus County (Permit FLR04E141), Hernando County (Permit FLR04E040), and FDOT District 7 (Permit FLR04E017 – Hernando, and

Permit 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.

6.3 Load Allocation (Nonpoint Sources)

Reductions in TN concentrations of 57% in the Chassahowitzka River and reductions in nitrate concentrations of 62% to 64% in Chassahowitzka Springs Group, 64% in Crab Creek Spring, 21% in Baird #1 Spring, 67% in Ruth Spring, and 49% in Beteejay Spring 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. Also, when estimating the required percent reduction to achieve the water quality target, the highest annual average of measured nitrogen concentration within the nine-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 this TMDL by rule, the Department will determine the best course of action regarding its implementation. Depending on the pollutant(s) causing the waterbody impairment and the significance of the waterbody, the Department will select the best course of action leading to the development of a plan to restore the waterbody. Often this will be accomplished cooperatively with stakeholders by creating a Basin Management Action Plan, referred to as the BMAP. BMAPs are the primary mechanism through which TMDLs are implemented in Florida (see Subsection 403.067[7], F.S.). A single BMAP may provide the conceptual plan for the restoration of one or many impaired waterbodies. 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.

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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 United States 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.