The Hydrology and Water Quality of Select Springs in the Southwest Florida Water Management District

Prepared by the
Water Quality Monitoring Program

Southwest Florida Water
Management District

May 2001
(Revised March, 2011)

PROFESSIONAL GEOLOGIST

The geological evaluation and interpretation contained in the report entitled, “The Hydrology and Water Quality of Select Springs in the Southwest Florida Water Management District” were prepared by or under the supervision of a Licensed Professional Geologist in the State of Florida

Kyle M. Champion	Date
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March, 2011 Revisions (by D.J. DeWitt, P.G.)

page i: report title was changed from Hydrology and Water Quality of Springs in West-Central Florida to; Hydrology and Water Quality of Select Springs in the Southwest Florida Water Management District.

page iii, paragraph 1, Preface: Hydrology and Water Quality of Springs in west-central Florida was changed to; Hydrology and Water Quality of Select Springs in the Southwest Florida Water Management District.

Page 65, paragraph 1: a single, large main spring was changed to a collection of head springs; mostly from the main spring was changed to mostly from the head springs

Page 65, paragraph 2: approximately 173 mgd was changed to approximately 118 mgd (134 cfs). Table 3 was replaced with a corrected table of reported historical discharge estimates for the Chassahowitzka Springs group.

Page 66, Figure 16: Crab spring was changed to Crab Creek Spring, and a location for the historical USGS discharge station transect is included on the map.

Page 71, paragraph 1: located south of was changed to; located west of the Chassahowitzka Main Spring.

HYDROLOGY AND WATER QUALITY OF SELECT SPRINGS IN THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Water Quality Monitoring Program

Southwest Florida Water Management District

May 2001 (Revised March, 2011)

Authors

Kyle M. Champion	Professional Geologist
Roberta Starks	Environmental Scientist

Contributors

Eric C. DeHaven	Manager, WQMP
David J. DeWitt	Professional Geologist
Jill Hood	Hydrologist
Chris Tomlinson	Water Resource Technician Supervisor
Chris Anastasiou	Water Resource Technician
Jason Hood	Water Resource Technician
Keith Morrison	Water Resource Technician
Nita Ostermann	Water Resource Technician
Kelly Permenter	Water Resource Technician
Chris Zajac	Water Resource Technician

The land had great depth of soil and gathered the water into itself and stored it up into the soil...as though it were a sort of natural water jar; it drew down into the natural hollow the water which it had absorbed from the high ground and so afforded in all districts of the country liberal sources of springs and rivers...
Critias, Plato (427-347 B.C.)

PREFACE

This report, entitled *The Hydrology and Water Quality of Select Springs in the Southwest Florida Water Management District,* combines and condenses into one document a wealth of information collected during previous water-quality studies performed by the Water Quality Monitoring Program (WQMP) at the Southwest Florida Water Management District (SWFWMD). The report is designed to present the reader with an up-to-date catalog of some of the larger and better known springs within the District, and summarizes nearly 10 years of research conducted on springs, providing a detailed description of the chemistry of spring waters throughout the SWFWMD.

The report is organized into three major sections. The first section, THE SPRINGS REGION, provides an overall description of the geology and hydrology of the springs. The second section, WATER QUALITY, details the chemistry and evolution of spring waters throughout the SWFWMD and is written for a more technical audience. A third section, SPRING DESCRIPTIONS, gives site-specific descriptions of springs and provides a photographic catalog of nearly 50 springs in the SWFWMD. It should be remembered that portions of this report have been taken directly from previous spring reports produced by the WQMP and that portions have been paraphrased for brevity.

ACKNOWLEDGMENTS

Since 1991 the WQMP has sampled nearly 100 springs throughout the SWFWMD. Almost half of these springs have become part of an ongoing program to monitor and document changes in the water quality of springs within the District. However, sampling many of the springs would not be possible without the help and cooperation of a number of individuals throughout the SWFWMD.

Because of their continuing assistance and cooperation, the WQMP would like to express its appreciation to: Phil Shultz, Florida Sheriff's Youth Ranch; R. L. King; David Jowers, Park Manager, Rainbow Springs State Park; Pete Sleszynski, Rainbow Springs Aquatic Preserve; the Chassahowitzka National Wildlife Refuge; Tom Linley, Park Manager, Homosassa Springs State Wildlife Park; Dr.Vesley and other generous homeowners along the southeast fork of the Homosassa River; Wilson Smith; Billy Bigham; Trusten Drake, Drake Ranch; Jake Williams, Shady Brooks Golf Course; Dennis Brungardt, Weeki Wachee Springs Attraction; Mr. and Mrs. James Rolston, Magnolia Springs; Mr. and Mrs. Bill Weiten, Aripeka Mobile Home Park; Mr. and Mrs. T. J. Storch, Beteejay Spring; Robert Thomas, Two Rivers Ranch; Meg Andronaco, Zephryhills Bottled Water; Cargill Fertilizer Inc.; Lithia Springs County Park; and Sam Herron, Manager, Florida Springs Inc.

The WQMP would also like to thank the many cave divers throughout northern and central Florida including Jeff Petersen and members of Karst Underwater Research, Inc.; K. Michael Garman and members of HydroGeo Environmental Research, Inc.; and Peter Butt and members of Karst Environmental Services for their technical assistance and invaluable contributions to exploring and expanding the boundaries of underwater karst geology.

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INTRODUCTION

In an open letter to the editors of the *Water Resources Atlas of Florida*, former Governor Lawton Chiles stated that:

> "Water resources are among Florida's most important natural assets....vital for our daily lives, future residents and visitors, natural systems, recreation and agriculture. Florida's freshwater supplies are finite and the demands of a growing population and the need to sustain our rivers, lakes, and wetlands and estuaries requires the utmost care and thoughtfulness in planning and using our freshwater supplies."(1)

Throughout Florida, freshwater supplies seem abundant; thousands of lakes dot the landscape and hundreds of miles of streams, canals, and large rivers crisscross the state. Productive aquifers lie underground in many places and supply what appears to be a limitless supply of fresh, potable water to water wells. In Florida, ground-water resources are used primarily for public water supply and agriculture uses. It is estimated that public water supply accounts for approximately 43 percent of the state's total ground-water use; agriculture accounts for approximately 35 percent. In addition, it has been estimated that nearly 93 percent of the state's population relies on ground water for its drinking water needs(2).

Another natural asset that is often overlooked in Florida are its springs. It is estimated that over 600 springs are scattered throughout the northern and central portions of the state. Most, if not all, of these springs rely on ground water derived solely from the Upper Floridan aquifer. The Upper Floridan aquifer, one of the most productive aquifers in the world, underlies the entire Florida peninsula. It has been estimated that on a daily basis Florida springs discharge more than 8 billion gallons of ground water from the Upper Floridan aquifer(3); by comparison, approximately 2.5 billion gallons of ground water were withdrawn daily from the Upper Floridan aquifer in 1995 throughout the state(2).

Many of the larger springs in Florida lie at the headwaters of large spring-fed rivers. Unique ecosystems, spring-fed rivers typically promote and harbor aquatic species that are incapable of surviving in rivers subject to wide fluctuations in temperature, water clarity, and/or sedimentation(4). This natural ability to regulate riverine ecosystems makes springs vital to the health and survival of many plant and animal species that live in or near the spring-fed systems. Manatees, for example, often congregate at or near springs during the winter months due to relatively warm spring water discharging from the Upper Floridan along the Gulf of Mexico.

HISTORICAL SIGNIFICANCE

For hundreds, if not thousands of years, springs have played an important part in Florida's cultural and economic history. For example, when Spanish explorers landed in what was to become St. Augustine, Native Americans were encamped near freshwater springs(5). Early explorers also found a Chatot Indian village at what would become Waddells Mill Pond Spring in northern Florida[3]. It would seem that thousands of years ago springs often served as the setting for villages and encampments because of their unique ability to supply Native Americans, and later, European explorers, with clean, reliable sources of freshwater.

In 1774 the naturalist William Bartram traveled through Florida and wrote of Manatee Springs:

"...We entered the grand fountain, the expansive circular bason [sic], the source of which arises from under the bases of the high woodland hills....The ebullition is astonishing, and continual....the waters appear of a lucid sea green colour, in some measure owing to the reflection of the leaves above....the bason and stream peopled with prodigious numbers and variety of fish and other animals; as the alligator, and the manatee or sea cow...."[6]

In the 1800's changes began to take place at many springs in the state. Springs began to be altered and developed for private and commercial uses. Though typically superficial, these changes were generally designed to enhance the recreational and economic opportunities for thousands of individuals visiting and living near the springs. White Spring in Hamilton County, for example, was developed into a bathhouse in 1835 because of the medicinal benefits thought to be gained by bathing in the mineralized spring water[3]. A small group of springs were also modified during the 19th century by damming the spring runs and forming spillways to power gristmills.

As early settlers moved into Florida and the state's population increased, a number of small communities became well established at many of the larger springs throughout northern Florida. These communities, and their associated spring attractions, quickly developed into popular tourist destinations. A theme park built at Silver Springs in the early 1900's is a good example[4]. By the middle of the 20th century, large springs began to be recognized as important ecosystems and natural assets. Some springs, like Rainbow Springs, were established as state parks. During this same time, SCUBA diving in many of the springs revived local economies and provided additional recreational opportunities to thousands of tourists and local residents.

Throughout the 1990's, water quality problems and an increased demand for bottled water have created a renewed interest in springs throughout northern and central Florida. Increasing nitrate concentrations and their effect on springs and spring-run ecosystems have been an issue in many springs throughout the state. In addition, there is mounting concern that as population increases in Florida, spring flow will decrease as ground water is withdrawn from the aquifer and used for urban consumption. Clearly, the need for clean, reliable sources of fresh water continues to be an important part in the story of springs throughout Florida.

THE SPRINGS REGION

INTRODUCTION

Hundreds of springs lie within the boundaries of the Southwest Florida Water Management District (SWFWMD or District). While some of these are isolated features, many are clustered into groups, or spring groups, of varying size and areal extent. Large spring groups, such as Rainbow Springs in southwestern Marion County, cover large areas, often draining tens or even hundreds of square miles. In addition, springs throughout the SWFWMD create an ideal environment by which to study and monitor ground-water quality in the Upper Floridan aquifer.

The largest concentration of springs in the SWFWMD can be found in the northern half of the district (Figure 1), where the Upper Floridan aquifer is mostly unconfined and relatively close to the land surface. Because soluble limestones of the Upper Floridan aquifer occur close to the land surface and are not covered by confining clay layers, the northern half of the district has developed into a karst landscape. This landscape is characterized by an abundance of sinkholes, sinking streams, underground caverns, and springs. Five of Florida's first-magnitude springs lie within the SWFWMD. Rainbow Springs is, in fact, one of the largest springs in the world[3].

Prior to development, much of the springs region was covered by high pine forests, hammock forests, and pockets of scrub[7]. Over time, this natural vegetation was replaced by agricultural lands, including livestock pastures, row crops and citrus. However, over the last several decades, urban development has increased dramatically in the region and altered much of the rural landscape. Thousands of acres of commercial and urban development, including residential areas and golf courses, are spreading rapidly across the region as population continues to grow in the vicinity of the springs.

Water-quality studies conducted within the SWFWMD have shown that nitrate concentrations have been increasing in a number of springs throughout the northern portions of the District. This nitrate, derived primarily from inorganic fertilizers, has leached into the Upper Floridan aquifer within the last 20 years and is now being discharged at springs across the region[9,10,11,12,13]. With population in the SWFWMD expected to reach 4.6 million by the year 2010[8], this situation can only become more serious.

GEOGRAPHIC SETTING, TOPOGRAPHY, and DRAINAGE

The SWFWMD covers nearly 10,000 square miles of west-central Florida. In 1995 the SWFWMD was home to more than 3.5 million people[8]. The northern half of the District encompasses a small portion of southeastern Levy County; the western half of Marion County; all of Sumter, Citrus, Hernando, and Pasco Counties; and portions of

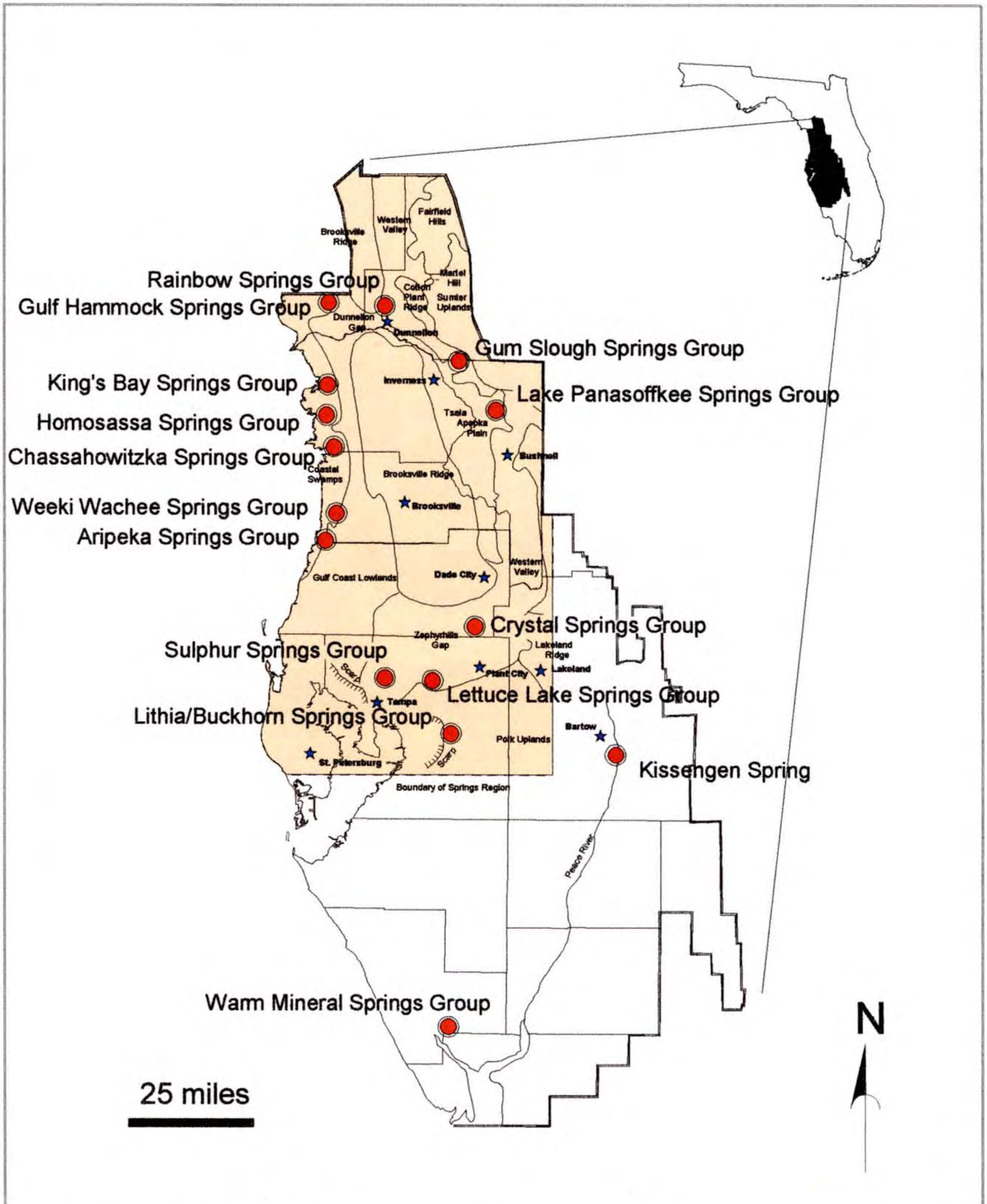


Figure 1. Location of Major Spring Groups, Municipalities and Physiographic Provinces in the Northern Portions of the SWFWMD.

Pinellas, Hillsborough, and Polk Counties (Figure 1). A number of small communities lie within this region including Dunnellon, Inverness, Bushnell, Brooksville, Dade City, Lakeland, and Plant City. The northern half of the district is typically rural in character with more urbanized areas near major highway corridors and centers of population, especially into Pinellas and Hillsborough Counties. The City of Tampa is the largest urban area in the Springs region with a population of nearly 300,000 in the mid 1990's[14].

Twelve physiographic provinces have been identified within the springs region (Figure 1), and include the Coastal Swamps, the Gulf Coast Lowlands, the Brooksville Ridge, the Tsala Apopka Plain, the Western Valley, the Sumter Uplands, the Fairfield Hills, the Cotton Plant Ridge, the Martel Hill, the Dunellon Gap, the Zephyrhills Gap, and the Polk Uplands[15]. These provinces have been characterized according to soil type(s), drainage patterns, topography and geology. Soils are generally well drained throughout much of the springs region (especially in the upland areas of the Brooksville Ridge, for example), and moderate to poorly drained in the lowland areas (e.g., the Coastal Swamps).

Land-surface elevations throughout the springs region vary widely. The karst nature of the landscape has created an undulating topography where surface elevations can change rapidly. The highest elevations in the region generally lie in the upland areas of the Brooksville Ridge, Sumter Uplands, and Fairfield Hills. Elevations can often exceed 275 feet above sea level on isolated hills in Marion, Citrus, Hernando, and Pasco Counties. Land surface elevations in the springs region are closely related to karst processes and marine terrace deposits.

The lack of rivers and streams in the interior of the springs region results from a well-developed underground drainage system in the limestone that underlies the northern parts of the SWFWMD. Precipitation falling on the Brooksville Ridge and other upland areas moves rapidly underground through numerous sinkholes and karst features, and begins moving towards the springs through an extensive system of conduits and passages within the limestone.

The main rivers in the springs region include the Rainbow, Withlacoochee, Crystal, Homosassa, Chassahowitzka, Weeki Wachee, Pithlachascotee, Anclote, Hillsborough, and Alafia Rivers (Figure 2). The Withlacoochee River originates in the Green Swamp (northern Polk County), and flows northwest to the Gulf of Mexico near Yankeetown in Levy County. The river drains nearly 2,000 square miles of west-central Florida, and has an average flow at its confluence with the Rainbow River of approximately 1,300 million gallons per day (mgd)[16]. In contrast to the tea-colored, tannic waters of the Withlacoochee River, the waters of the Rainbow River are crystal clear. This is largely because nearly all of the flow of the Rainbow River is derived from ground water discharged at Rainbow Springs. It is estimated that approximately 89 percent of the river's discharge at the confluence with the Withlacoochee River enters the Rainbow River in the first 1.5 miles[11].

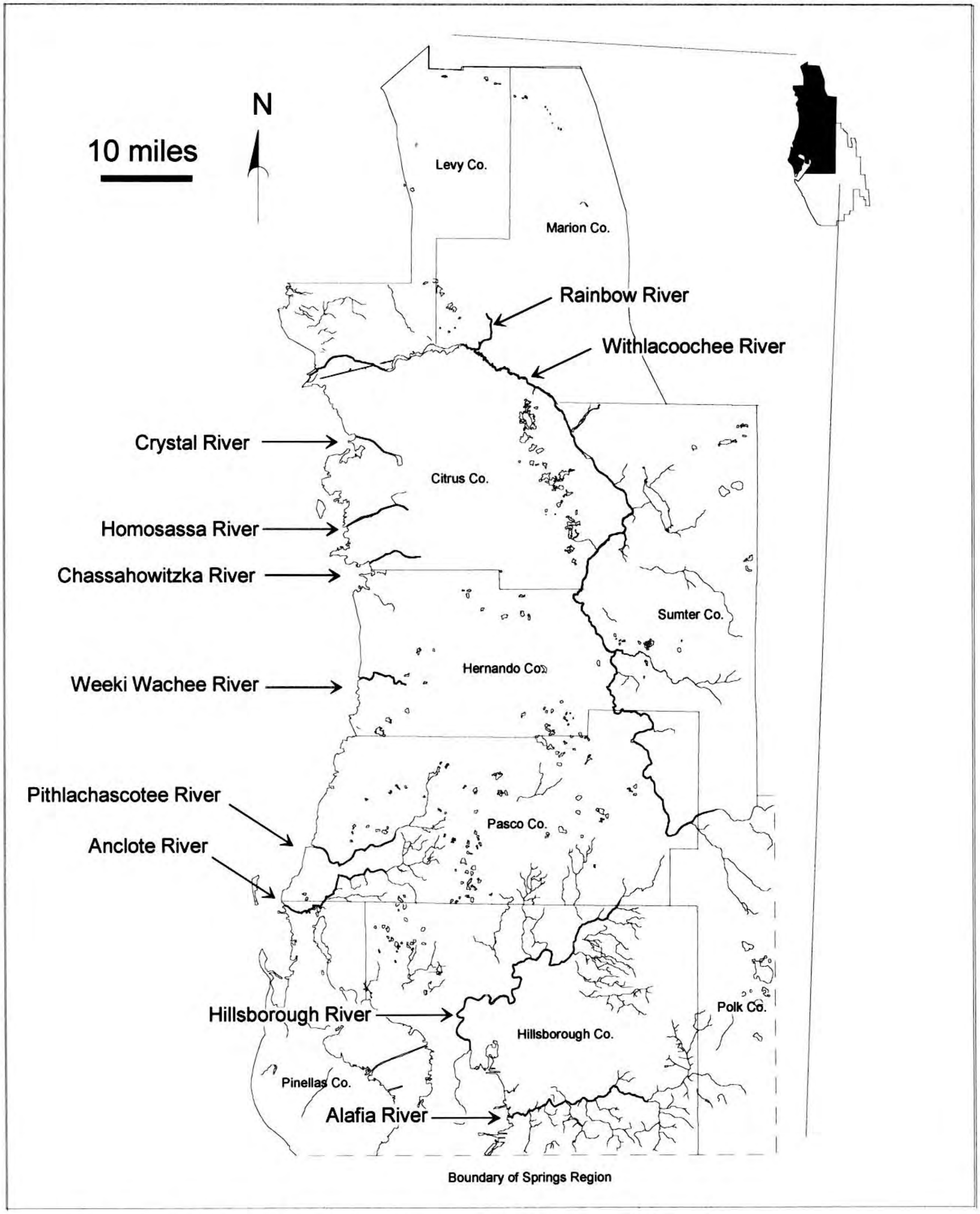


Figure 2. Major Surface Water Features in the Springs Region.

The Crystal, Homosassa, Chassahowitzka, and Weeki Wachee Rivers are located in coastal portions of the SWFWMD. Like the Rainbow River to the north, the sources of these four rivers are major springs or spring groups. The flow of the rivers, prior to mixing with sea water moving upriver under the influence of tides, is predominantly ground water. The Crystal, Homosassa, Chassahowitzka, and Weeki Wachee Rivers flow westward for short distances (generally less than 10 miles) through mangrove swamps, hardwood hammocks, and salt marshes prior to reaching the Gulf of Mexico(7).

The Pithlachascotee and Anclote Rivers originate in south-central Hernando and Pasco Counties, respectively. These two rivers flow southwestward through western Pasco County and enter the Gulf of Mexico near New Port Richey and Tarpon Springs. The waters of the Pithlachascotee and Anclote Rivers are a mixture of surface-water runoff and ground-water discharge from the Upper Floridan aquifer. It is estimated that ground-water discharge contributes approximately 10-15% of the flow in the two rivers. The mineral content of the Pithlachascotee and Anclote Rivers varies seasonally; during low flow conditions (i.e., dry season), ground-water seepage contributes to the high mineral content in the rivers. As overland flow increases, the mineral content in the rivers drops due to surface-water contributions(17).

The Hillsborough River originates in the Green Swamp near the Withlacoochee River in northeastern Pasco County. The river drains approximately 690 square miles, including portions of Pasco, Polk, and Hillsborough Counties. The river flows southwestward for 54 miles before reaching Hillsborough Bay at the City of Tampa. During the dry season, a large percentage of the flow in the Hillsborough River is derived from ground-water discharge at Crystal Springs. Between 1980 and 1985, for example, 50 to 80 percent of the river's discharge was contributed by Crystal Springs(18).

The Alafia River originates in the "Phosphate District" of Polk and Hillsborough Counties. The river is formed by the confluence of the North and South Prongs of the Alafia River and flows westward for nearly 25 miles where it empties into Hillsborough Bay near Gibsonton. Average flow in the Alafia River at Lithia is approximately 217 mgd(19); however, the river's flow is increased by an additional 35 mgd due to ground-water discharge from Lithia and Buckhorn Springs(9).

GEOLOGY

Figures 3a and 3b are a geologic map and cross section showing the stratigraphic units at or near land surface throughout the springs region, respectively. The generalized hydrogeology of the region is presented in Table 1. It is apparent from Figures 3a and 3b, and Table 1 that the geology in the northern portions of the SWFWMD is relatively simple.

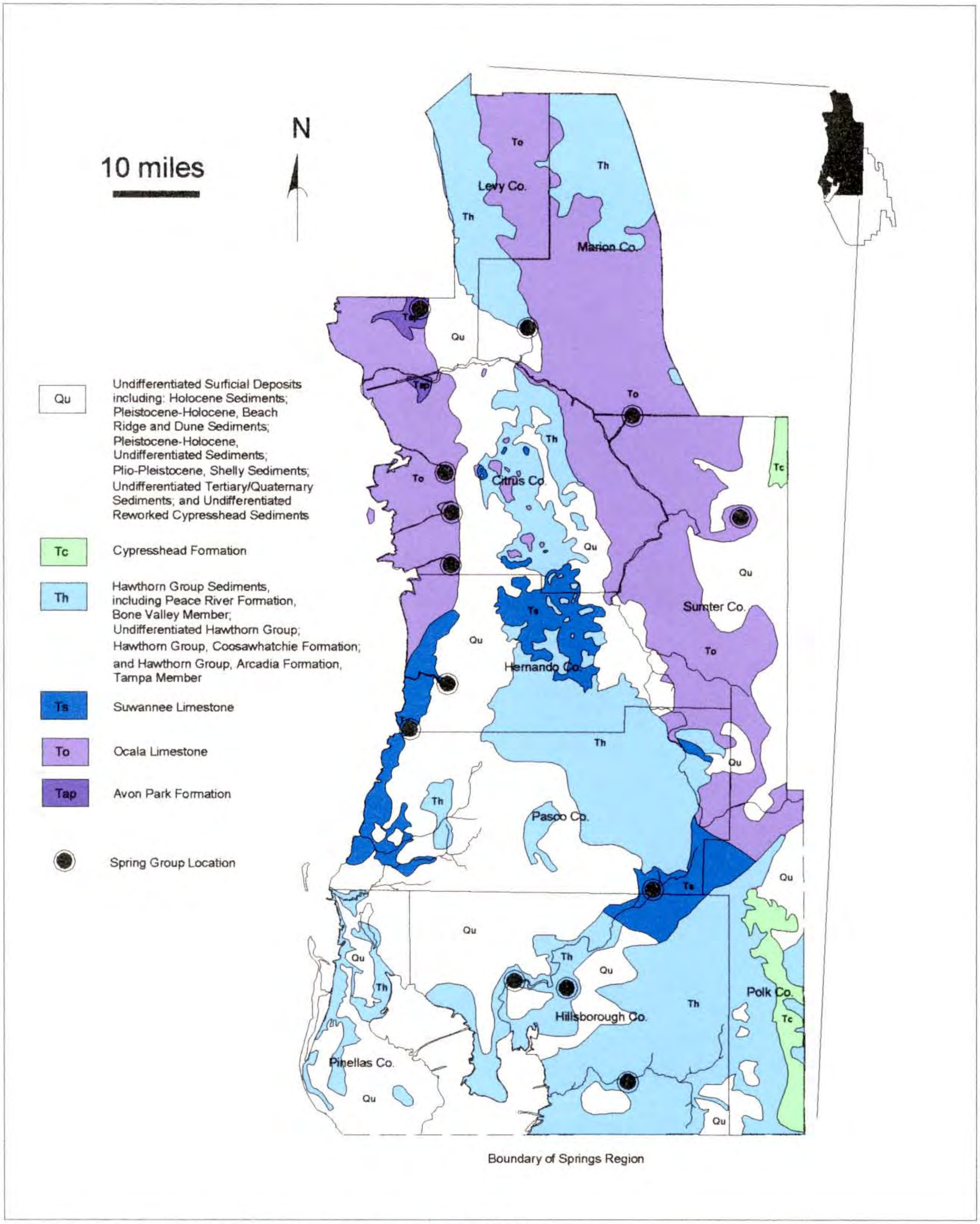


Figure 3a. Geologic Map of the Springs Region [(20-28)].

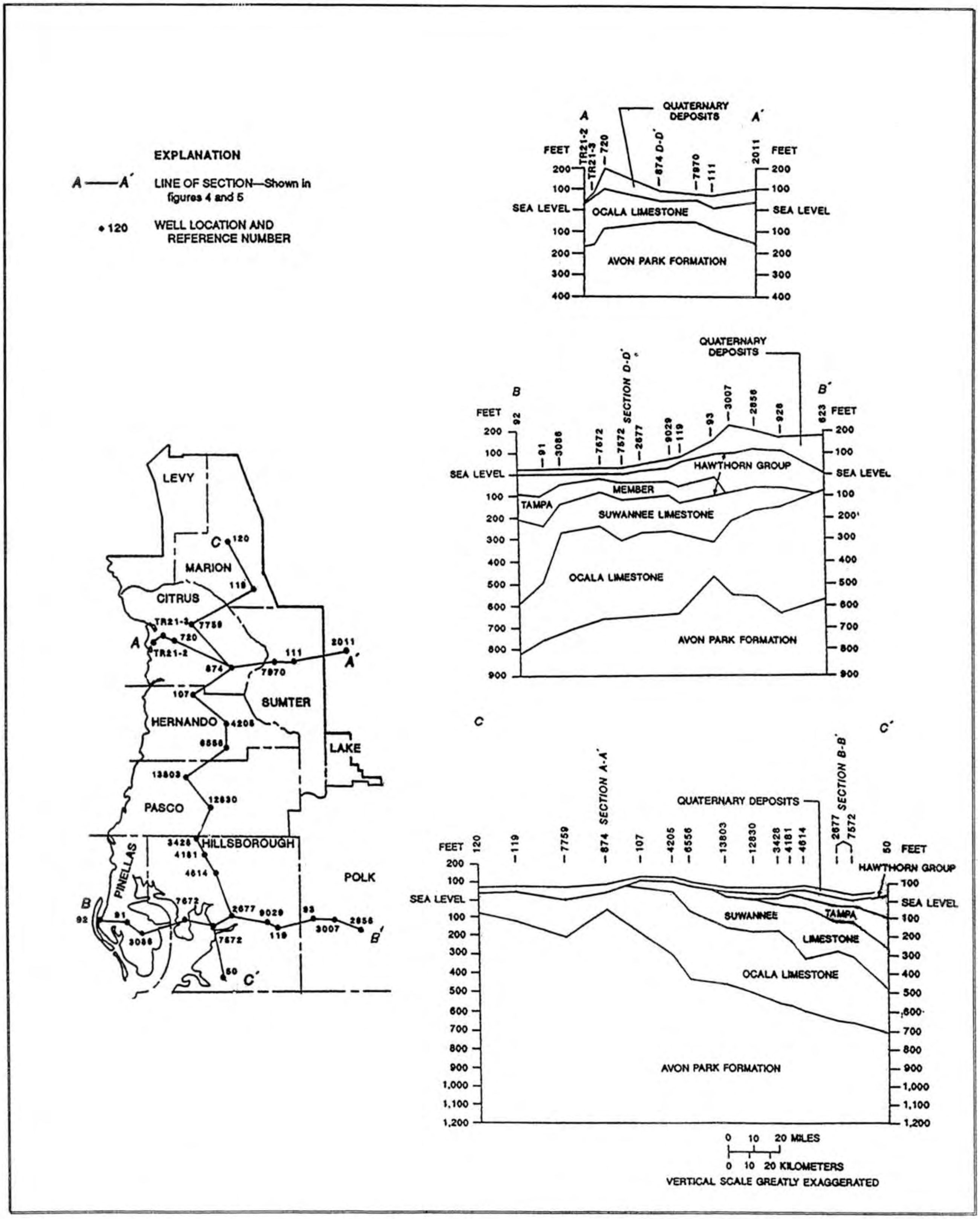


Figure 3b. Geologic Cross Sections of the Springs Region[31].

Table 1. Generalized Hydrogeology of the Northern SWFWMD Area[30].

SYSTEM	SERIES	STRATIGRAPHIC UNIT	THICKNESS (FEET)	LITHOLOGY	WATER PRODUCING CHARACTERISTICS
Quaternary	Holocene and Pleistocene	Undifferentiated deposits	0-100	Soil, sand, and clay of marine and estuarine terraces, alluvial, lake, and windblown deposits.	Generally not a source of water
Tertiary	Pliocene and Miocene	Hawthorne Group	0-100	Predominantly clay; some grayish-green, waxy; some interbedded sand and limestone, phosphatic clay, marl, calcareous sandstone, limestone residuum.	Confining layer in some places; generally not a source of water. Tampa Member may produce water locally.
Tertiary	Oligocene	Suwannee Limestone	0-150	Limestone, cream to tan colored, fine-grained, fossiliferous, thin-bedded to massive, porous.	Many domestic and irrigation wells produce water from the lower part.
Tertiary	Eocene (upper)	Ocala Limestone	100-150	Limestone, white to tan fossiliferous, massive, soft to hard, porous.	Yields large quantities of water to wells completed above evaporites.
Tertiary	Eocene (middle)	Avon Park Formation	200-800	Limestone and dolomite. Limestone is light to dark-brown, highly fossiliferous, and porosity is variable in lower part. Dolomite is gray to dark-brown, very fine to microcrystalline and contains porous fossil molds, thin beds of carbonaceous material, and peat fragments. Formation generally contains evaporites in lower part.	Yields large quantities of water to wells completed above evaporites.

Approximately 2,000 to 2,500 feet of limestone and dolostone are overlain by a thin section of marine, transitional, and terrestrial deposits which are predominantly siliciclastic in nature. The uppermost limestone units of the region include the Tampa Member (Arcadia Formation) of Miocene age, the Suwannee Limestone of Oligocene age and the Ocala Limestone of Late Eocene age. The Middle Eocene age Avon Park Formation underlies the Suwannee and Ocala Limestones throughout most of the entire region. However, the Avon Park Formation is exposed in restricted portions of Levy and Citrus Counties where the overlying units have been removed by erosion (Figure 3a).

The Tampa Member of the Arcadia Formation occurs in the southern third of the springs region. The Tampa consists predominantly of limestone, however, some dolostone, sand and clay are present. Phosphate also occurs in the Tampa Member, but only in small amounts (generally less than 3 percent[(31)]). The Tampa is generally fossiliferous, with molds of mollusks, foraminifera and algae often present. In areas near the City of Tampa, the Tampa Member is well known for silicified corals, siliceous pseudomorphs of fossils and chert boulders[(31)].

The Suwannee Limestone is absent in the extreme northern portions of the SWFWMD due to erosion[(32)]. Where the Suwannee does occur, it tends to be a marine, bioclastic limestone that can be described as a partially crystalline to crystalline limestone, very pale orange in color, firmly to weakly cemented with calcite, sandy, silty and/or clayey, of moderate to high moldic porosity, and generally very fossiliferous. The Suwannee Limestone, as seen in quarries throughout Hernando and Pasco Counties, contains alternating beds of hard and soft limestone of varying thickness. In most of the rock quarries, chert nodules and thin beds of chert are associated with the limestone[(33)].

The Ocala Limestone underlies the Suwannee Limestone, except where the Suwannee has been removed by erosion. The lower portion of the Ocala may consist of a granular, highly fossiliferous to coquinal, tan and brown limestone, or a gray and cream to white limestone. In places, both the upper and lower portions of the Ocala Limestone are coquinas, consisting almost entirely of foraminifera. Chert is usually found near the top of the Ocala, but may occur at any depth within the unit. Differential erosion of the Ocala Limestone has caused the formation of pinnacles and a wide variation in the altitude of the limestone surface.

The Avon Park Formation is the deepest carbonate formation containing potable water in the region. The Avon Park is present at or near the land surface in northwestern Citrus and southeastern Levy Counties (Figure 3a). The Avon Park in this region consists of several hundred feet of brown, finely fragmental, highly fossiliferous limestone and dolostone with low to high porosity. The occurrence of fossil seagrass beds in the Avon Park Formation indicates a shallow-water environment existed during deposition of the limestone during the Middle Eocene[(34)]. Gypsum is also present in small amounts in the Avon Park Formation. The Suwannee and Ocala Limestones, and the Avon Park Formation comprise the Upper Floridan aquifer in the region.

Throughout much of the upland areas in the springs region, the limestones of the Upper Floridan aquifer are overlain by undifferentiated quartz sand and sediments of the Hawthorn Group. The Brooksville Ridge Quaternary terrace deposits and Hawthorn Group sediments overlie the Upper Floridan aquifer in the central portions of the springs region. These sediments act as an upper semi-confining unit, but are typically breached by sinkholes. The Hawthorn Group sediments were deposited in shallow marine environments, with subsequent reworking through subaerial erosion and karst modification. Hawthorn sediments consist of clayey sand, silt, and reddish grey to green weathered clay. Phosphorite pebbles and fossils, common to the Hawthorn, are absent in the Brooksville Ridge(35) and the highly weathered and reworked nature of the formation complicates recognition of the facies originally deposited there. Between the City of Brooksville and the Hernando/Citrus County line to the north, the Hawthorn sediments have been eroded, and the Suwannee Limestone lies exposed or is near the land surface.

GROUND-WATER HYDROLOGY

Surficial Aquifer

The surficial aquifer system consists of Miocene to Holocene siliciclastic deposits that are contiguous with the land surface. The clastics are usually quartz sand, silty sand, and kaolinitic to smectitic clay. The surficial aquifer is most likely to occur as a distinct hydrostratigraphic unit along the Brooksville Ridge, or other upland areas, where low permeability clays of the Hawthorn Group, or its residuum, separate the surficial aquifer from the underlying Upper Floridan aquifer. The downward movement of water into the Upper Floridan aquifer is retarded by these lower permeability units; however, the collapse of surficial sediments into voids in the underlying limestone has produced numerous breaches in the clays that act as vertical conduits for the movement of water from the surficial to the Upper Floridan aquifer.

Floridan Aquifer

The Floridan aquifer system is divided into two major hydrostratigraphic horizons. The Upper Floridan, which contains potable water, and the Lower Floridan which is saline. The Upper Floridan, henceforth termed the Floridan aquifer, is the principal source of ground water for springs throughout the District.

The Floridan aquifer is composed of several geologic formations that are considered to act as a single hydrologic unit(36). In the northern and central portions of the SWFWMD the fresh-water-bearing part of the Floridan aquifer is composed of the Suwannee and Ocala Limestones, and the Avon Park Formation, in descending order. The lower part of the Avon Park Formation contains evaporites consisting of gypsum and anhydrite that reduce permeability of the rock and defines the base of the Upper Floridan aquifer. In general, the Floridan aquifer is unconfined in the northern portions of the district; however, clay layers in the Brooksville Ridge may be sufficiently thick to cause localized, semi-confined conditions to exist.

Karst

A prerequisite to comprehending the ground-water hydrology of the springs region is an understanding of the dominant role karst processes play in ground-water flow through the Floridan aquifer. The northern portions of the District contain areas of intensive karst development that are characterized by numerous sinkholes, closed depressions, lack of surface-water drainage, and undulating topography. Figure 4 shows the abundance of closed depression features in the northern half of the SWFWMD. In karst areas the dissolution of limestone has created and enlarged cavities along fractures in the limestone which eventually collapse to form sinkholes. Sinkholes capture surface-water drainage and funnel it underground, which promotes further dissolution of the limestone. This leads to progressive integration of voids beneath the surface and allows larger and larger amounts of water to be funneled into the underground drainage system.

Ground water may flow rapidly through conduits and passages within the limestone, or slowly through minute pore spaces within the rock matrix. Dye-trace studies in Columbia County show that ground water near Ichetucknee Springs may travel approximately 220 feet per hour (1 mile per day) in active conduits of the Floridan aquifer[37]. Dye-tracing studies conducted in Hillsborough County reveal similar ground-water velocities (0.8-1.7 miles per day) at Sulphur Springs[38]. Studies such as these indicate that ground water can move rapidly in the karst environment near springs.

In contrast, recent studies conducted by the USGS and Suwannee River Water Management District have demonstrated that much of the spring water in northern Florida has been in the Floridan aquifer for 10-25 years[39]. This estimate is based on age-dating techniques using chlorofluorocarbons (CFC's) derived from the use of aerosol propellants and refrigerants. These CFC compounds, released into the atmosphere over the last 50 years have dissolved in precipitation that recharges ground water[40]. The occurrence of CFC's in spring waters of northern Florida indicates that while a portion of the ground water moves quickly through conduits in the Floridan aquifer, much of the water percolates slowly through the soil and into the aquifer. Once the ground water enters the aquifer, it begins to travel through smaller pores and openings in the limestone before reaching a particular spring. The slower movement of ground water through the aquifer is known as diffuse flow.

It is important to remember and understand that rapid conduit flow and slower diffuse flow are, in fact, very useful in deciphering the hydrology of springs in the karst landscape. Older ground water that appears to dominate much of the spring flow mixes with younger ground water making up rapid conduit flow near the spring vent. Two recent studies of springs in the St. Johns River and Suwannee River Water Management Districts demonstrate and support this mixing model of ground water at springs[39,41]. Therefore, the mixing of ground waters must not be overlooked when assessing the origin, health, and history of spring water in the karst environment.

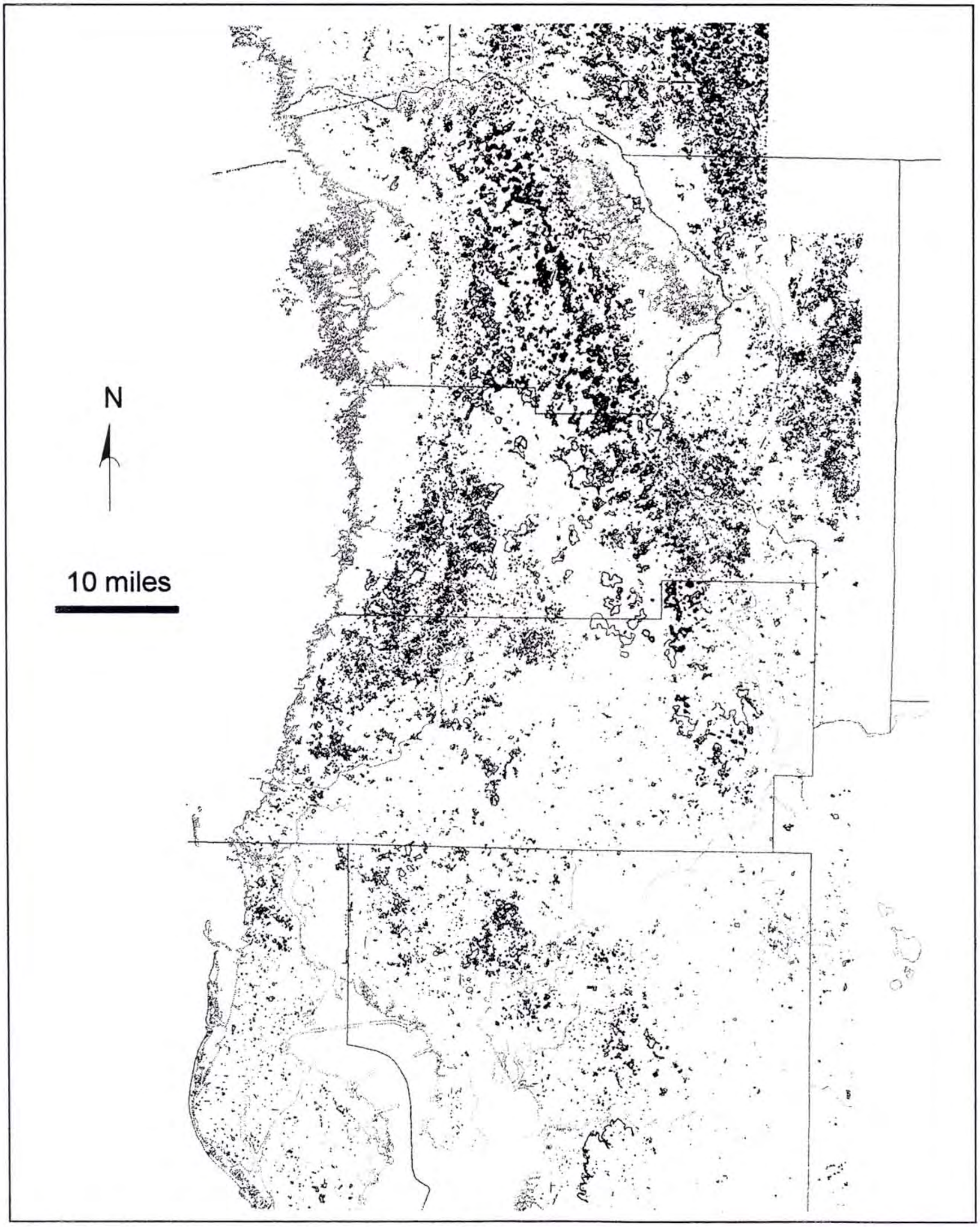


Figure 4. Closed Depression Features in the Springs Region.

Recharge

A number of studies have investigated ground-water recharge in the northern portions of the District. These studies show that the recharge potential for the Floridan aquifer is controlled primarily by the thickness and composition of surficial sediments overlying the aquifer, and the presence of karst topography[42,43,44,45]. Other factors affecting recharge rates include the development of surface drainage, variations in water-level gradients between surface water, the surficial aquifer, and the Floridan aquifer, and aquifer permeability. Generally, high recharge rates occur where limestone is near the land surface, or where overlying sediments lack low-permeability materials. The occurrences of sinkholes, and associated internal drainage of surface waters, also results in higher recharge to the Floridan aquifer. Lower recharge rates occur where confining materials overlying the aquifer retard downward vertical movement of water, or where an upward water-level gradient exists between the Floridan and surficial aquifers[42,43,44,45]. Figure 5 shows the recharge potential of the Floridan aquifer in the springs region.

Fresh-Water/Salt-Water Transition Zone

Many coastal springs in the SWFWMD lie in or near the fresh-water/salt-water transition zone; a brackish zone in the Floridan aquifer where seaward-moving fresh water meets landward-moving salt water. As a result of their proximity to the coastal transition zone, some springs discharge brackish water. Homosassa and Chassahowitzka Springs are good examples of brackish-water springs. Brackish ground-water discharge indicates that sea water from the Gulf of Mexico is present in the aquifer gulfward of and below the springs[36].

The coastal transition zone is often defined by chloride concentrations greater than 250 milligrams per liter (mg/l)[46]. Springs located inland of the transition zone discharge fresh water (Figure 6). The transition zone moves horizontally and vertically in the Floridan aquifer in response to tidal fluctuations in the gulf and to changes in water levels in the aquifer. As a result of the movements in the transition zone, the water quality and magnitude of the spring flows continuously change; salinity is generally lowest at low tide when the transition zone is further seaward, while discharge generally peaks at low tide[36].

Discharge

It is estimated that springs in the SWFWMD discharge more than 1,600 mgd of ground water from the Floridan aquifer. Prior to development spring flow in the region accounted for 80% of the ground-water discharge from the Floridan aquifer, however, as development has occurred this percentage has decreased[47]. Ground-water discharge from the Floridan aquifer is important to springs in the region for several reasons: 1) it provides the springs with adequate ground-water supplies to maintain flow; 2) it is an important

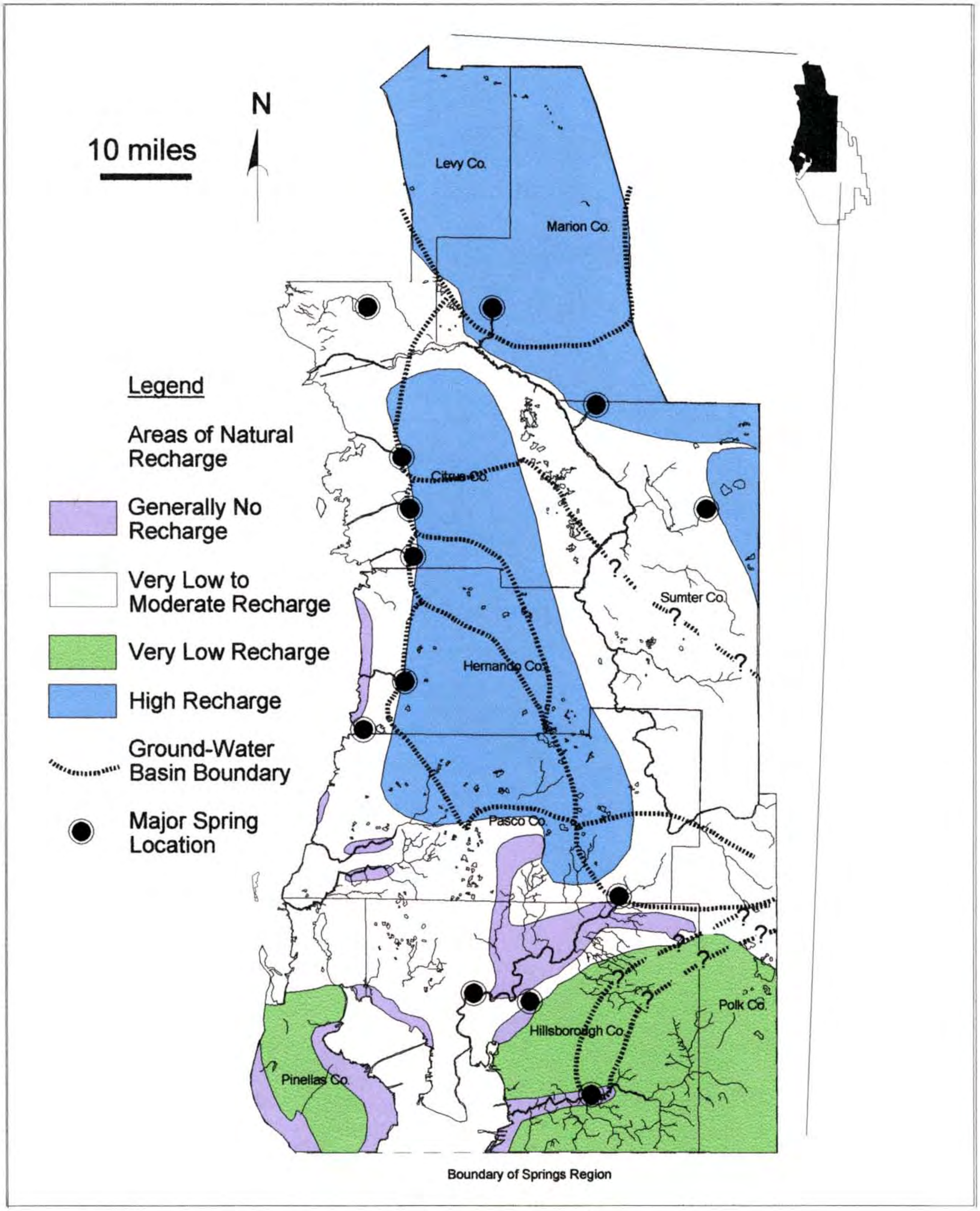


Figure 5. Recharge Potential of the Floridan Aquifer [45].

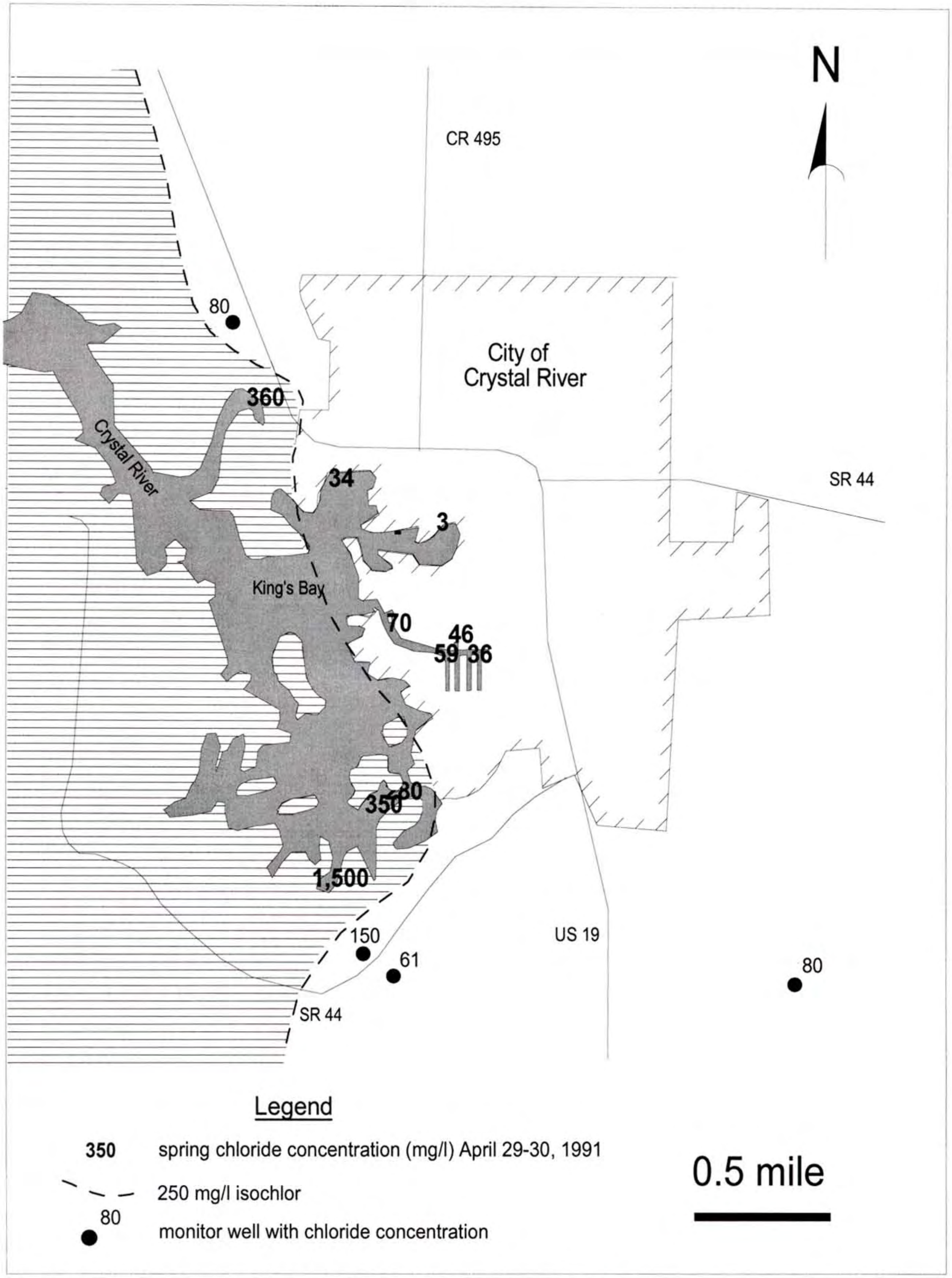


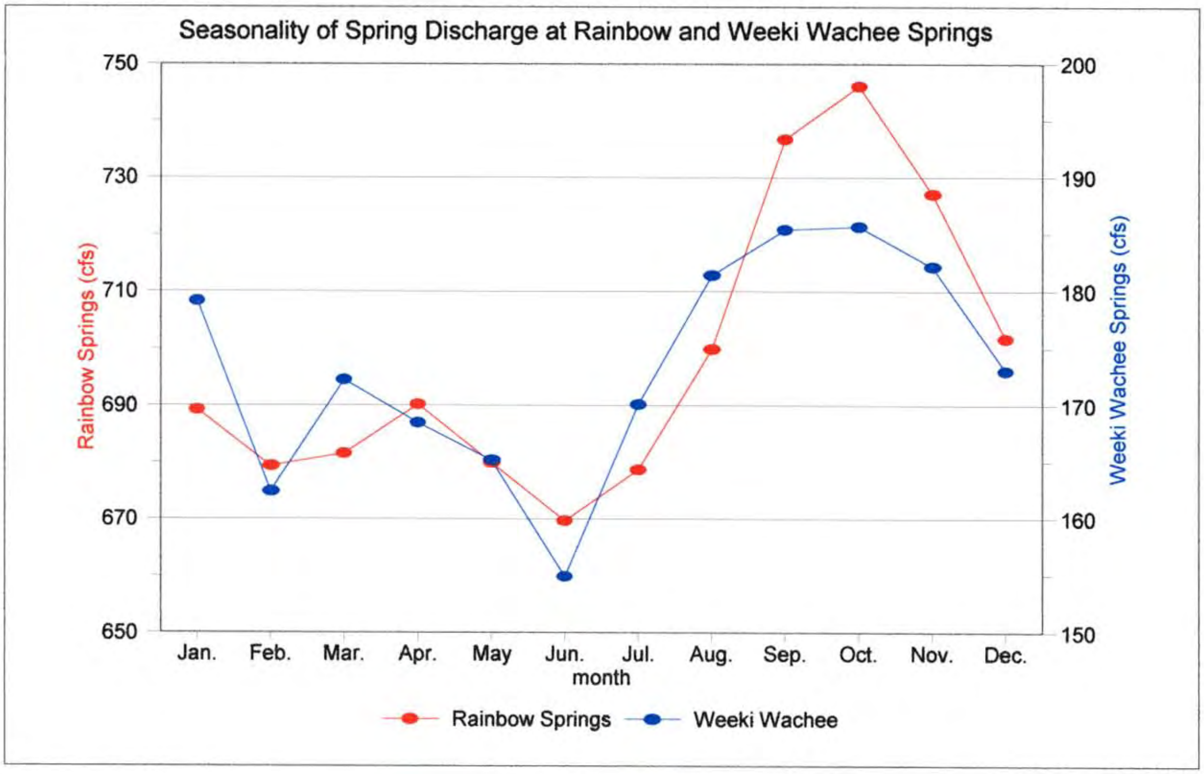
Figure 6. The King's Bay Springs and the Coastal Transition Zone.

component of many aquatic and terrestrial ecosystems throughout the region; and 3) it is an ideal barometer by which to gage the water quality of the Floridan aquifer over large areas (tens to hundreds of square miles).

Springs throughout the District exhibit seasonality in discharge as rainfall recharges the Floridan aquifer inland of the springs. This recharge causes water levels in the aquifer to rise and spring discharge to increase. Studies by the USGS have shown that spring flow along the coast of Citrus and Hernando Counties can vary considerably during the year[(36)]. A number of other springs throughout the SWFWMD exhibit similar variations in discharge as well, with lowest flows occurring late in the dry season (May/June) and highest flows occurring late in the wet season (Sept./Oct.) (Figure 7).

Variations in Spring Discharge

Anecdotal reports throughout the springs region indicate that spring discharge may have decreased in recent years. Discharge has been measured for several decades at spring locations throughout the District, including Rainbow, Weeki Wachee, Crystal, Lithia, and Sulphur Springs. Most of these flow data extend back to the 1960's with some extending back to the 1930's. Figure 8 shows two graphs depicting the average spring flow at Rainbow, Weeki Wachee, Crystal, Lithia and Sulphur Springs. It may be apparent from Figure 8 that the average annual spring discharge has fluctuated significantly over the last 30 years. These fluctuations may result from variations in rainfall[(44)], ground-water withdrawals[(48)], or a combination of these factors.



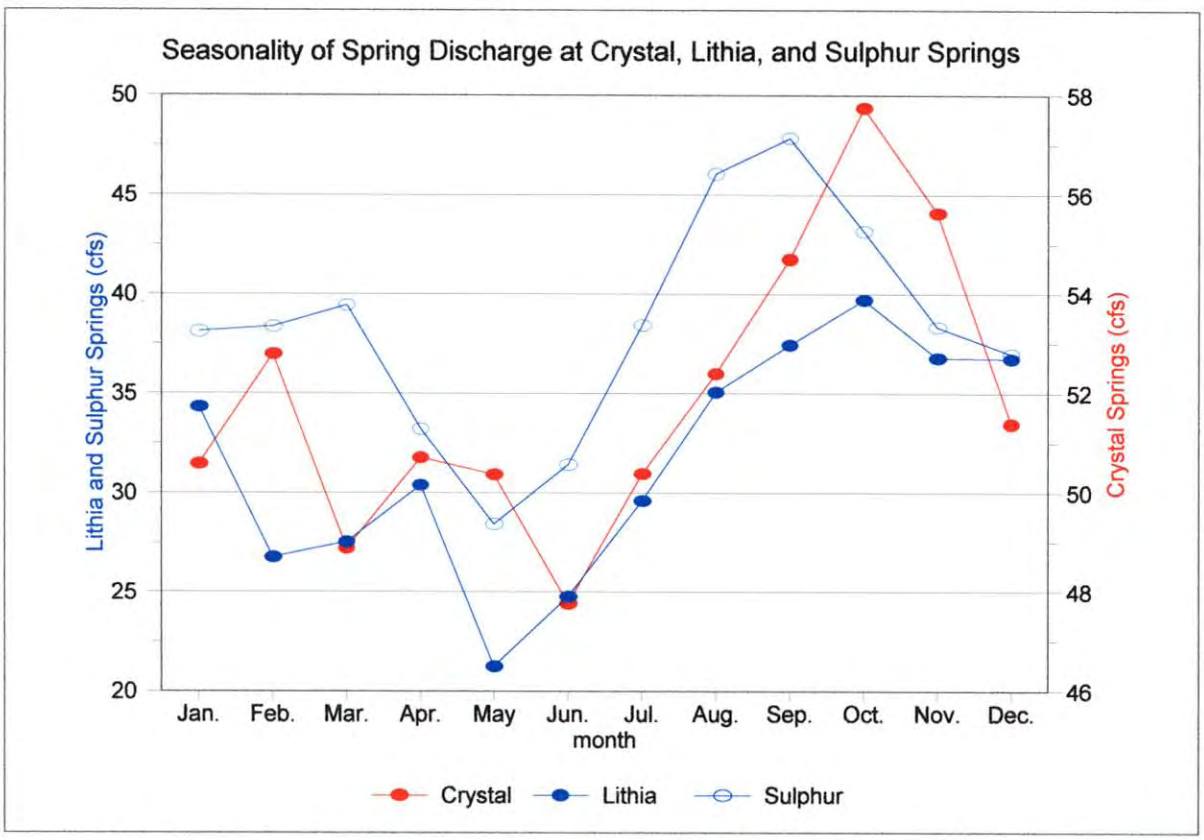


Figure 7. Seasonality in Spring Discharge at Various Springs throughout the SWFWMD (1966-1997).

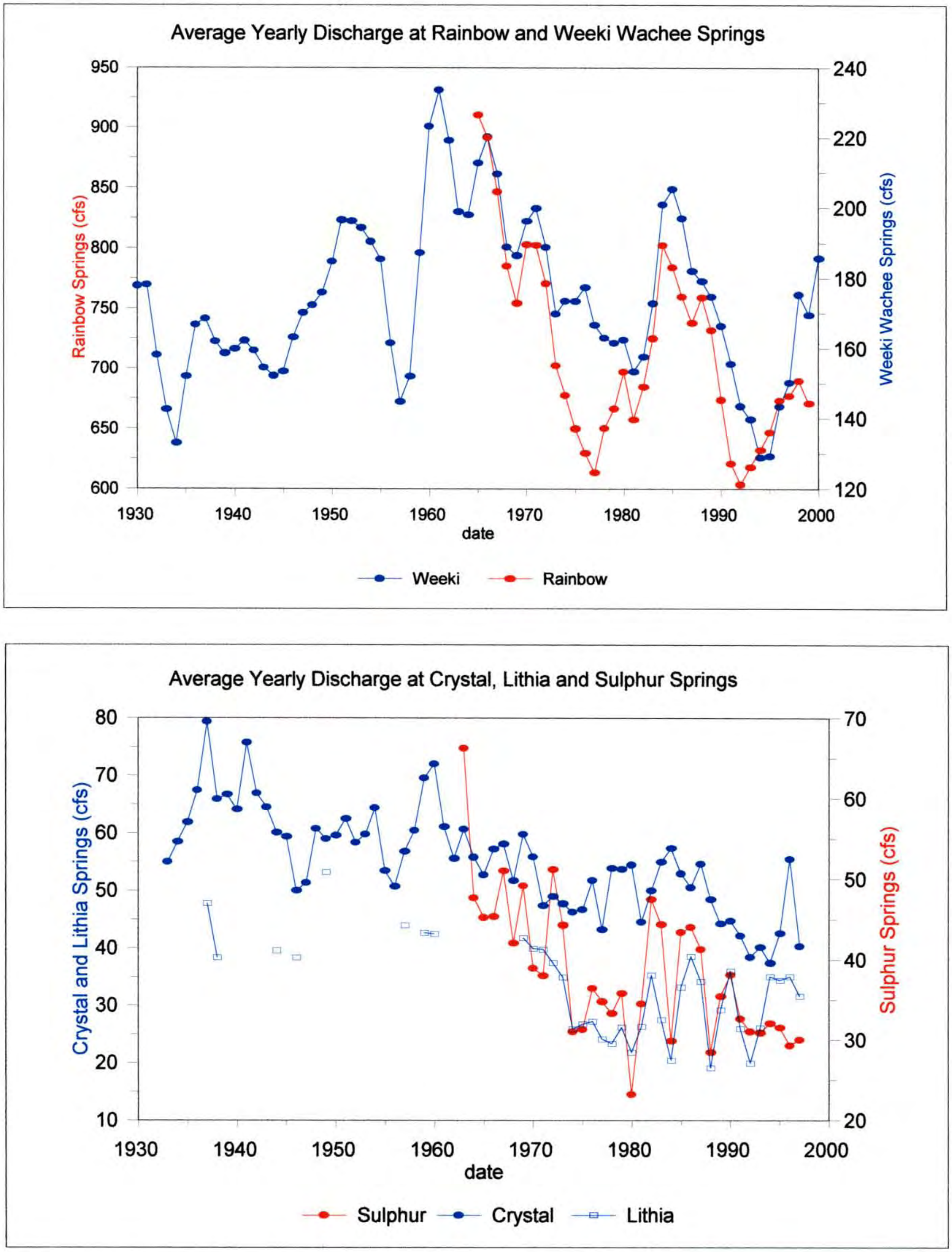


Figure 8. Fluctuations in Spring Discharge at Various Springs throughout the SWFWMD (1930-1997).

WATER QUALITY

INTRODUCTION

The following section provides a detailed description of spring-water chemistry throughout the District, based largely on previous water-quality investigations and ongoing quarterly monitoring conducted by the WQMP. Where possible, recent data have been utilized to provide an up-to-date view of the chemical composition of spring water. These data are reviewed in the context of current interpretations of the hydrology of the springs region, as well as current understandings of the geochemical evolution of Floridan aquifer ground water. The reader is referred to previous spring publications and references in the "References Cited" section of this report for a more in-depth discussion of water quality at the individual spring groups of the SWFWMD.

HYDROCHEMICAL FACIES

Hydrochemical facies analysis(46) is an excellent way to place a series of water-quality analyses into a spatial context. The analysis has been used successfully in a number of studies of the Floridan aquifer(36,46,48) and depends on pattern recognition techniques. Hydrochemical facies analysis has become a common method in understanding and describing the chemical evolution of ground water in aquifers like the Floridan aquifer.

Using the PLOTCHEM© software (a computer program that produces Piper(49) and Stiff(50) diagrams for the graphical representation of dissolved constituents in ground-water samples), spring samples collected throughout the District are plotted on Stiff diagrams, which show the relative proportions, in milliequivalents per liter, of major ions in a sample. The size of the Stiff diagram is proportional to the total dissolved solids content of the sample, and the shape conveys a rapid impression of the water type, or dominant ions in the sample.

Figure 9 displays four Stiff diagrams that are representative of the four principal water-quality types delineated from the spring data. The Stiff diagrams indicate that the spring samples may be dominated by calcium-bicarbonate (e.g. Weeki Wachee Main), sodium-chloride (e.g. Blue Run), calcium-bicarbonate-sulfate (e.g. Lithia Main), or calcium-sodium-chloride-bicarbonate (e.g. Trotter Main). These water types reflect the chemical evolution of spring water in the northern SWFWMD area.

Spring samples are also plotted on a Piper diagram, which relates the variations in proportions, but not concentrations, between samples (Figure 9). It is apparent in the figure that the spring samples cluster across the center portion of the Piper diagram. The clustering of samples across the diagram is indicative of an unconfined ground-water flow system that is comprised of fresh recharge waters mixing with sea waters at the coast(36,48).

It should be noted that the hydrochemical facies shown in Figure 9 closely resembles those identified in earlier ground-water studies of the springs

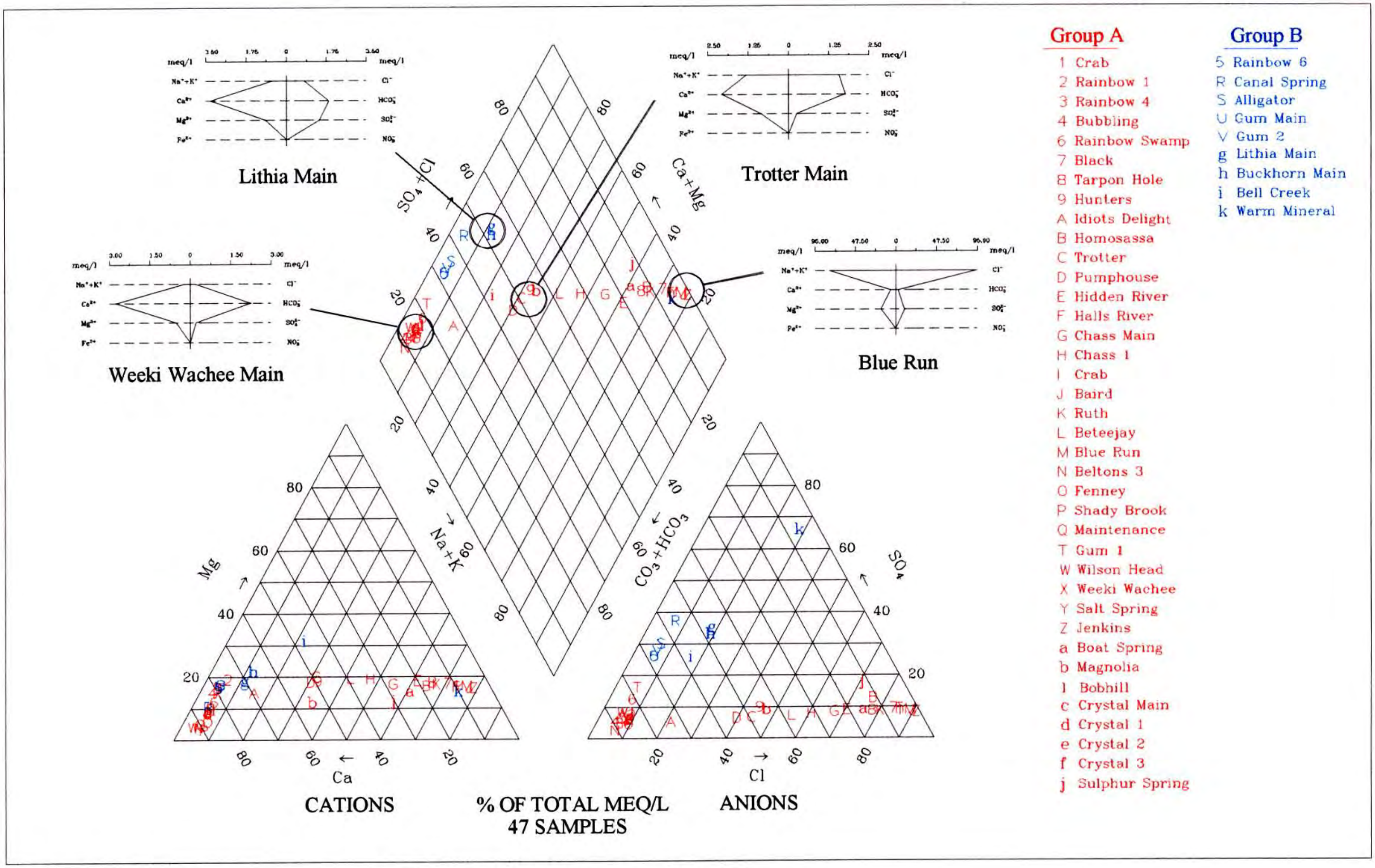


Figure 9. Characterization of Spring Waters Using Piper and Stiff Diagrams.

region[9,10,11,12,13,36]. Therefore, the interpretation, presented below, closely follows hydrologic and geochemical concepts provided by this earlier research.

It is also apparent from Figure 9 that the spring samples can be divided into two major groups: group A and group B. Group A samples, which plot across the central portion of the diagram, represent springs that discharge a variety of water types including: 1) calcium-bicarbonate rich ground water derived from aquifer recharge, 2) sodium-chloride rich ground water derived from salt-water influences, and 3) mixtures of fresh and saline ground water. Group A springs discharge ground water that is strongly influenced by the dissolution of limestone inland of the coastal transition zone; however, as ground water nears and moves into the mixing zone, mixtures of fresh and saline ground water are produced. Group A springs may eventually discharge saline ground water that has intruded inland toward the springs.

Group B samples, which typically plot above group A samples on the Piper diagram, represent spring samples that discharge sulfate-rich ground-water. This enrichment reflects the upwelling of sulfate along the inner margin of the coastal transition zone and in highly fractured areas inland of the coast. Group B samples occur sporadically throughout the SWFWMD, but are concentrated at Gum Slough Springs and Lithia/Buckhorn Springs, and to a lesser extent at Rainbow and Panasoffkee Spring groups. Ground water discharging from Warm Mineral Springs is enriched in sulfate due to the deep, confined flow path taken by the ground water through the Floridan aquifer prior to reaching the spring[51].

MAJOR ANALYTES

Bicarbonate, Calcium, and pH

As rainfall passes through the soil layer it becomes increasingly acidic (low pH) as a result of its reaction with the carbon dioxide (CO_2) to form carbonic acid (H_2CO_3) and by addition of natural organic acids (humic acid, etc.). Carbonic acid reacts with limestone ($CaCO_3$) to produce dissolved calcium (Ca^{2+}) and bicarbonate (HCO_3^-). As the limestone is dissolved by carbonic acid, pH increases because carbonic acid is consumed and calcium and bicarbonate are produced.

In a limestone aquifer, the concentrations of calcium and bicarbonate ions and the pH of ground water are important indicators of chemical maturity or the extent of chemical equilibrium with the aquifer rock materials. Water that has been in contact with limestone for a relatively short length of time should have low concentrations of these ions and a relatively low pH, while water that has been in the flow system for a long period of time should typically have higher concentrations and a higher pH.

Spring water throughout the District reflects the dissolution of limestone in the Floridan aquifer. Ground water discharging from the springs is generally dominated by calcium-bicarbonate, except along the coast where the coastal transition zone becomes an important influence on water quality. In addition, the pH of spring water typically varies between 7 and 8, indicating that the ground water is at or near chemical equilibrium with limestone in the Floridan aquifer.

Chloride

Chloride is a chemically conservative element in that it does not readily react with aquifer materials, so it is usually used as a tracer of physical water flow. Chloride is the most common component of sea water, and is a major constituent of marine aerosols. Rainfall in Florida typically contains less than 10 milligrams per liter (mg/l) chloride[46].

Except near the salt-water transition zone, springs throughout the District have chloride concentrations that reflect rapid recharge to the Floridan aquifer. As one approaches the coast, however, mixing in the transition zone increases chloride in the ground water dramatically. A good example of this may be found at the King's Bay Springs group where chloride concentrations in the springs may range from less than 10mg/l to greater than 1,000 mg/l across the bay at low tide (Figure 6).

Sulfate

Sulfate (SO_4^{2-}) is formed by oxidation of pyrite (FeS_2), a common mineral in marine sediments; oxidation of organics; and dissolution of gypsum ($CaSO_4 \cdot 2H_2O$) or anhydrite ($CaSO_4$). Pyrite is widespread in Florida rocks, and may be present in clays of the Hawthorn Group. Oxidation of organics is also important in the occurrence of sulfate. There is minimal gypsum and/or anhydrite in near-surface sediments, but the base of the Upper Floridan aquifer is characterized by these minerals. Sulfate is also abundant in sea water and rainfall[46].

With the exception of the transition zone along the coastline, shallow spring water in the SWFWMD typically contains minor amounts of sulfate. Deep-flow systems (e.g. Warm Mineral Springs) that come in contact with the base of the aquifer, however, may contain significant concentrations of sulfate. Therefore, the distribution and concentration of sulfate can be used to deduce the depth and extent of flow systems that contribute ground water to the springs.

Sulfate concentrations in most springs are low enough to indicate that the flow system in the Floridan aquifer is shallow (probably within the upper 200-300 feet of the aquifer). In addition, the residence time of ground water in the system is relatively short, and upwelling from the deeper flow system is not occurring in many springs. Several inland spring groups, however, discharge ground water that contains elevated amounts of sulfate. This sulfate is most likely derived from localized upwelling of sulfate in the immediate vicinity of the springs. Coastal springs, as explained earlier, are mixtures of salt water and fresh water, and contain sulfate derived from sea water.

Total Dissolved Solids

Total Dissolved Solids (TDS) is a measure of all the chemical constituents dissolved in the ground water. In west-central Florida TDS is mostly influenced by the concentrations of the major ions: calcium, bicarbonate, magnesium, sodium, sulfate and chloride. TDS is often used to estimate the relative residence time of ground water in the aquifer. TDS typically increases as the length of ground-water flow paths increase, and in coastal areas is often used to determine the influence of salt water on water quality.

TDS concentrations vary among spring groups in the District as well as within a given spring group. This is especially important in coastal springs where the coastal transition zone strongly influences ground-water quality (e.g., King's Bay Springs). In coastal springs that are tidally influenced, TDS may vary several thousand milligrams per liter over a given tidal cycle.

Ammonium

Ammonium (NH_4^+) in ground water can be derived from a number of sources, including animal waste products, decay of complex organic molecules, and the use of inorganic fertilizers. It can only persist in reducing environments and/or in the immediate vicinity of a source. Ammonium is strongly absorbed to clays and organic materials disseminated within an aquifer(46).

Spring water in the District typically contains very little ammonium. Concentrations are generally below 0.05 mg/l with nearly 70 percent of the samples at or below the laboratory detection limit (<0.01mg/l). These low concentrations reflect the conversion of the ammonium to nitrate in an oxidizing ground-water environment prior to reaching the springs. Low ammonium concentrations also indicate that any nitrogen sources contributing nitrogen to the ground-water system are not in the immediate vicinity of the springs.

Nitrite

Nitrite (NO_2^-) is very unstable in the ground-water environment. Nitrite is the primary step in the oxidation of ammonium and other nitrogen compounds to nitrate. Because nitrite is chemically unstable, it can usually only persist near a source.

Nitrite concentrations are at or below the detection limit (<0.01mg/l) in nearly all spring waters of the District. The lack of significant nitrite concentrations in the spring water indicates that the Floridan aquifer is an oxidizing environment. It also indicates that nitrogen sources contributing nitrite to the ground-water system are not in the immediate vicinity of the springs.

Nitrate

Nitrate (NO_3^-) is generally more stable in ground water than either nitrite or ammonium. It is the final step in the oxidation of ammonium and other nitrogen compounds. Nitrate is nearly inert in the ground-water environment, and can travel significant distances from a nitrogen source. The natural, or background, concentration of nitrate in the Floridan aquifer has been shown to be < 0.01 mg/l(46).

Nitrate is an important component in the cycling of nutrients (nitrogen and phosphorus) in plant and animal physiology. Nitrate typically act as a fertilizer in soils and surface-water bodies where it promotes growth of terrestrial and aquatic vegetation. However, high amounts of nitrates may lead to excessive growth and eventual eutrophication of surface-water bodies, especially those that are nitrogen limited. The likelihood of eutrophication, and the increasing amounts of nitrate seen in water bodies and aquifers across the United States, has alerted many to the dangers of nitrate in surface and ground water across the country. In fact, the United States Environmental Protection Agency (USEPA) recently stated that nutrients (nitrogen and phosphorus) are the leading causes of water-quality impairment in the Nation's rivers, lakes and estuaries(52).

Nitrate concentrations in spring water have been a concern in the SWFWMD (as well as other regions of Florida) for a number of years. Increased levels of nitrate are detected at many springs in the District, and may be responsible for the increased growth of nuisance aquatic vegetation such as Lyngbya (a filamentous cyanobacteria) in spring runs throughout the region. Since 1991 a number of ground-water studies have been conducted throughout the northern portions of the SWFWMD in an effort to determine the source(s) of nitrate in the spring water(9,10,11,12,13). These studies have shown that most of the nitrate discharging from springs in the SWFWMD is derived from inorganic fertilizers. This nitrate was applied to a variety of land uses inland of the springs decades ago as fertilizer for pastures, residential lawns, golf courses, and/or citrus groves.

Nitrate concentrations in spring water throughout the District range from below detection limit (<0.01 mg/l) to slightly greater than 3.0 mg/l. All of the spring samples are well below the primary drinking water standard established by the FDEP for nitrate, 10 mg/l(53). One exception, however, is Bell Creek spring in central Hillsborough County. This spring discharges ground water that typically contains nitrate levels in excess of the 10 mg/l drinking water standard. Bell Creek spring discharges approximately 0.03 mgd and is affected by nitrate derived from a local animal-waste source(9,54).

ADDITIONAL NUTRIENTS AND IRON

Total Organic Carbon

Total organic carbon (TOC) is a measure of the complex carbon-compound concentrations in the ground water. Organic carbon can be derived from natural organics or humic substances(46), synthetic organics, or waste disposal. Synthetic organic compounds are rarely present in sufficient quantities to be reflected in typical TOC concentrations, so TOC usually reflects either natural or waste sources. High TOC concentrations are found in the Floridan aquifer in North Florida at the base of the Hawthorn escarpment(55). In this area the recharge of surface water and organic-rich surficial aquifer water is rapid due to lack of confinement above the Floridan aquifer.

Spring water in the District typically contains TOC concentrations below 1 mg/l.

This may reflect the microbial degradation of the carbon in the ground-water system prior to reaching the springs[11]. Elevated concentrations of TOC are found, however, along the coastal margins of Citrus and Hernando Counties, where organic-rich surface water in the coastal swamps may have recharged the aquifer prior to discharging at the springs.

Total Phosphorus

Total phosphorus includes complex organic compounds as well as simple inorganic phosphorus. High phosphorus concentrations in ground water indicate localized contamination by organic sources, such as human and animal wastes. Total phosphorus concentrations may also indicate where surface water and shallow ground water have come into contact with phosphate-rich minerals in the overlying surficial sediments prior to recharging the Floridan aquifer.

Spring water throughout the District typically contains very little total phosphorus. In fact, concentrations vary only slightly among springs and are often between 0.01 and 0.05 mg/l. Since phosphorus (more specifically orthophosphate) tends to precipitate as a calcium-phosphate mineral (carbonate-hydroxylapatite) in the alkaline environment of the Floridan aquifer, the low concentrations indicate that significant sources of phosphorus (organic-rich surface water or animal wastes) are not in close proximity to the springs.

Iron

The sources of iron in ground water include the oxidation of pyrite (FeS_2), the oxidation of organic compounds, and the dissolution of iron-oxide minerals. Iron has two valence states, Fe^{2+} and Fe^{3+}. Fe^{2+} is generally the stable form of iron in chemically-reducing ground water. In oxidizing ground water, bacteria induce colloidal ferric hydroxide ($Fe(OH)_3$) to precipitate. Well screens and aquifer pore throats may become clogged by the precipitation of iron hydroxides by iron-oxidizing bacteria[56]. The Secondary Drinking Water Standard for iron is 0.3 mg/l[53]. Ferric hydroxide is the reddish to yellowish scale or stain that is so commonly found where iron-rich waters are utilized.

Iron concentrations are typically below detection limits (<0.03 mg/l) in many spring waters. The low iron content of the spring water is indicative of oxidizing conditions in the Floridan aquifer. However, high iron concentrations in some springs may indicate that local sources of iron (e.g., wetlands and surface-water bodies) may locally affect some springs.

TEMPERATURE

Temperature of ground water is included in this report because it is an indicator of conditions in the ground-water environment and of surface recharge to the Floridan aquifer. Temperature affects the nature and rate of chemical reactions and microbial activity in aquifers. It can also be used to determine the residence time of water in an aquifer, and the depth to which ground water has traveled[46].

The temperature of spring water throughout the district should reflect the average annual air temperature in the vicinity of the springs. Mean annual air temperatures in the District range from 22-23°C (71-74°F) from north to south across the SWFWMD[16,57]; springs in the District typically have temperatures that range 23-25°C. The lowest spring temperatures are often found in the extreme northern portions of the district (e.g., Rainbow Springs) where recharge may be rapid and somewhat cooler in temperature. The warmest spring temperatures, not counting Warm Mineral Springs in southern Sarasota County, occur in central Hillsborough County at Sulphur and Lithia Springs. These springs have temperatures that are typically near 25°C which is slightly elevated above the mean annual air temperature measured in Hillsborough County, 22°C (72°F)[58]. This difference in temperature may reflect slightly deeper flow paths taken by ground water through the Floridan aquifer.

Ground water discharging from Warm Mineral Springs is typically near 30°C[3,51], while the mean annual air temperature in Sarasota/Charlotte County is 25°C[59]. Therefore, the anomalously warm ground water flowing from Warm Mineral Springs does not reflect the average annual air temperature in southern Sarasota County. Studies have shown that Warm Mineral Springs is a deep-seated spring that discharges water from more than 1,200 feet below the land surface[51]. Its spring water has traveled deep into the Floridan aquifer and has been warmed by the geothermal gradient within the limestone.

ISOTOPIC CONTENT

Tritium

Tritium (^{3}H) is an isotope of hydrogen that is formed by cosmic-ray activation of nitrogen and by atmospheric testing of nuclear weapons. Determining the tritium content of aquifer water helps to determine whether the aquifer is being recharged locally or from a more distant source. Because of the dramatic increase in tritium in 1952 as a result of the onset of atmospheric testing of hydrogen bombs, tritium provides a useful marker for relatively young water in the hydrologic cycle. Before 1952, the tritium content of meteoric water ranged from 1 to 10 tritium units (TU)[59]. A tritium unit (TU) represents one atom of ^{3}H in every 10^{18} hydrogen atoms, and is roughly equivalent to 3.2 picoCuries per liter. Water recharged in Florida prior to 1952 should have a tritium concentration of less than 2 TU[36].

Atmospheric, nuclear-weapons testing has raised tritium activities as much as two orders of magnitude. While tritium began to be introduced into the hydrologic cycle in the mid-1940's, the major build-up of tritium began with increased atmospheric testing in the 1950's. This resulted in rainfall concentrations of tritium reaching 1,188 TU at Ocala, Florida, in 1963[36]. With the advent of the Nuclear Test-Ban Treaty in 1963, tritium levels have decreased, and in 1988 they averaged about 5 TU. Tritium has a half life of 12.4 years, so decay and cessation of atmospheric testing have resulted in a decline of tritium in precipitation to activities similar to pre-1950 background. Thus, any ground water (or spring water) that contains tritium above background levels can be assumed to have been recharged in the period from 1950 to 1975. Ground waters with tritium activities less than 10 TU can be assumed to have been recharged before 1952 or within the last 20 years.

Most of the springs in the SWFWMD have not been sampled for tritium. This is because a number of investigations have already determined that ground water in the shallow portion of the Floridan aquifer has entered the aquifer very recently(10,60,61). In the Rainbow Springs area, for example, tritium activities in wells and springs were as high as 174 TU at the same time (1966-68) that rainfall contained activities as high as 158 TU. In addition, tritium activities in Rainbow and Silver Springs ranged from 38 to 85 TU and 25 to 150 TU, respectively. This indicates that a large percentage of the water discharging from Rainbow and Silver Springs in 1966-68 could not have been in the flow system for more than 16 years(11).

Studies conducted by the USGS in the late 1980's indicate that tritium activities in the Floridan aquifer ground water in the northern half of the SWFWMD reflect relatively recent recharge, with activities of 8 to over 10 TU common. The studies strongly implicate rapid recharge to the Floridan aquifer, with subsequent flow of ground water toward the coastal springs(60).

Uranium

Uranium is intimately associated with phosphorite and phosphate deposits throughout northern and central Florida. Uranium, predominantly ^{238}U, is incorporated in francolite ($Ca_5(PO_4CO_3)_3F$), a carbonate-fluorapatite mineral. Having dissolved from sedimentary apatite, uranium is readily precipitated in secondary phosphate minerals and is concentrated in phosphate ores to an average of 100 ppm(62,63). The naturally occurring concentrations of uranium and the activity ratio of ^{234}U to ^{238}U in spring and well-water samples has been successfully utilized to trace ground-water flow systems, determine relative ages of ground-water masses, and determine provenance of water masses.

Ground water in the deep, slow-moving portions of the Floridan aquifer flow system is characterized by low concentrations of uranium (<0.1 μg/l) associated with relatively high $^{234}U/^{238}U$ activity ratios (appreciably greater than the equilibrium ratio of 1.0). However, rapidly recharging waters in a shallow, karst flow system, which is characteristic of the northern SWFWMD, tend to have a uranium signature that is distinctly different from deeper Floridan flow systems. These shallow waters exhibit higher concentrations of uranium with much lower $^{234}U/^{238}U$ activity ratios (sometimes with less than the equilibrium value of 1). Because uranium is most soluble in oxidizing environments where it forms uranyl (UO_2^{+2}) ions, uranium concentration can be used to roughly determine the age and history of ground water in Florida(64,65).

Twenty-nine springs in the SWFWMD were sampled for uranium isotopes between 1992 and 1999. Most of the spring samples have the low activity ratios (<1.0), and high concentration signatures (>0.1) characteristic of ground water that has recharged rapidly and traveled a relatively short distance (more than several thousand feet) in a shallow flow system. This is consistent with the tritium interpretations which indicate shallow, rapid flow in the karst limestones of the Floridan aquifer.

Based on uranium concentrations and similar activity ratios, spring samples in Citrus and Hernando Counties were grouped into two main clusters; a northern cluster (Citrus County), and a southern cluster (Weeki Wachee and Aripeka). The differentiation of springs along the coast is possibly related to differences in the uranium content of the Hawthorn Group sediments in the northern and southern portions of the Brooksville Ridge(12). A similar differentiation was identified at Rainbow Springs in Marion County where three separate geographic regions appeared to contribute ground water to the spring group(11,65).

Nitrogen

Although many proven sources of nitrate, including septic-tank effluent, treated sewage effluent, commercial and residential landscape fertilizers, land spreading of septic and sewage sludge, and agricultural fertilizers are present in the northern half of the SWFWMD, it is difficult to determine the relative contributions of these sources to nitrate in spring water. However, the isotopic ratio of $^{15}N/^{14}N$ (expressed as $\delta^{15}N$) can provide a direct indication of the importance of certain nitrate sources. It is especially useful for characterization of animal waste (organic) sources as opposed to inorganic sources (inorganic fertilizers).

The ratio of nitrogen isotopes in dissolved nitrate is expressed in per mil notation ($^{\circ}/_{\circ\circ}$) and is calculated using the following equation:

$$\delta^{15}N\ (^{\circ}/_{\circ\circ}) = 1000\ \mathrm{X}\ \frac{\left(\frac{\alpha_{15_N}}{\alpha_{14_N}}\right)_{sample} - \left(\frac{\alpha_{15_N}}{\alpha_{14_N}}\right)_{air}}{\left(\frac{\alpha_{15_N}}{\alpha_{14_N}}\right)_{sample}},$$

Where: α = the activity of the specified isotope

Three $\delta^{15}N$ ranges have been defined for nitrate from different sources. The $\delta^{15}N$ values for nitrate from unfertilized, cultivated fields (nitrate resulting from the oxidation of part of the organic nitrogen in the soil from crop plowing) range from +2 to +8 $^{\circ}/_{\circ\circ}$(66). In the warm, humid environment of west-central Florida, only a minimal amount of nitrate should leach from undisturbed soils(66). Isotropic ratios in water affected by animal waste (organic nitrogen) sources, such as septic tanks, feedlots, and barnyards, range from +10 to +20 $^{\circ}/_{\circ\circ}$. However these sources cannot be distinguished from each other. Nitrate leached from synthetic, ammonium nitrate fertilizers composed of inorganic nitrogen (the type most likely to be used on row crops, citrus, and landscaping) have associated $\delta^{15}N$ ratios of -8 to +6.2 $^{\circ}/_{\circ\circ}$, with 90 percent of the samples ranging from -3 to +2 $^{\circ}/_{\circ\circ}$(66,67,68).

Twenty-four springs in the SWFWMD were sampled for nitrogen isotopes between 1991 and 1999. The nitrogen isotopic ratios found in spring waters throughout the District range from 0.7 to 18.1 $^{\circ}/_{\circ\circ}$ (Figure 10). As stated previously, ratios that fall between the +2 to +8 $^{\circ}/_{\circ\circ}$ range could be attributable to natural oxidation of organic material in soil[68]. However, this is unlikely because the nitrate concentrations in the springs are too high to have originated from natural sources.

Over 80% of the nitrogen-isotopic ratios reported in the SWFWMD since 1991 are below 6.2 $^{\circ}/_{\circ\circ}$. This indicates that inorganic fertilizers are the most significant source of nitrate in the springs region. Much of the fertilizer appears to be derived from: 1) subdivisions and golf courses near the coastal springs[12], 2) pasture fertilization in the vicinity of Rainbow Springs[11], and 3) fertilization of citrus in the vicinity of Crystal, Lithia and Buckhorn Springs[9,13]. Less than 10% of the nitrogen-isotopic ratios are between 6.2 and 9.3 $^{\circ}/_{\circ\circ}$. These ratios indicate that a mixing of inorganic fertilizer nitrogen and animal waste nitrogen, with animal waste nitrogen being the dominant component, is likely occurring at some springs. Three samples collected at Bell Creek Spring in central Hillsborough County were consistently above 10 $^{\circ}/_{\circ\circ}$ (the lower end of the animal waste range[66,67]), indicating that this spring is influenced by nitrate derived from animal-wastes sources[9,54].

Based on increasing nitrate trends and nitrogen isotopic data, it should be apparent that water quality in the Floridan aquifer is already affected by land-use practices within the springs region. Fertilizers that have been applied to urban and agriculture land-use settings near the springs have leached nitrate into the Floridan aquifer. This nitrate has traveled slowly through the aquifer and is now beginning to impact water quality at the springs. In addition, due to the slow movement of ground water through the aquifer (diffuse flow), water-quality changes have been subtle, and even though land uses may have changed in the intervening decades, nitrate continues to discharge from the springs.

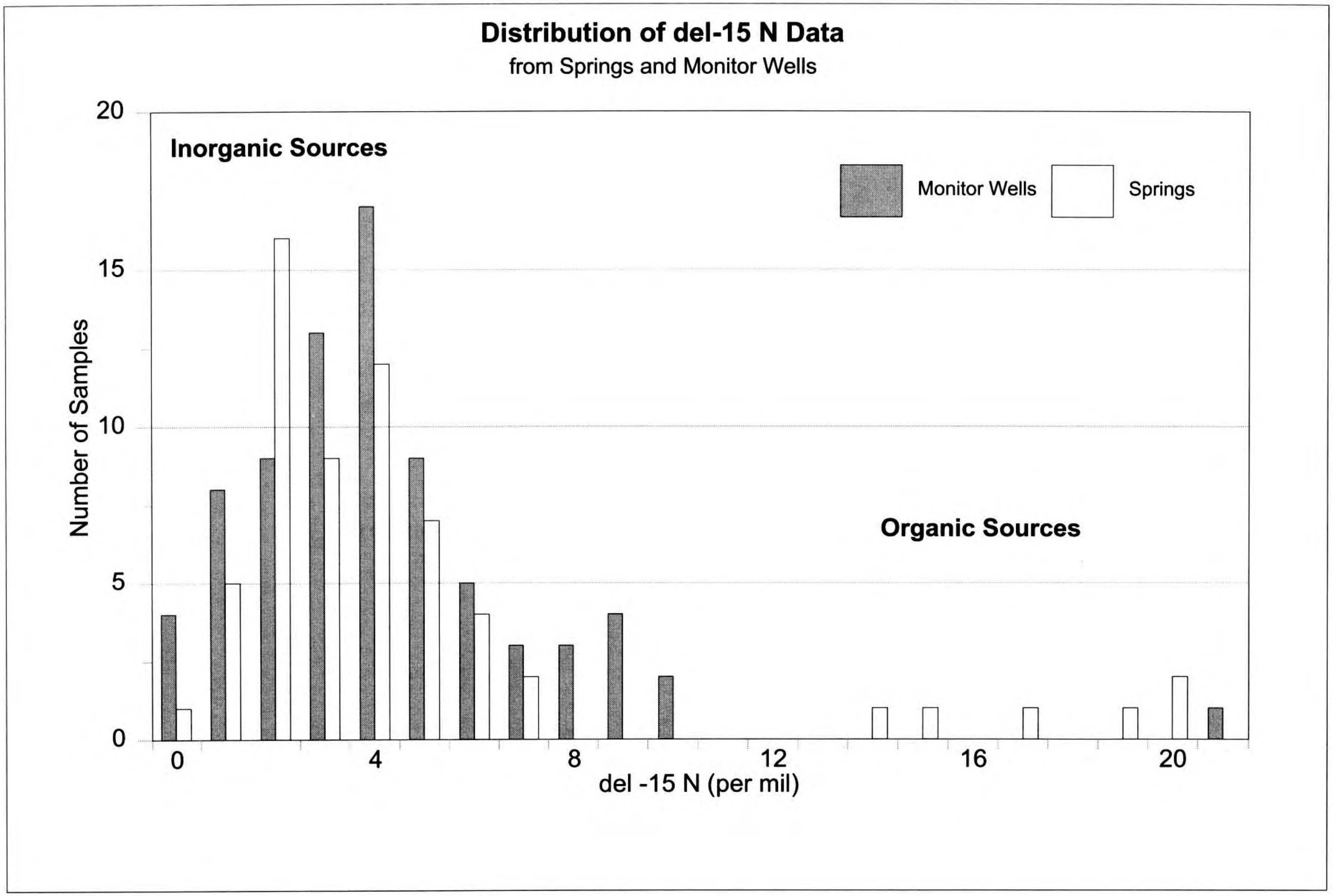


Figure 10. Distribution of Nitrogen Isotopic Ratios in the Springs Region.

SPRING DESCRIPTIONS

INTRODUCTION

The following section provides a detailed catalog of some of the larger and better known springs in the SWFWMD. This section includes: 1) a brief description of each of the springs and associated spring group, 2) photographs of the springs, 3) recent water-quality data, 4) location information, and 5) graphs depicting changes in nitrate concentrations through time at over 40 springs in the District. Many of the descriptions have been copied from previous spring reports and have been shortened for brevity.

The photographs depicted on the following pages were taken by WQMP staff between January 1999 and July 2000. The water-quality data included with each spring description contain a number of chemical analytes (e.g., calcium, bicarbonate, etc.) that are considered diagnostic to the chemistry of the springs in the region. A cursory review of the chemical analytes listed with the springs was given on pages 21 through 27 and is not covered here. Sample dates are given in the chemical summaries, as well as field parameters (e.g., pH) measured by the WQMP staff at the time of sampling.

Nitrate concentrations, as well as nitrate sources, in various springs groups throughout the District have been extensively studied by the WQMP since 1991. Quarterly sampling of many springs is currently in progress and nitrate trends are included in this section to demonstrate any changes in nitrate through time at springs in the SWFWMD. The trends typically cover 1994 to the present, but may extend back further in time for a limited number of springs.

LEVY COUNTY

Gulf Hammock Springs Group

The Gulf Hammock Springs group (Figure 11) is located in southern Levy County approximately six miles north of Inglis and the Withlacoochee River. The spring group is comprised of Little King and Big King Springs. Little King Spring lies on property owned by the Florida Sheriff's Youth Ranch. Big King Spring lies approximately 2000 feet to the north of Little King Spring, along the northern boundary of the Youth Ranch property.

<u>Discharge</u>

Historical discharge measurements are not available for the Gulf Hammock Springs group. However, visual estimates indicate that the springs may discharge one cfs (0.6 mgd).

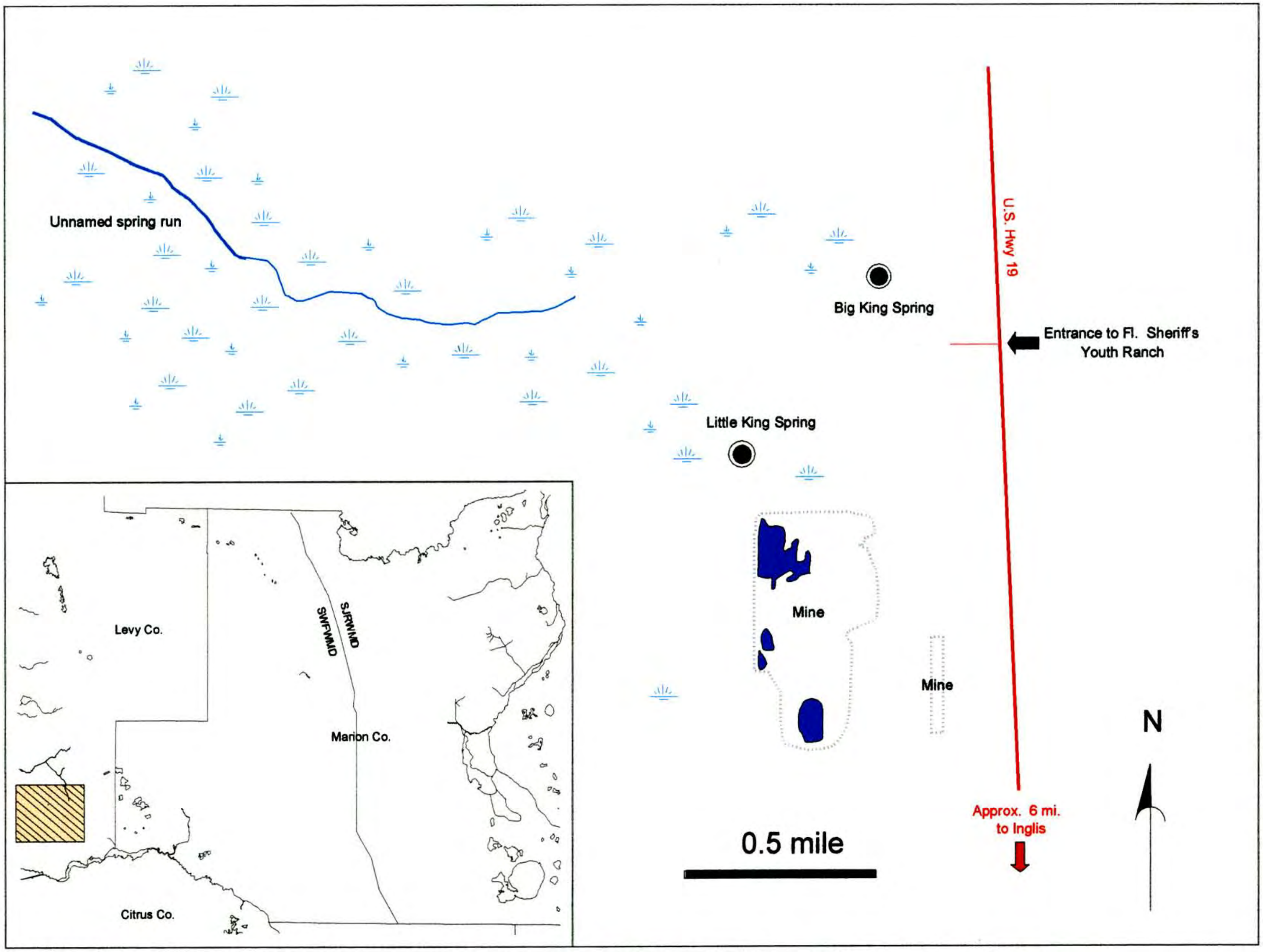


Figure 11. Location and Distribution of Springs in the Gulf Hammock Springs Group, Levy County.

Water Quality

The water quality at the Gulf Hammock Springs group has not been extensively studied by WQMP staff. However, cursory review of water-quality data suggests that ground water discharging at the group is fresh and typically contains less than 300 mg/l (TDS)[(69)]. Water quality varies slightly across the spring group with sulfate concentrations ranging between 5 and 20 mg/l. Chloride concentrations in the springs are generally less than 15 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs.

Nitrate concentrations at the Gulf Hammock group are significantly elevated above background concentration measured in the Floridan aquifer. The concentrations vary among the two springs of the group, however, they are typically around 1 mg/l. Research to determine the source of the nitrate discharging at Gulf Hammock Springs has not been conducted.

Big King Spring

Big King Spring is located on the King family property immediately north of the Sheriff's Youth Ranch Caruth Camp, approximately six miles north of Inglis and the Withlacoochee River in the southeastern corner of Gulf Hammock. The spring emanates from an enlarged fracture in limestone in the center of a small oval pool. The spring pool is roughly 20 feet across by 30 feet long, and discharges northward into a narrow, shallow stream that flows westward through the surrounding swamp.

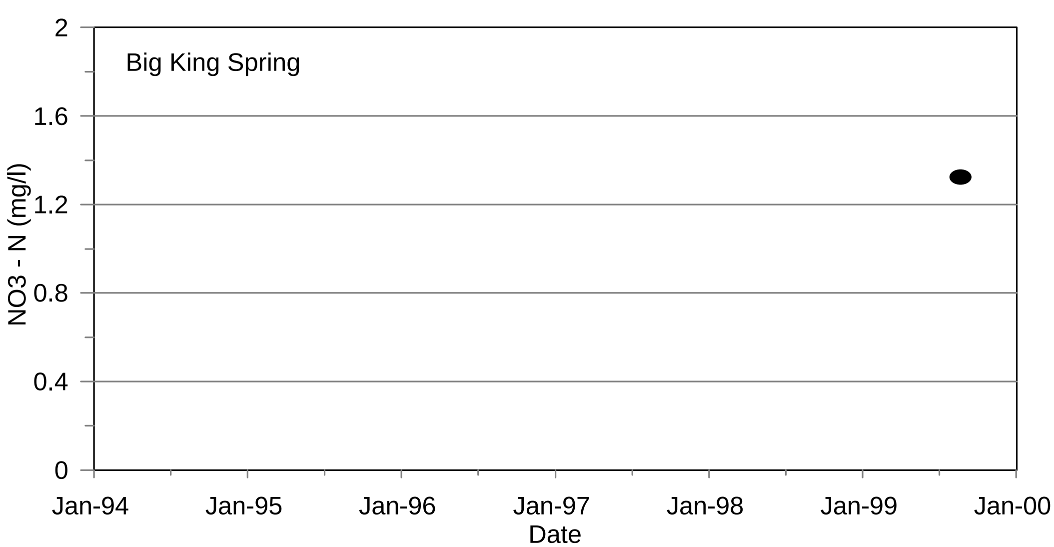
Statistical Summary

Latitude: 290659.717
Longitude: 8238832.861
County: Levy
Basin: Withlacoochee
Period of Record: 7/99 - present

Parameter*	Value
Sample Date	8/04/99
Calcium	84.20
Magnesium	12.60
Sodium	4..34
Potassium	0.35
Bicarbonate	225.00
Chloride	11.00
Sulfate	16.20
Nitrate	1.33
Phosphorus	0.12
TDS	280.00
Temp. (^{O}C)	22.90
pH (s.u.)	7.16
Sp. Cond. (µS/cm)	493.00

* (mg/l) unless noted otherwise

Nitrate Trend



Little King Spring

Little King Spring is located in the Florida Sheriff's Youth Ranch, Caruth Camp facility, approximately six miles north of Inglis and the Withlacoochee River in the southeastern corner of Gulf Hammock. The spring pool is approximately 50 feet in diameter and from 5 to 10 feet deep, with a rock ledge visible roughly in the pool center. A narrow run located in the northwest margin of the pool discharges spring water into a shallow stream that flows westward through the surrounding swamp.

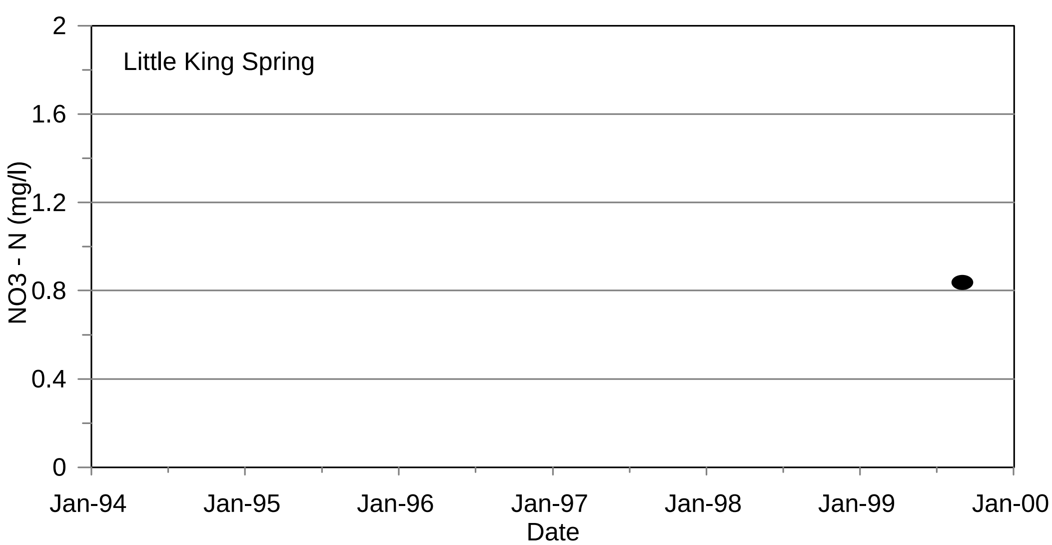
Statistical Summary

Latitude: 290639.130
Longitude: 823846.023
County: Levy
Basin: Withlacoochee
Period of Record: 7/99 - present

Parameter*	Value
Sample Date	8/04/99
Calcium	74.70
Magnesium	15.10
Sodium	3.91
Potassium	0.51
Bicarbonate	218.00
Chloride	7.38
Sulfate	6.45
Nitrate	0.84
Phosphorus	0.12
TDS	264.00
Temp. (^{O}C)	22.90
pH (s.u.)	7.22
Sp. Cond. (µS/cm)	458.00

* (mg/l) unless noted otherwise

Nitrate Trend



MARION COUNTY

Rainbow Springs Group

The Rainbow Springs group (Figure 12) is the fourth largest spring system in terms of discharge in Florida[70]. The group is the second largest spring group in the SWFWMD and in Marion County. Rainbow Springs is generally considered to be the group of springs in the area that encompasses the first 1.5 miles of the Rainbow River[11].

Like many of the major springs in Florida, Rainbow Springs is composed of numerous vents distributed over a large area, rather than a single, very large discharge point. In addition to the springs at the head of the river, numerous springs discharge into the bed of the river through most of its length. A number of small springs also feed Indian Creek, a tributary that flows southwest and intersects the Rainbow River about one mile south of the head spring area. Springs that comprise the Rainbow Springs group and are included in this report are: Bridge Seep North, Rainbow Springs #1, Rainbow Springs #4, Bubbling Spring, Rainbow Springs #6, and Rainbow Swamp Spring #3.

Discharge

Historically, the average annual discharge at Rainbow Springs is approximately 459 mgd[70]. The total discharge of Rainbow Springs is represented by the cumulative discharge of springs in the head spring area, springs in the bed of the river, and springs along Indian Creek. Discharge of the Rainbow River is regularly measured by the USGS approximately five miles downstream from the head spring area at the C.R. 484 bridge, and about one-half mile above the confluence of the Withlacoochee and Rainbow Rivers. Eighty-nine percent of the rivers discharge, as measured at the C.R. 484 bridge, enters the river in the first 1.5 miles[11].

Figure 7 is a graph of the mean monthly discharge between 1965 and 1997 at the C.R. 484 bridge. Discharge exhibits significant seasonality, reaching a minimum at the end of the dry season in June and peaking in October, after the end of the summer wet season. This pattern indicates that the lag time between seasonal changes in rainfall and the response of the system is minimal. The pattern also indicates that the circulation of ground water in the Floridan aquifer is open and vigorous and the springs are largely recharged by precipitation falling in close proximity (5-10 mile radius) of the springs.

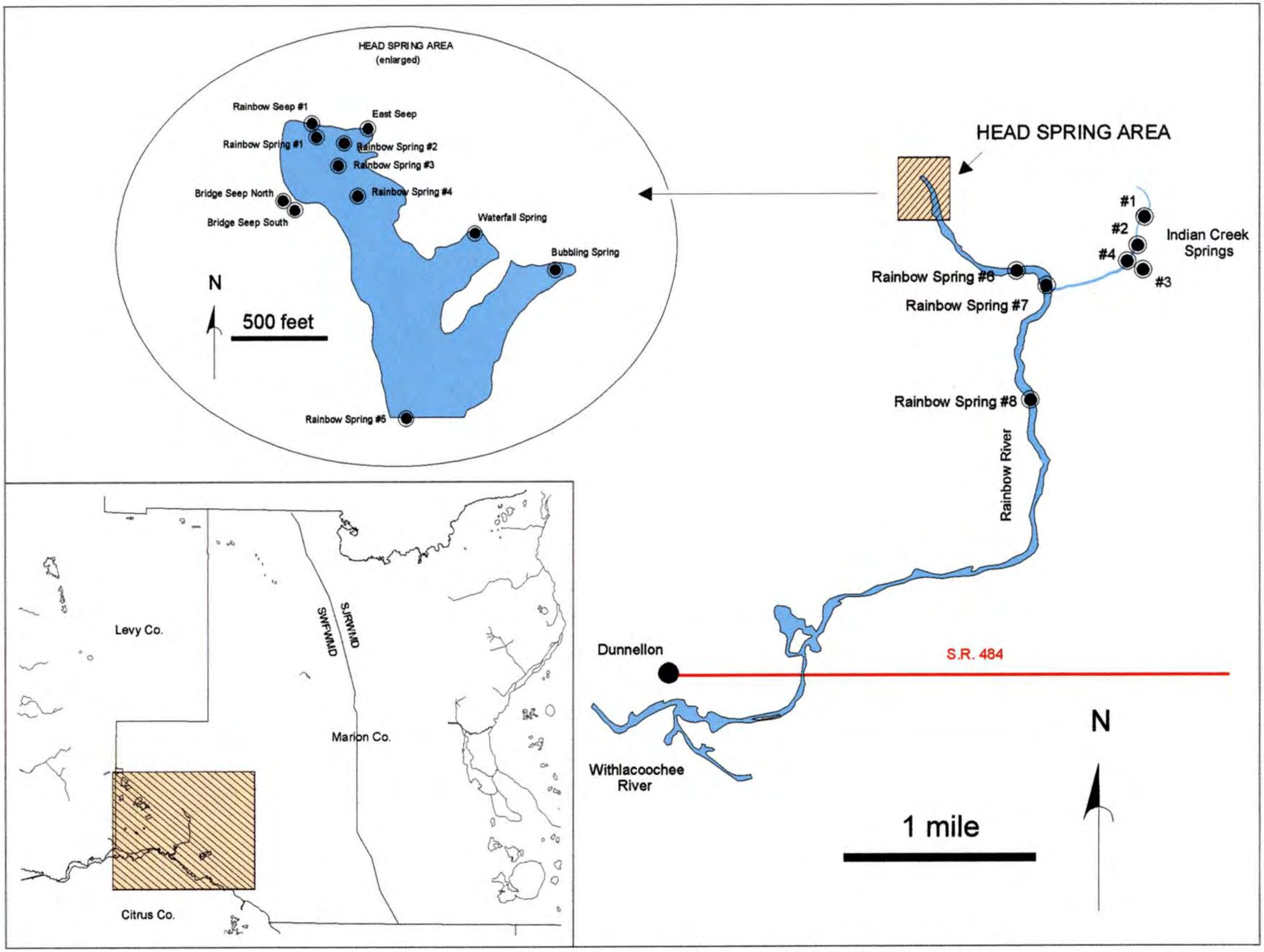


Figure 12. Location and Distribution of Springs in the Rainbow Springs Group, Marion County.

Water Quality

Ground water discharging at Rainbow Springs is fresh, typically containing less than 200 mg/l TDS. Water quality varies slightly across the spring group; sulfate concentrations increasing from less than 10 mg/l in the head spring area to greater than 30 mg/l in springs near the confluence of Rainbow River and Indian Creek. Chloride concentrations in the springs are generally less than 10 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs(11).

Nitrate concentrations at Rainbow Springs are significantly elevated above background concentration measured in the Floridan aquifer (<0.01 mg/l). Nitrate concentrations vary among the individual springs of the group; however, concentrations are typically around 1 mg/l. Research conducted by the WQMP indicates that the nitrate discharging from the springs is derived from an inorganic source of nitrate, namely inorganic fertilizers applied to pasture areas near the springs(11).

Bridge Seep North

Bridge Seep North is one of two seeps located on the west side of the main spring pool. The spring discharges horizontally from beneath a small outcrop of limestone, and flow from the spring discharges into a short spring run that flows under a foot bridge into the head spring area. The combined flow from Bridge Seep North and another seep 20 feet east of the spring (Bridge Seep South) averaged 3 cfs for two flow measurements taken in 1996[12]. The spring is located within the boundaries of the Rainbow Springs State Park.

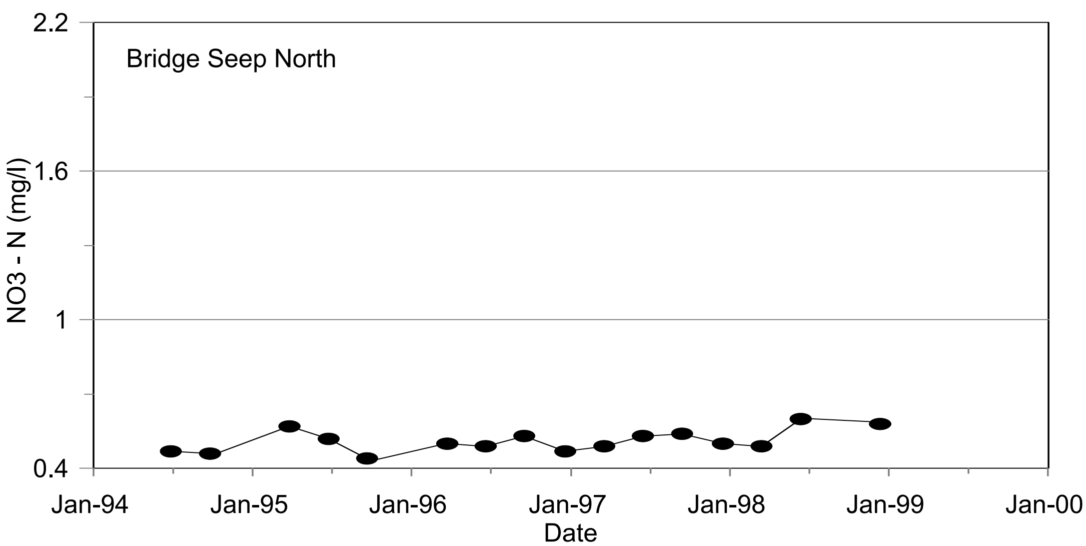
Statistical Summary

Latitude: 290606.992
Longitude: 822615.982
County: Marion
Basin: Withlacoochee
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	1/12/99
Calcium	17.50
Magnesium	3.10
Sodium	2.01
Potassium	0.06
Bicarbonate	47.00
Chloride	3.07
Sulfate	4.11
Nitrate	0.58
Phosphorus	0.03
TDS	89.00
Temp. (^{O}C)	22.80
pH (s.u.)	8.16
Sp. Cond. (µS/cm)	123.00

* (mg/l) unless noted otherwise

Nitrate Trend



Rainbow Springs #1

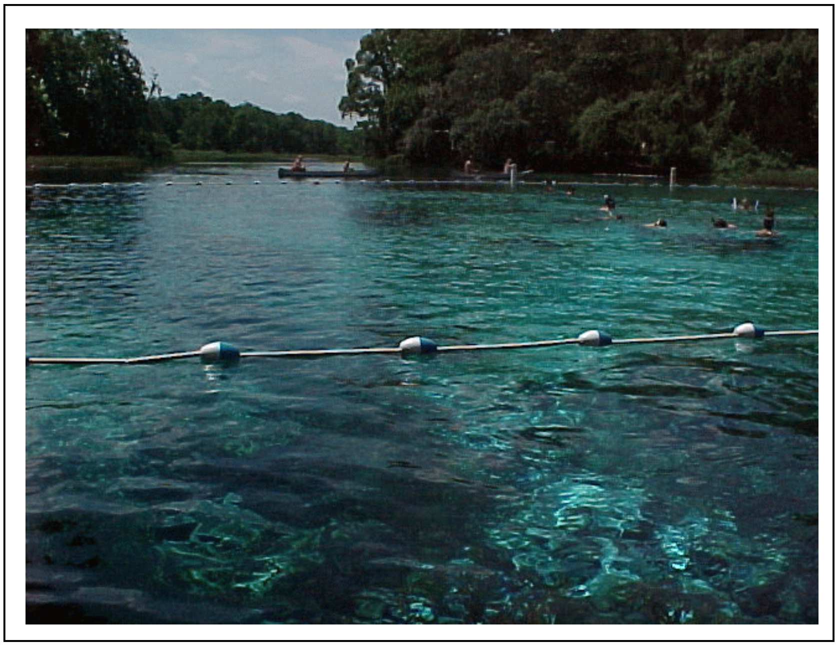
Rainbow Springs #1 is located on the north side of the head spring area in close proximity to two other vents in the spring pool. The spring, as well as two others, emanates from one of the largest vents in the group (30-50 feet in length). The spring vent is located just outside the boundary of a designated swimming area in approximately 10-15 feet of water. Discharge is not concentrated, however, faint boils can sometimes be seen on the pool's surface above the vents. The spring is located within the boundaries of the Rainbow Springs State Park.

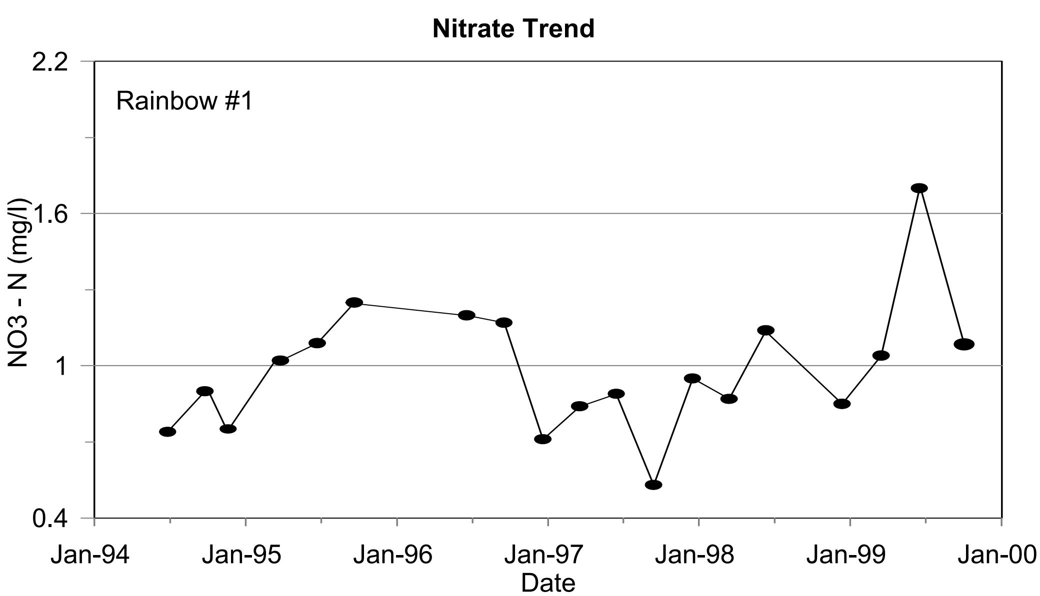
Statistical Summary

Latitude: 290609.192
Longitude: 822615.104
County: Marion
Basin: Withlacoochee
Period of Record: 4/94 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	25.30
Magnesium	3.92
Sodium	2.25
Potassium	0.04
Bicarbonate	65.00
Chloride	3.92
Sulfate	4.59
Nitrate	1.70
Phosphorus	0.03
TDS	85.00
Temp. (^{O}C)	25.00
pH (s.u.)	8.02
Sp. Cond. (µS/cm)	161.00

* (mg/l) unless noted otherwise



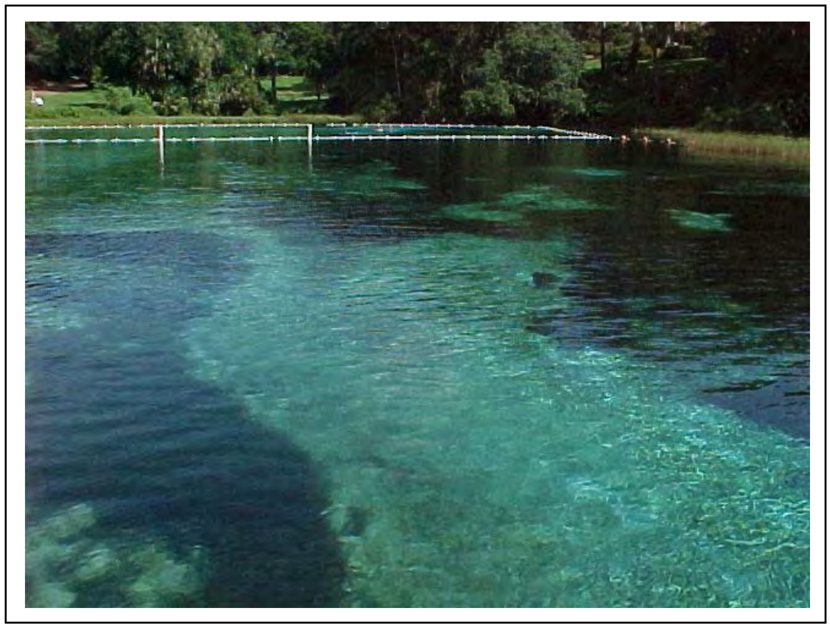


Rainbow Springs #4

Rainbow Springs #4 lies near the center of the Rainbow River about 250 feet south (downstream) of Rainbow Springs #1. The spring vent is elliptical in shape; about five feet long and three feet wide. The spring lies 10 feet below the surface of the pool, and is first encountered upon entering the head spring area from the south. The spring creates a pronounced boil on the surface of the spring pool. The spring is located within the boundaries of the Rainbow Springs State Park.

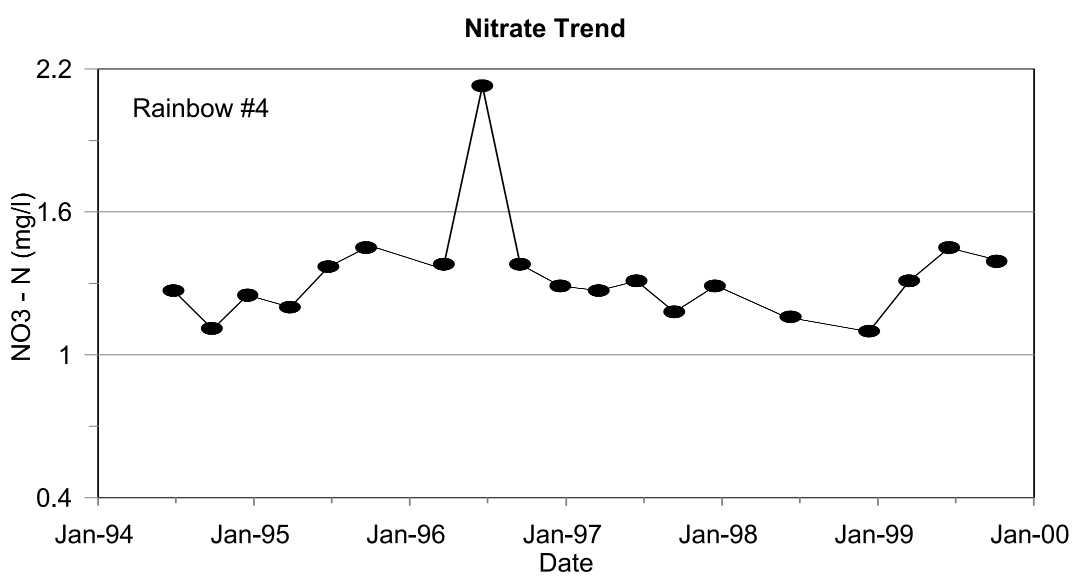
Statistical Summary

Latitude: 290606.727
Longitude: 822613.771
County: Marion
Basin: Withlacoochee
Period of Record: 10/93 - present



Parameter*	Value
Sample Date	7/21/99
Calcium	39.30
Magnesium	4.90
Sodium	2.32
Potassium	-0.04
Bicarbonate	101.00
Chloride	4.24
Sulfate	4.38
Nitrate	1.45
Phosphorus	0.03
TDS	128.00
Temp. (^{O}C)	23.50
pH (s.u.)	7.83
Sp. Cond. (µS/cm)	238.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



Bubbling Spring

Bubbling Spring is located about 1,500 feet southeast of the main spring pool in a small tributary on the eastern side of the Rainbow River. The spring lies 500 feet east of the river, and emanates from at least three fractures in the limestone floor of the run. The fractures in the limestone are in three feet of water and measure no more than four feet long and six inches wide. The spring boil is so vigorous that the sound of flowing water is clearly audible for some distance away from the spring. The spring is located within the boundaries of the Rainbow Springs State Park.

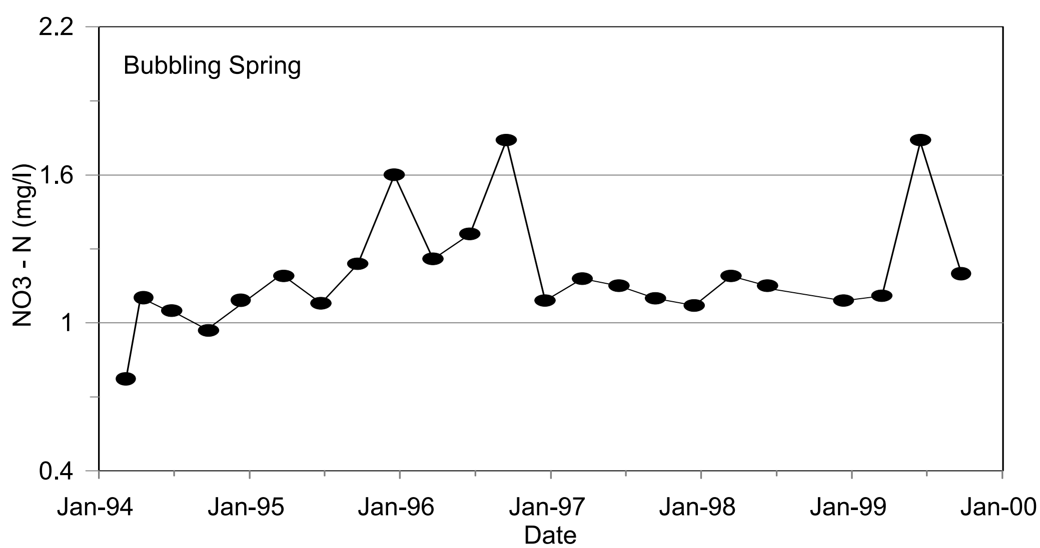
Statistical Summary

Latitude: 290604.396
Longitude: 822605.337
County: Marion
Basin: Withlacoochee
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	53.00
Magnesium	5.91
Sodium	2.70
Potassium	-0.04
Bicarbonate	142.00
Chloride	4.94
Sulfate	6.78
Nitrate	1.74
Phosphorus	0.03
TDS	168.00
Temp. (^{O}C)	23.20
pH (s.u.)	7.60
Sp. Cond. (μS/cm)	312.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit

Nitrate Trend



Rainbow Spring #6

Rainbow Spring #6 is located about one-half mile downstream of the head spring area in a limestone-floored depression approximately 100 feet across. The spring lies in the channel of the Rainbow River in about 15 feet of water. The spring does not produce a strong boil at the water surface, however, swimmers report that a very strong flow emanates from the spring vent. The spring vent is elliptical in shape; about five feet long and two feet wide.

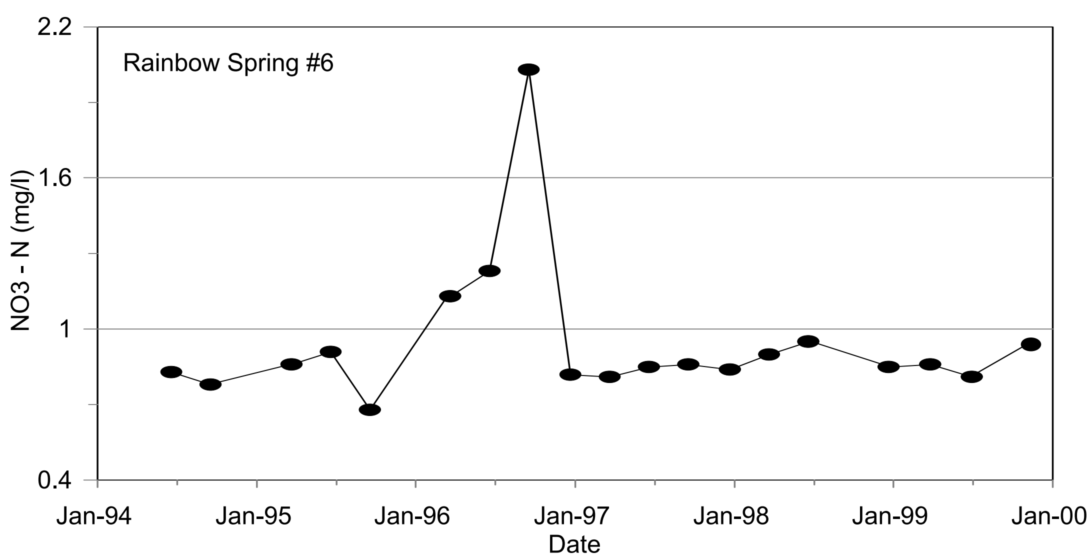
Statistical Summary

Latitude: 290534.262
Longitude: 822542.327
County: Marion
Basin: Withlacoochee
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	52.10
Magnesium	6.59
Sodium	3.36
Potassium	-0.04
Bicarbonate	112.00
Chloride	5.87
Sulfate	33.90
Nitrate	0.81
Phosphorus	0.03
TDS	184.00
Temp. (^{O}C)	23.80
pH (s.u.)	7.72
Sp. Cond. (µS/cm)	321.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit

Nitrate Trend



Rainbow Swamp #3

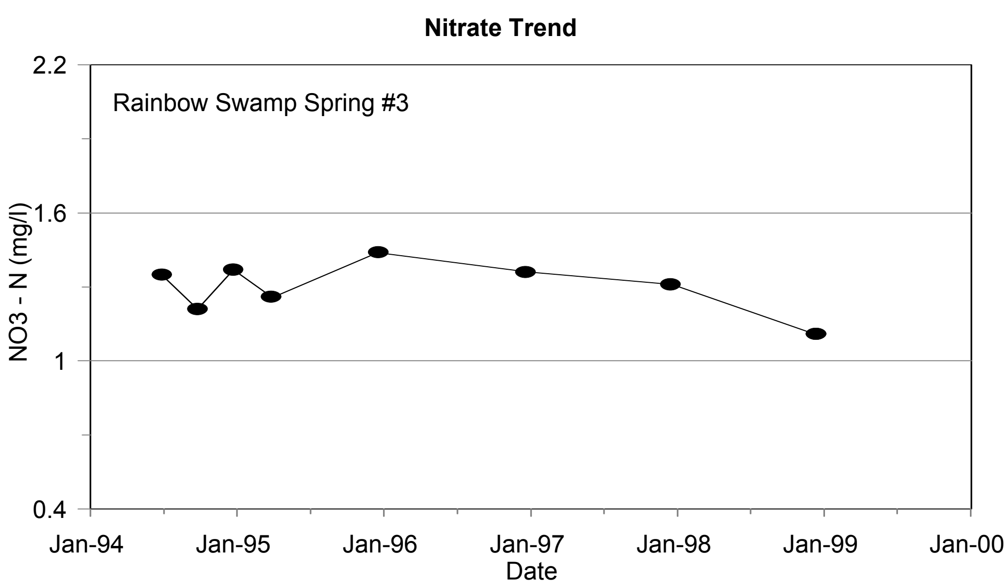
Rainbow Swamp Spring #3 is located along Indian Creek, a small and heavily wooded spring run that lies about 200 yards upstream from the Rainbow Springs State Park Campground. The spring lies at the bottom of an oval-shaped pool in about 10-15 feet of water, and is situated approximately 50 feet to the northeast of Rainbow Swamp #4. Three other springs occur along Indian Creek, and when combined, discharge ~5 mgd to the Rainbow River[(10)].

Statistical Summary

Latitude: 290609
Longitude: 822614
County: Marion
Basin: Withlacoochee
Period of Record: 2/94 - present

Parameter*	Value
Sample Date	1/12/99
Calcium	40.30
Magnesium	3.53
Sodium	2.56
Potassium	0.08
Bicarbonate	97.00
Chloride	4.53
Sulfate	11.70
Nitrate	1.11
Phosphorus	0.03
TDS	142.00
Temp. (^{O}C)	23.1
pH (s.u.)	7.79
Sp. Cond. (µS/cm)	243.00

* (mg/l) unless noted otherwise



CITRUS COUNTY

King's Bay Springs Group

The King's Bay Springs group is the second largest spring system in Florida[70], and is the largest of three spring groups in western Citrus County (Figure 13). Manatees often visit the springs during the winter months, and as a result, a large portion of the bay has been designated a manatee sanctuary. Much like Rainbow Springs, the King's Bay Springs group is composed of numerous springs distributed over a large area (approximately one square mile), rather than a single, very large discharge point. Springs that comprise the King's Bay Spring group and are included in this report: Black, Tarpon Hole, Idiots Delight, and Hunters Springs.

Discharge

The King's Bay Springs (also known as the Crystal River Springs) discharge approximately 567 mgd to King's Bay, the headwaters of Crystal River[70]. This discharge is derived from a mixture of fresh and brackish water vents located throughout the bay. Fresh-water springs are mostly clustered on the eastern side of King's Bay, while brackish-water springs occur in the central and western portions of the bay (Figure 6). Recent discharge measurements taken at King's Bay indicate that spring flow is only 75% of the long-term average[71]. This reduction is similar to other springs in the region and may be attributable to decreased rainfall and/or increased ground-water withdrawals in recharge areas near the springs.

Water Quality

Ground water discharging at the King's Bay Springs may be fresh or brackish, depending on tides and water levels in the Floridan aquifer. At low tide, water quality varies across the spring group with TDS concentrations increasing from less than 200 mg/l along the eastern side of the bay to greater than 1,000 mg/l in springs near the center and southwestern shore. In addition, chloride concentrations across the group may range from less than 10 mg/l to greater than 1,000 mg/l at low tide (Figure 6). This indicates that water quality at the springs is strongly influenced by the coastal transition zone even at low tide[10].

Nitrate concentrations at the King's Bay Springs are below 0.4 mg/l. The nitrate levels vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and variations in nitrate in Floridan aquifer ground water. Research conducted by the WQMP indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs[10].

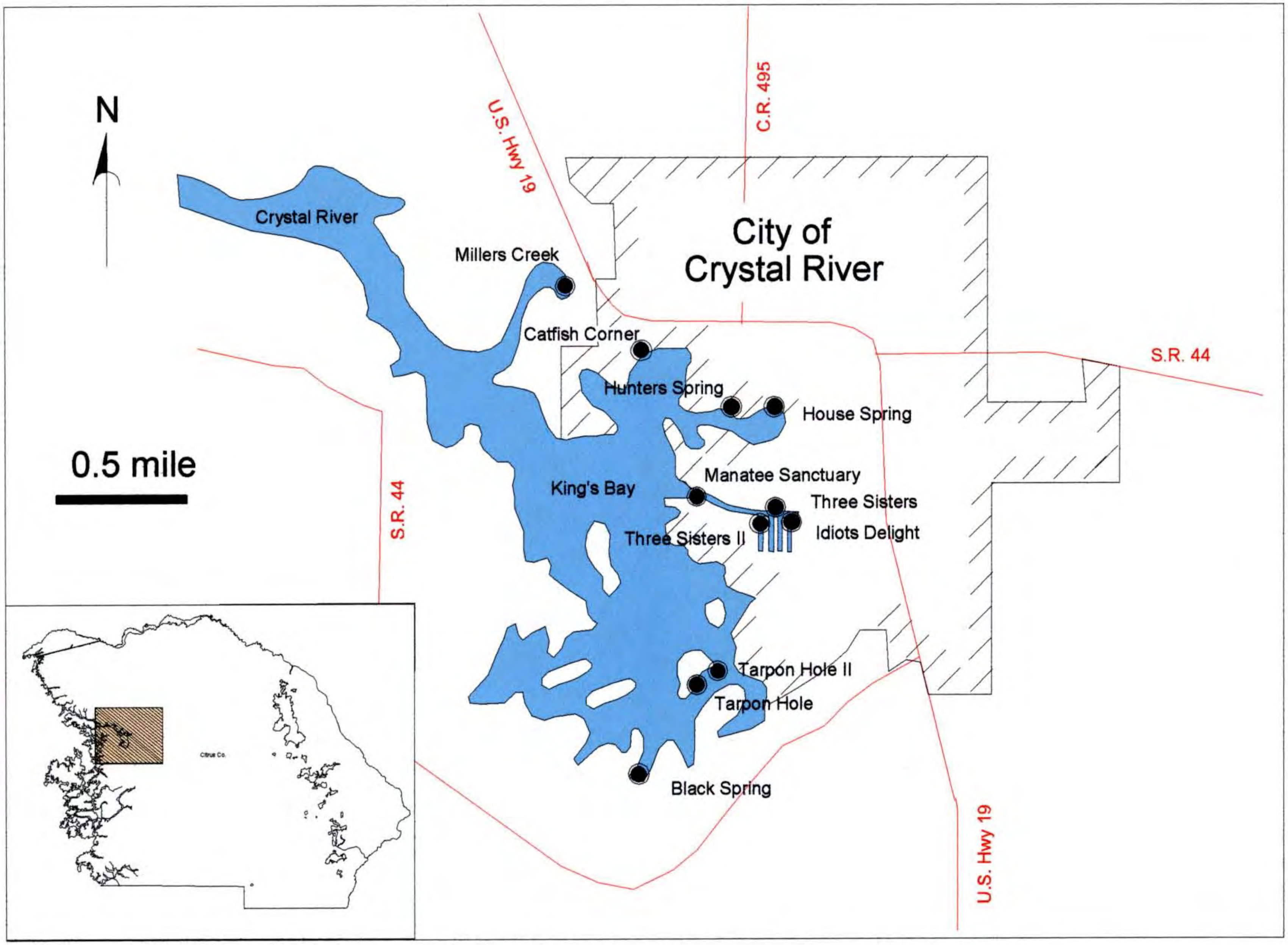


Figure 13. Location and Distribution of Springs in the King's Bay Springs Group, CitrusCounty.

Black Spring

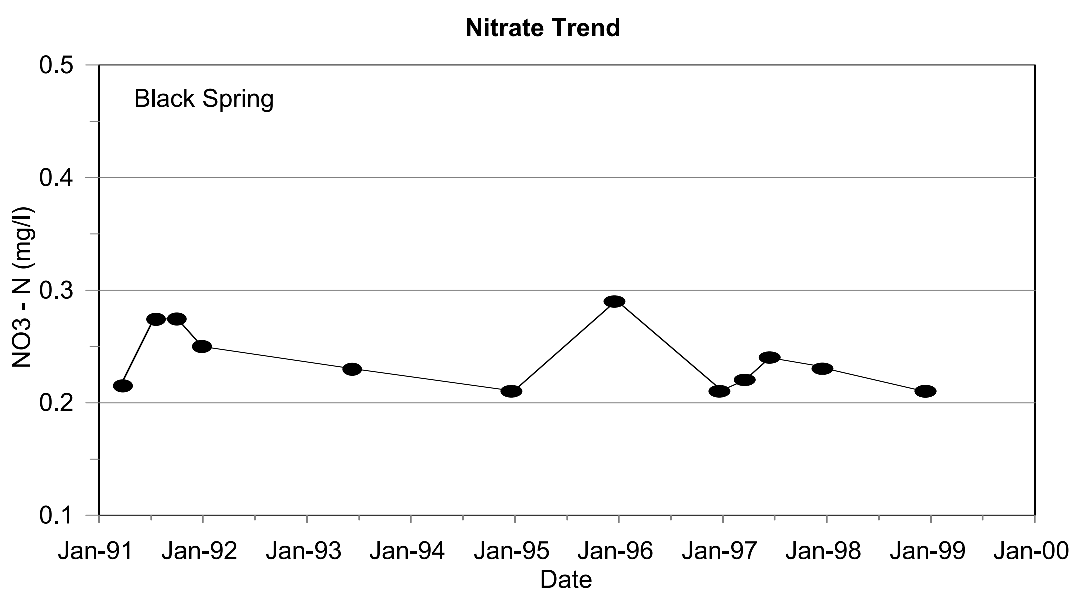
Black Spring is located near the end of a canal in a residential neighborhood at the southern margin of King's Bay. The spring lies in several feet of water, and may produce a boil at the surface of the canal. The spring is one of several vents in the area, and is tidally influenced.

Statistical Summary

Latitude: 285238.628
Longitude: 823557.196
County: Citrus
Basin: Coastal Rivers
Period of Record: 2/91 - present

Parameter*	Value
Sample Date	1/20/99
Calcium	63.30
Magnesium	57.70
Sodium	421.00
Potassium	17.40
Bicarbonate	115.00
Chloride	781.00
Sulfate	122.00
Nitrate	0.21
Phosphorus	0.04
TDS	1,472.00
Temp. (^{O}C)	23.3
pH (s.u.)	7.59
Sp. Cond. (µS/cm)	2,920.00

* (mg/l) unless noted otherwise



Tarpon Hole

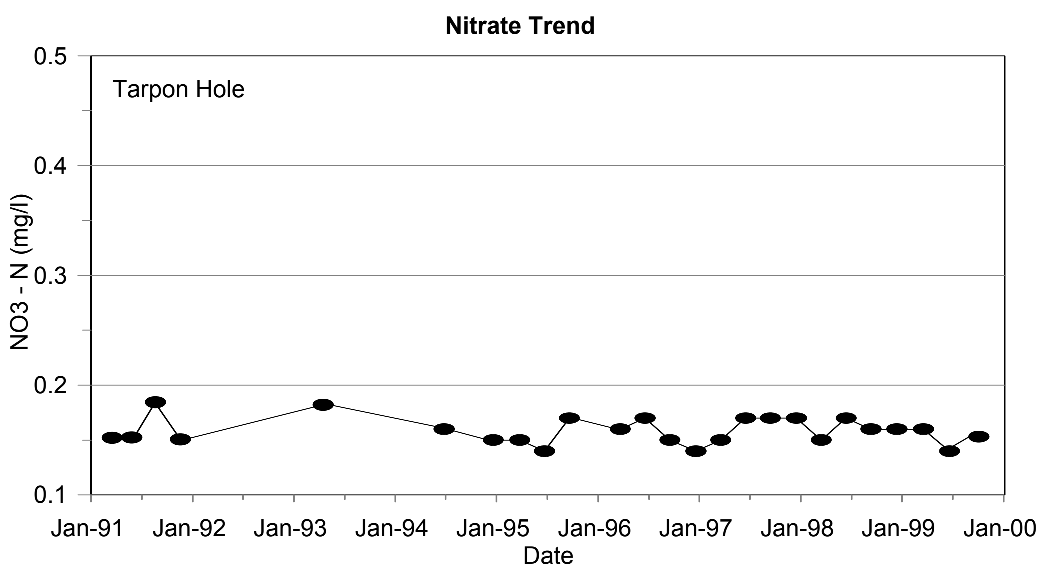
Tarpon Hole is located just south of Banana Island in the central portion of King's Bay. The largest of the thirty springs that make up the headwaters of Crystal River, it is a popular scuba diving location and is easily accessible by boat. The spring vent is approximately 200 feet in diameter and 50 feet deep. The spring is tidally influenced.

Statistical Summary

Latitude: 285254.416
Longitude: 823541.008
County: Citrus
Basin: Coastal Rivers
Period of Record: 2/91 - present

Parameter*	Value
Sample Date	7/28/99
Calcium	51.20
Magnesium	28.40
Sodium	200.00
Potassium	7.18
Bicarbonate	110.00
Chloride	364.00
Sulfate	56.00
Nitrate	0.13
Phosphorus	0.03
TDS	779.00
Temp. (^{O}C)	24.2
pH (s.u.)	7.78
Sp. Cond. (µS/cm)	1,502.00

* (mg/l) unless noted otherwise

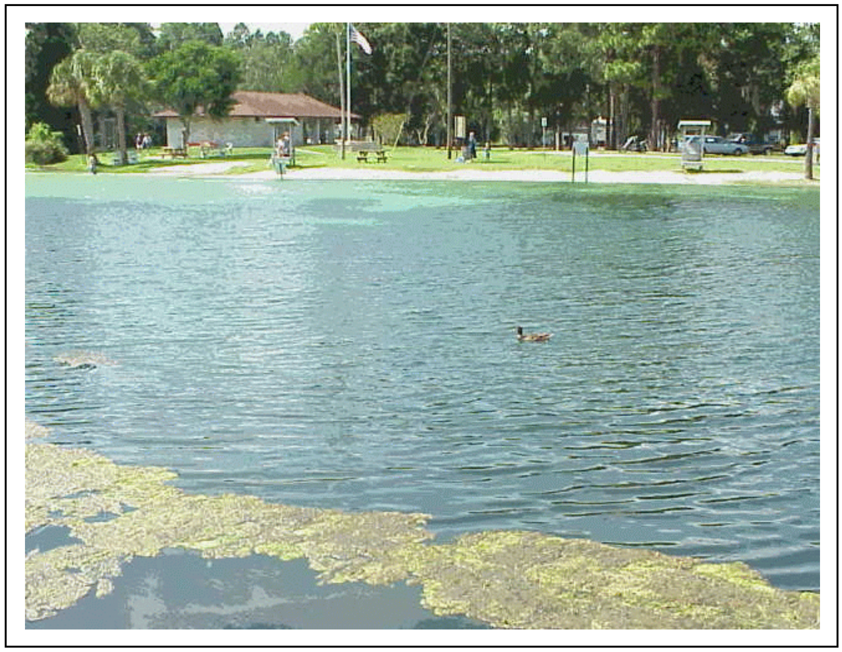


Hunters Spring

Hunters spring is located in the northeast portion of King's Bay. The spring is surrounded by a recreational park to the north and a residential area to the south. The spring vent is located within a designated swimming area about 40 feet offshore of the park. This spring is tidally influenced.

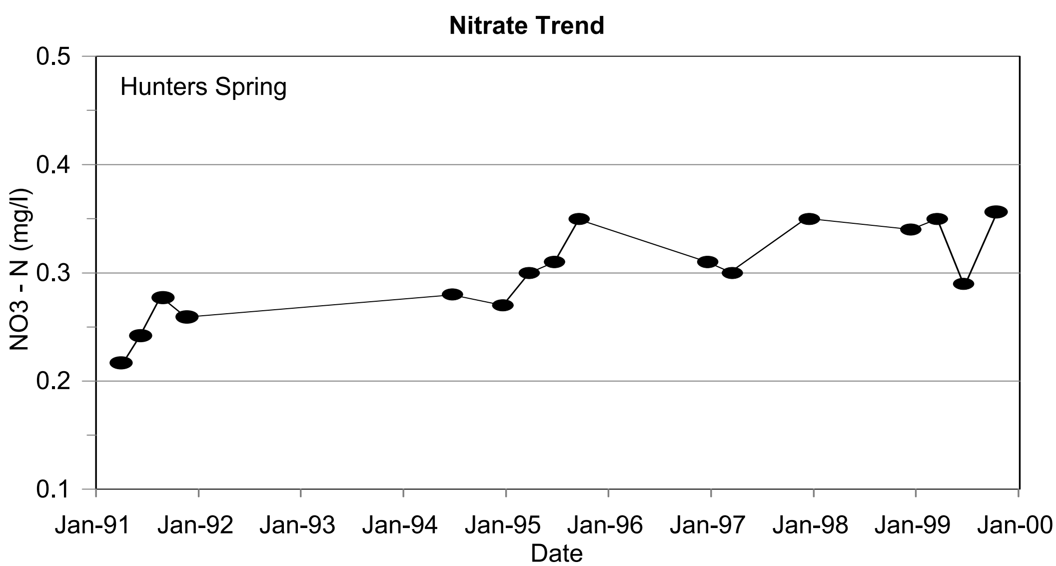
Statistical Summary

Latitude: 285339.541
Longitude: 823533.090
County: Citrus
Basin: Coastal Rivers
Period of Record: 2/91 - present



Parameter*	Value
Sample Date	7/28/99
Calcium	32.40
Magnesium	7.46
Sodium	23.80
Potassium	0.70
Bicarbonate	78.20
Chloride	44.20
Sulfate	13.60
Nitrate	0.29
Phosphorus	0.02
TDS	173.00
Temp. (^{O}C)	24.50
pH (s.u.)	8.19
Sp. Cond. (µS/cm)	332.00

* (mg/l) unless noted otherwise



Idiots Delight

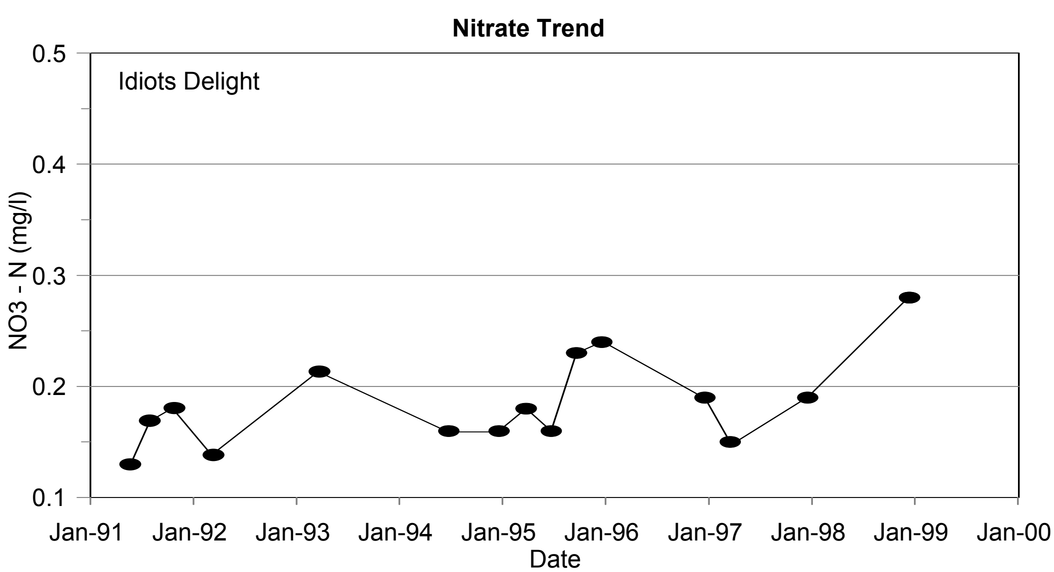
Idiots Delight is located on the east side of King's Bay. The spring consists of a group of three vertical shafts at least 20 feet in depth. The largest of the three shafts is documented to be five feet in diameter. The spring lies adjacent to the shoreline, and is in several feet of water. This spring is tidally influenced.

Statistical Summary

Latitude: 285316.669
Longitude: 823521.932
County: Citrus
Basin: Coastal Rivers
Period of Record: 4/91 - present

Parameter*	Value
Sample Date	1/20/99
Calcium	32.10
Magnesium	4.22
Sodium	8.13
Potassium	0.20
Bicarbonate	87.00
Chloride	14.60
Sulfate	4.95
Nitrate	0.28
Phosphorus	0.05
TDS	132.00
Temp. (^{O}C)	23.7
pH (s.u.)	7.87
Sp. Cond. (µS/cm)	240.00

* (mg/l) unless noted otherwise



Homosassa Springs Group

The Homosassa Springs group lies in Western Citrus County approximately three miles south of King's Bay and one mile southwest of the intersection of S.R. 490A and U.S. Hwy 19 (Figure 14). The spring group is composed of the main spring, which includes three large vents contained within a collapsed-cavern feature, and many smaller secondary vents spread over an area of nearly four square miles. The Homosassa River originates at the main springs and receives additional flow from the spring-fed Southeast Fork of the Homosassa River, and the spring-fed Hall's River. Springs in the Homosassa Springs group include Homosassa Main Spring #1, #2, and #3, Trotter Main, Pumphouse, Hidden River Head, and Hall's River Head Spring.

Discharge

The average annual discharge of the springs in the Homosassa Springs group is approximately 229 mgd. Table 2 contains discharge information for the springs in the Homosassa group.

Table 2. Discharge Information for Several Springs in the Homosassa Group[12].

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN[3,36]
HOMOSASSA MAIN SPRING AREA			
Homosassa Main 1, 2, and 3	104.0	11	1988-1989
Homosassa River	unknown (<10 ?)	0	N/A
SOUTHEAST FORK OF THE HOMOSASSA RIVER			
Abdoney, Belcher McClain, Pumphouse, Trotter #1, Trotter Main	69.1 (Springs have not been measured individually - this is the combined discharge of these and other springs on the Southeast Fork)	89	1931-1974
HIDDEN RIVER			
Hidden River Head Hidden River #1	9.3 (Springs have not been measured individually - this is the combined discharge)	7	1988-1989
HALL'S RIVER			
Hall's River - Long shallow river, difficult to access - discrete discharge points are rare	162.0 (This is the combined discharge of an unknown number of springs and seeps)	12	1964-1966

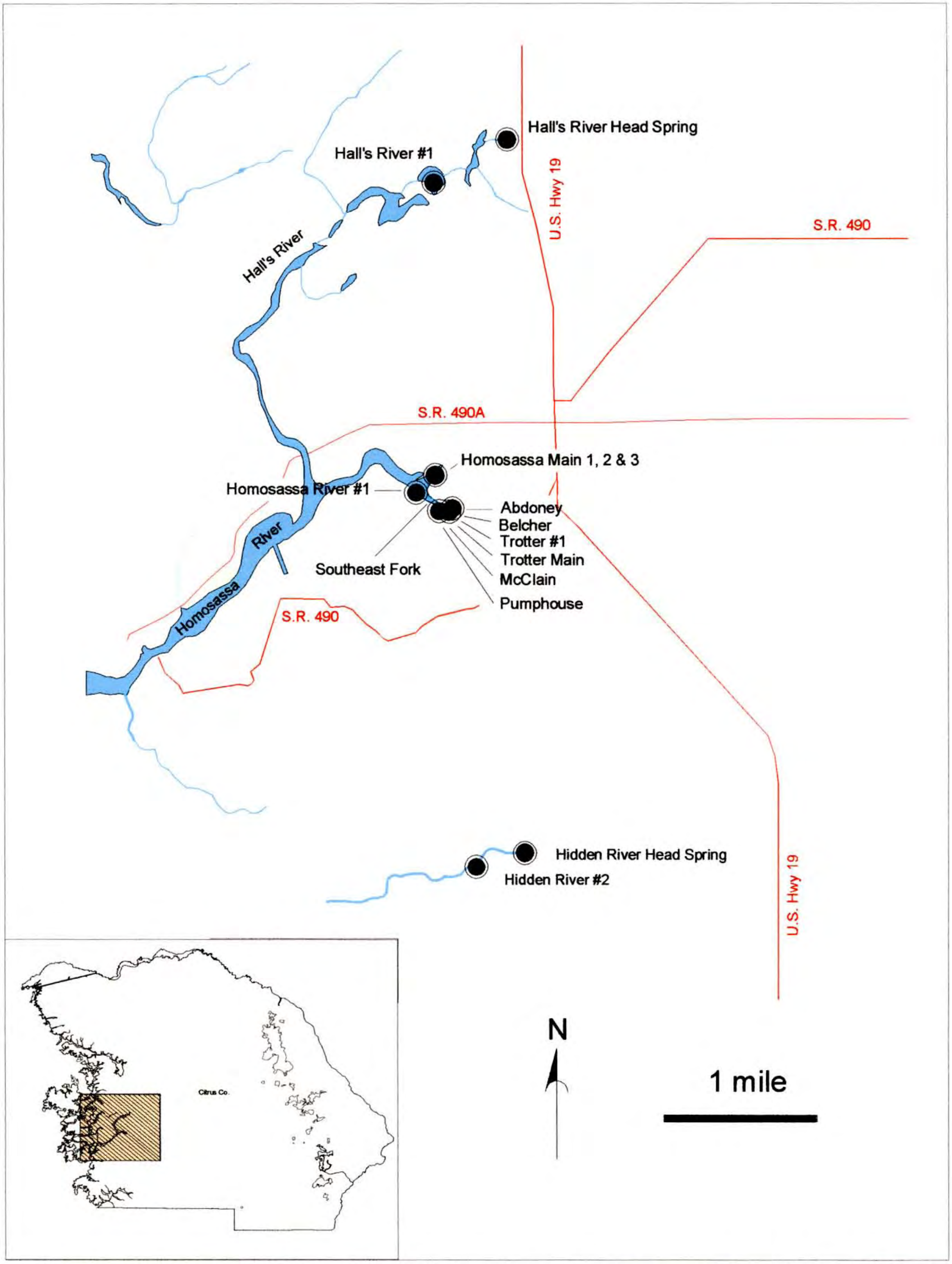


Figure 14. Location and Distribution of Springs in the Homosassa Springs Group Citrus County.

Water Quality

Ground water discharging the Homosassa Springs group may be fresh or brackish, depending on tides and water levels in the Floridan aquifer. At low tide, water quality varies across the spring group with TDS concentrations increasing from less than 250 mg/l along the southeastern fork of the Homosassa River to greater than 1,500 mg/l in springs at the head of Hall's River. Chloride concentrations across the group may range from less than 50 mg/l to greater than 500 mg/l, indicating that water quality at the spring group is strongly influenced by the coastal transition zone even at low tide(12).

Nitrate concentrations at the Homosassa Springs group are typically below 0.7 mg/l. The concentrations vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and variations in nitrate in Floridan aquifer ground water. Research conducted by the WQMP indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs(12).

Cavern Features

The Homosassa Main Spring was studied in 1992 by Karst Environmental Services (KES); a ground-water consulting firm. A portion of the study involved the mapping of the main-spring cave system by a team of divers. Their investigation revealed that the accessible portion of the system is not extensive (Figure 15). Most of the spring's cavern system has developed in the Ocala Limestone. However, the contact between the Ocala Limestone and Avon Park Formation was observed to occur at a depth of 48 feet below sea level(72).

The maximum depth reached by the divers in the cave was 70 feet. Although extremely narrow passages continued deeper into the system, they were judged to be beyond the safe reach of the divers. The divers also determined that most of the flow in the main spring emanates from three vents, each of which discharges water that is chemically distinct from the others. Subsequent samplings of the main spring were greatly improved by the installation of sampling tubes into the individual vents(72).

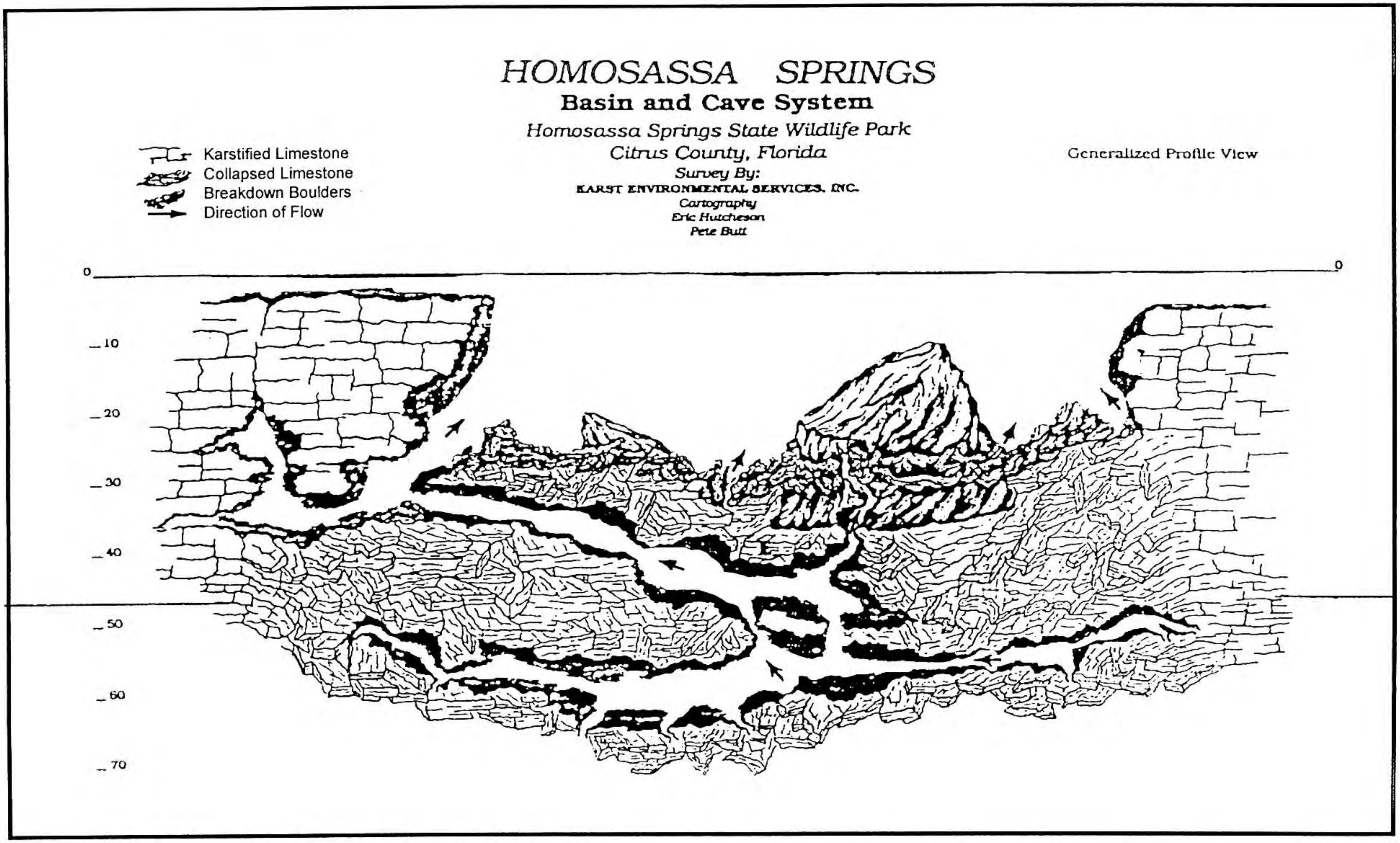


Figure 15. The Homosassa Springs Cavern System[72].

Homosassa Main Spring

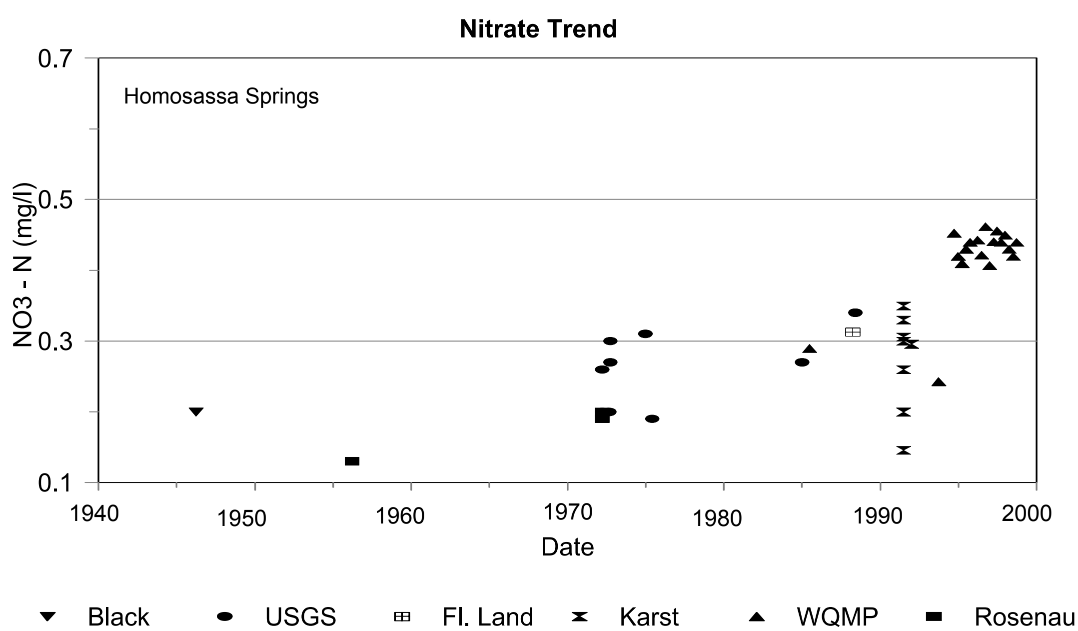
Homosassa Springs is located within the Homosassa Springs State Wildlife Park. The main spring lies in a collapsed-cavern feature, and is comprised of three chemically distinct vents. A floating platform (commonly known as "the fishbowl"), pictured below, features an underwater viewing area that allows visitors to the park to see manatees and fish that frequent the spring. The spring is tidally influenced, and the data presented below represents water quality from vent # 3 (the "freshest" of the three vents in the main spring).

Statistical Summary

Latitude: 284757.156
Longitude: 823517.851
County: Citrus
Basin: Coastal Rivers
Period of Record: 11/93 - present

Parameter*	Value
Sample Date	7/28/99
Calcium	46.90
Magnesium	31.70
Sodium	213.00
Potassium	7.85
Bicarbonate	105.00
Chloride	409.00
Sulfate	93.80
Nitrate	0.42
Phosphorus	0.02
TDS	832.00
Temp. (^{O}C)	24.20
pH (s.u.)	7.72
Sp. Cond. (µS/cm)	1,604.00

* (mg/l) unless noted otherwise



Trotter Main Spring

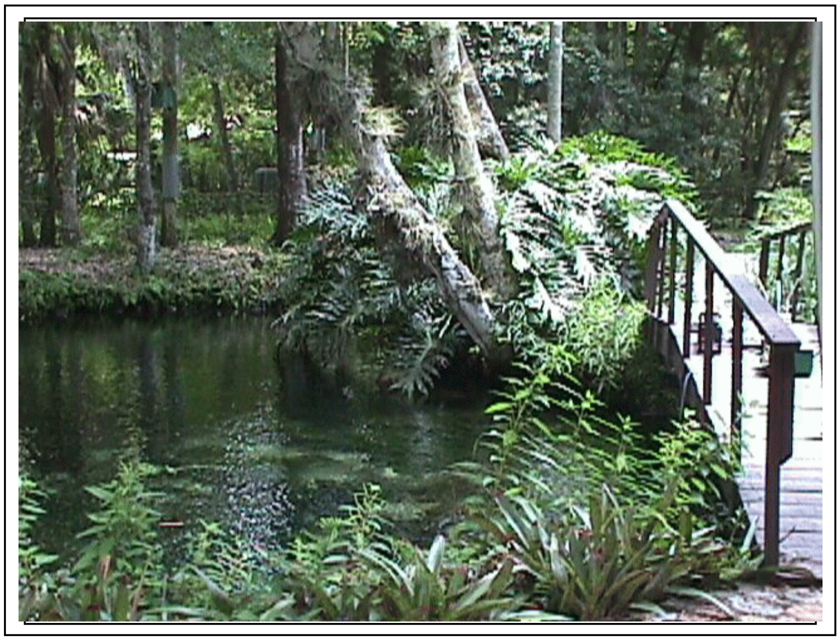
Trotter Main Spring is located on the southeast fork of the Homosassa River, approximately 1000 feet south of the Homosassa Main spring area. The spring emanates from one of several large fractures in the limestone bedrock, and lies 2-3 feet below the water surface. The spring is not tidally influenced, but may be affected by a spring-fed stream that flows underground approximately 400 feet south of Trotter and Pumphouse Springs (tannic water is often reported to flow from the spring(s) after heavy rains). The spring is situated on private property.

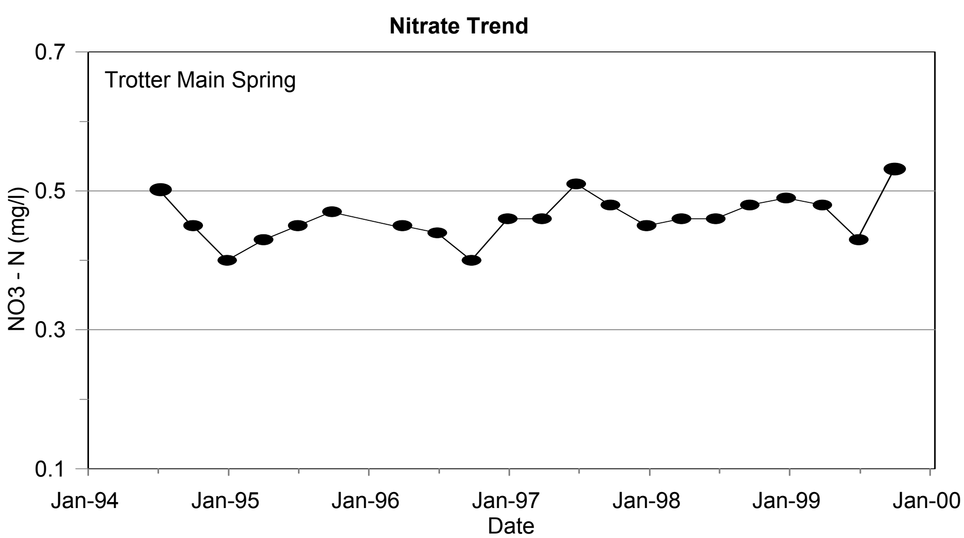
Statistical Summary

Latitude: 284747.299
Longitude: 823510.971
County: Citrus
Basin: Coastal Rivers
Period of Record: 11/93 - present

Parameter*	Value
Sample Date	7/28/99
Calcium	41.40
Magnesium	10.20
Sodium	29.40
Potassium	0.91
Bicarbonate	108.00
Chloride	55.60
Sulfate	11.80
Nitrate	0.43
Phosphorus	0.02
TDS	224.00
Temp. (^{O}C)	23.50
pH (s.u.)	7.76
Sp. Cond. (µS/cm)	420.00

* (mg/l) unless noted otherwise





Pumphouse Spring

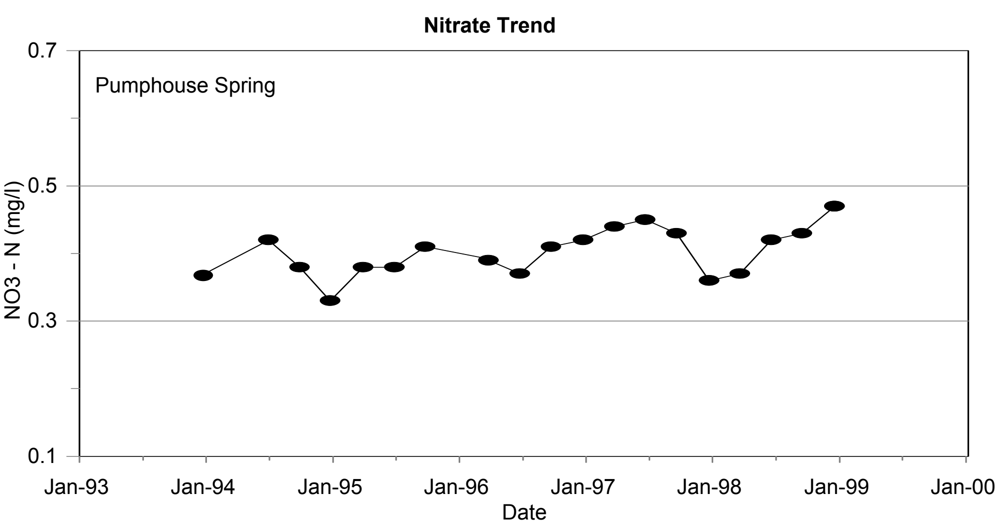
Pumphouse spring is located in the southeast fork of the Homosassa River, approximately 1000 feet south of the Homosassa Main Spring, and 500 feet east of Trotter Main Spring. At one time, a pumphouse at the spring supplied water to the community of Old Homosassa Springs. The spring is not tidally influenced, but may be affected by a spring-fed stream that flows underground approximately 400 feet south of Trotter and Pumphouse Springs (tannic water is often reported to flow from the spring(s) after heavy rains). The spring is situated on private property.

Statistical Summary

Latitude: 284746.955
Longitude: 823517.646
County: Citrus
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	1/19/99
Calcium	40.40
Magnesium	8.71
Sodium	26.90
Potassium	0.78
Bicarbonate	115.00
Chloride	49.40
Sulfate	11.00
Nitrate	0.47
Phosphorus	0.02
TDS	214.00
Temp. (^{O}C)	22.80
pH (s.u.)	7.75
Sp. Cond. (µS/cm)	359.00

* (mg/l) unless noted otherwise



Hidden River Head Spring

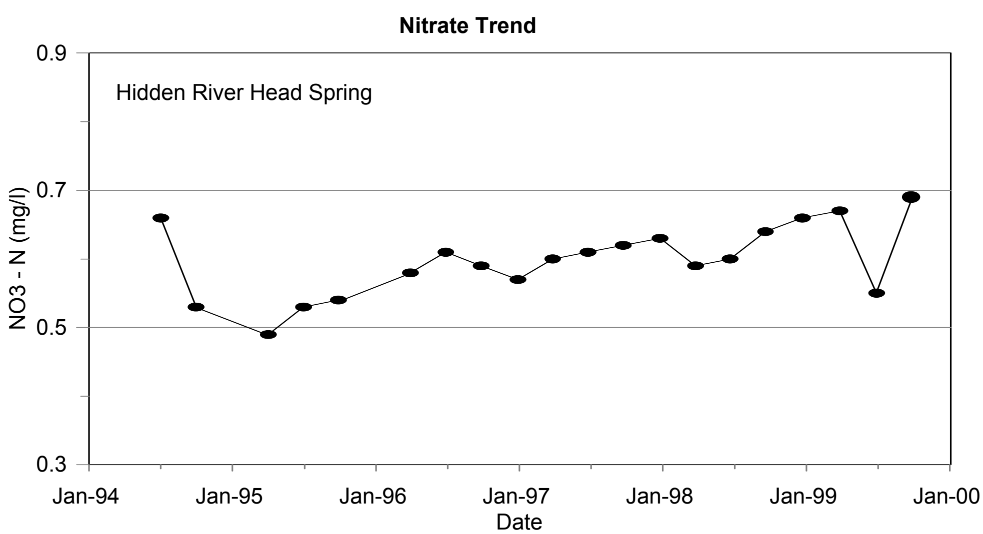
Hidden River Head Spring is found at the upstream end of Hidden River, approximately four feet below the water surface in a small circular depression, five feet in diameter. The spring is located about two miles south of Homosassa Springs. Hidden River flows overland approximately two miles before sinking underground and entering the Homosassa River downstream from Homosassa Springs. The spring is tidally influenced.

Statistical Summary

Latitude: 284607.357
Longitude: 823459.689
County: Citrus
Basin: Coastal Rivers
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	1/19/99
Calcium	37.10
Magnesium	21.00
Sodium	127.00
Potassium	6.03
Bicarbonate	111.00
Chloride	221.00
Sulfate	38.50
Nitrate	0.66
Phosphorus	0.03
TDS	506.00
Temp. (^{O}C)	23.20
pH (s.u.)	7.84
Sp. Cond. (µS/cm)	1,024.00

* (mg/l) unless noted otherwise



Hall's River Head Spring

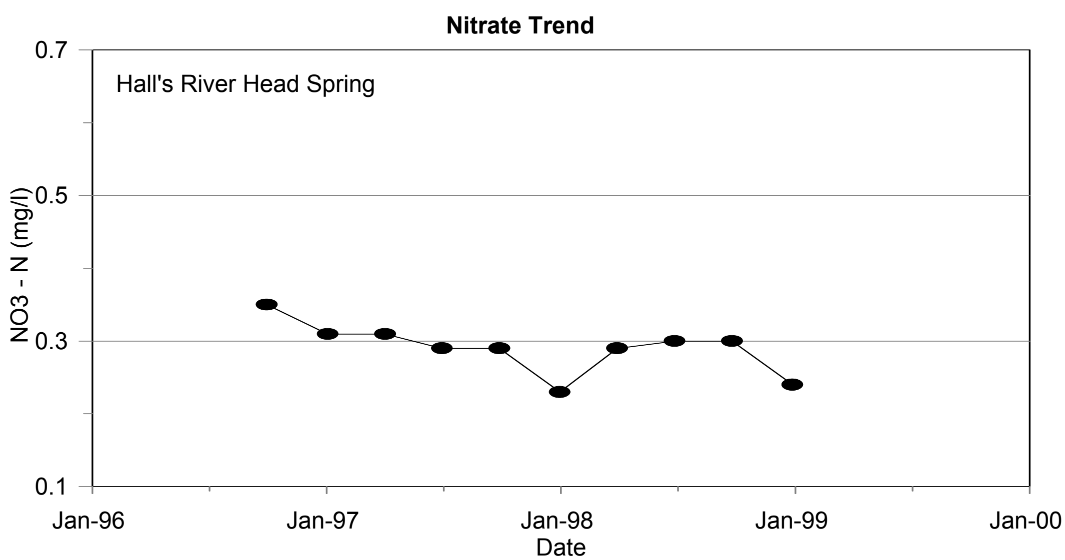
Hall's River Head Spring is located at the upstream end of Hall's River, a 2.5 mile long tributary of the Homosassa River. Many springs in Hall's River are hard to access due to the width, shallowness, and vegetation in the river. The spring pool is approximately 200 feet across and contains a few sand boils, but no obvious vent or boil at the water surface. The spring is tidally influenced.

Statistical Summary

Latitude: 284936.509
Longitude: 823449.176
County: Citrus
Basin: Coastal Rivers
Period of Record: 10/96 - present

Parameter*	Value
Sample Date	1/19/99
Calcium	64.40
Magnesium	65.20
Sodium	526.00
Potassium	22.60
Bicarbonate	109.00
Chloride	992.00
Sulfate	148.00
Nitrate	0.24
Phosphorus	0.03
TDS	1,878.00
Temp. (^{O}C)	22.2
pH (s.u.)	7.64
Sp. Cond. (µS/cm)	3,260.00

* (mg/l) unless noted otherwise



Chassahowitzka Springs Group

The Chassahowitzka Springs group is located in southwestern Citrus County approximately six miles south of the town of Homosassa Springs (Figure 16). The group, much like the Homosassa Springs group to the north, is composed of a collection of head springs and numerous smaller springs spread over an area of nearly five square miles. The Chassahowitzka River emanates mostly from the head springs but receives additional flow from several short spring runs (Baird, Salt, Crab and Potter Creeks) in its first two miles. Springs in the Chassahowitzka Springs group include Chassahowitzka Main, Chassahowitzka #1, Crab Creek, Baird, Ruth, Beteejay, and Blue Run Springs.

Discharge

The average annual discharge of the springs in the Chassahowitzka Springs group is approximately 118 mgd (134 cfs). Table 3 contains historical discharge information for most of the springs in the Chassahowitzka group.

Table 3. Discharge Information for Several Springs in the Chassahowitzka Group (12)

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN (3, 36)
Chassahowitzka River	139 below Crab Creek	81	1930-1972
Chassahowitzka Springs	92.6 below Crab Creek	1	1988
Chassahowitzka #1	30 combined discharge of all springs above Chassahowitzka Main	13	1988-1989
Crab Creek	48.7	20	1988-1989
Chassahowitzka Main *	13.3	1	1988
Baird Creek Head Spring	5.6	8	1988
Potter Creek **	18.6	14	1988-1989
Beteejay Springs ***	10.4	2	1988-1989
Blue Run Head Spring	6.6	13	1988-1989

* difference of discharge on 10-24-1988; Chassahowitzka #1 (35.7 cfs) and Crab Creek (43.6 cfs) from Chassahowitzka Springs
** includes discharge from Ruth Spring (13.3 cfs)
*** combined discharge of Beteejay Head Spring (6.4 cfs) and Beteejay Lower Spring

Water Quality

Ground water discharging at the Chassahowitzka Springs group may be fresh or brackish, depending on tides and water levels in the Floridan aquifer. At low tide, water quality varies across the spring group, with TDS concentrations increasing from less than 500 mg/l to greater than 5,000 mg/l in springs nearest the Gulf of Mexico. Chloride concentrations across the spring group may range from less than 150 mg/l

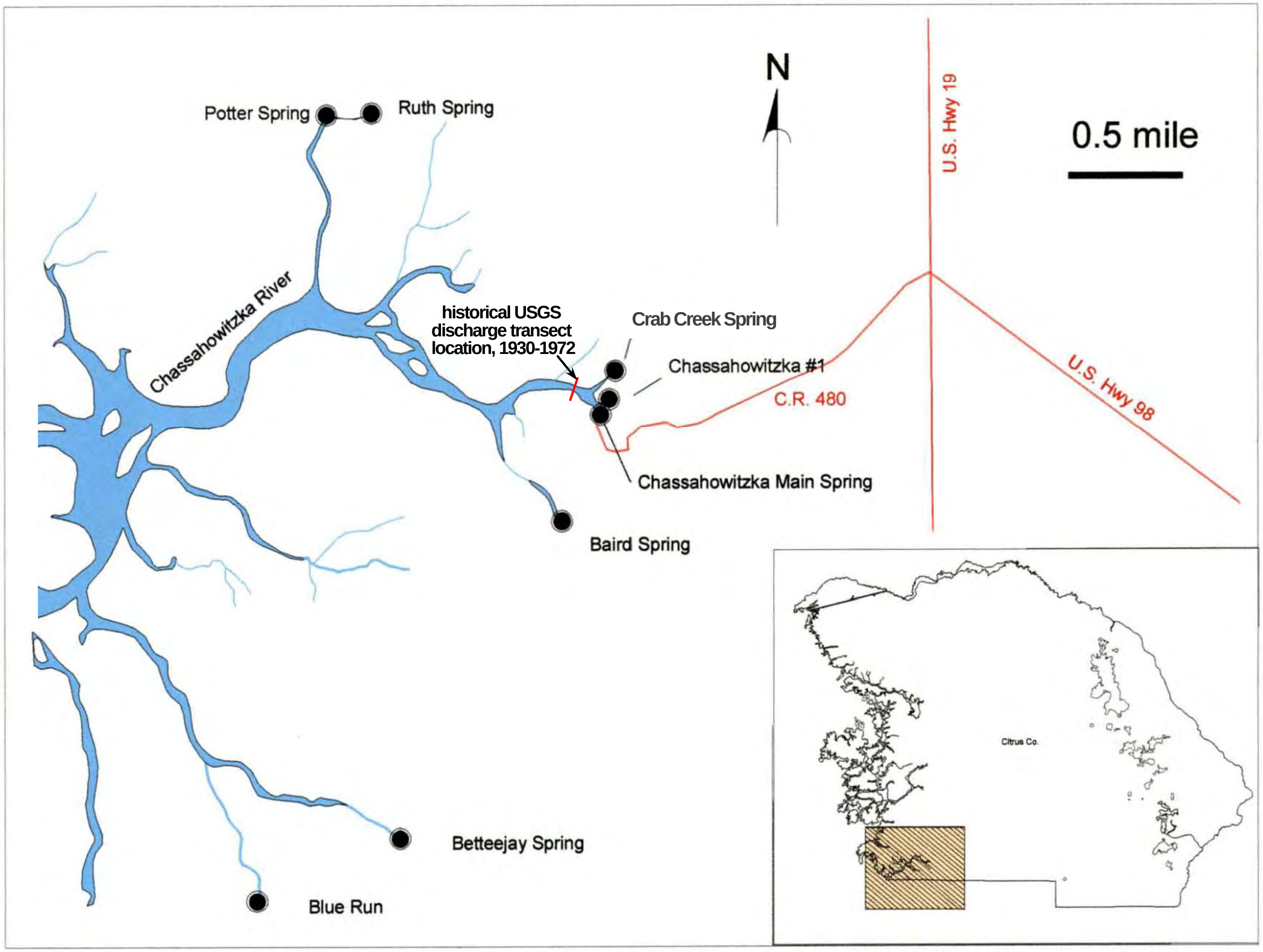


Figure 16. Location and Distribution of Springs in the Chassahowitzka Springs Group, Citrus County.

to greater than 3,000 mg/l, indicating that water quality at the springs is strongly influenced by the coastal transition zone even at low tide[(12)].

Nitrate concentrations at the Chassahowitzka Springs group are typically below 0.6 mg/l. The concentrations vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and variations in nitrate in Floridan aquifer ground water. Research conducted by the WQMP indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs[(12)].

Chassahowitzka Main

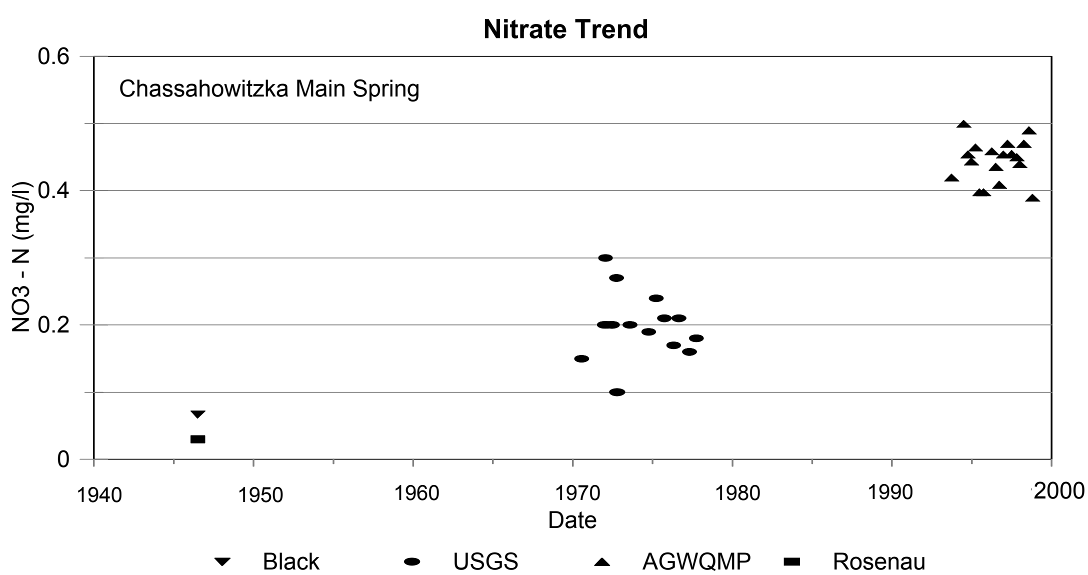
Chassahowitzka Main is located in southwestern Citrus County. The vent is situated in about 20 feet of water approximately 100 feet east of a public boat ramp. This spring contributes significantly to the flow of the Chassahowitzka River. The main pool is nearly circular, and about 150 feet in diameter. The bottom slopes gently toward the vent which is a crevice about 25 feet long and 1-2 feet wide. This spring is tidally influenced.

Statistical Summary

Latitude: 284255.441
Longitude: 823434.393
County: Citrus
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	1/21/99
Calcium	53.00
Magnesium	20.50
Sodium	117.00
Potassium	4.57
Bicarbonate	137.00
Chloride	216.00
Sulfate	37.40
Nitrate	0.25
Phosphorus	0.09
TDS	508.00
Temp. (^{O}C)	23.5
pH (s.u.)	7.51
Sp. Cond. (µS/cm)	1,040.00

* (mg/l) unless noted otherwise



Chassahowitzka #1

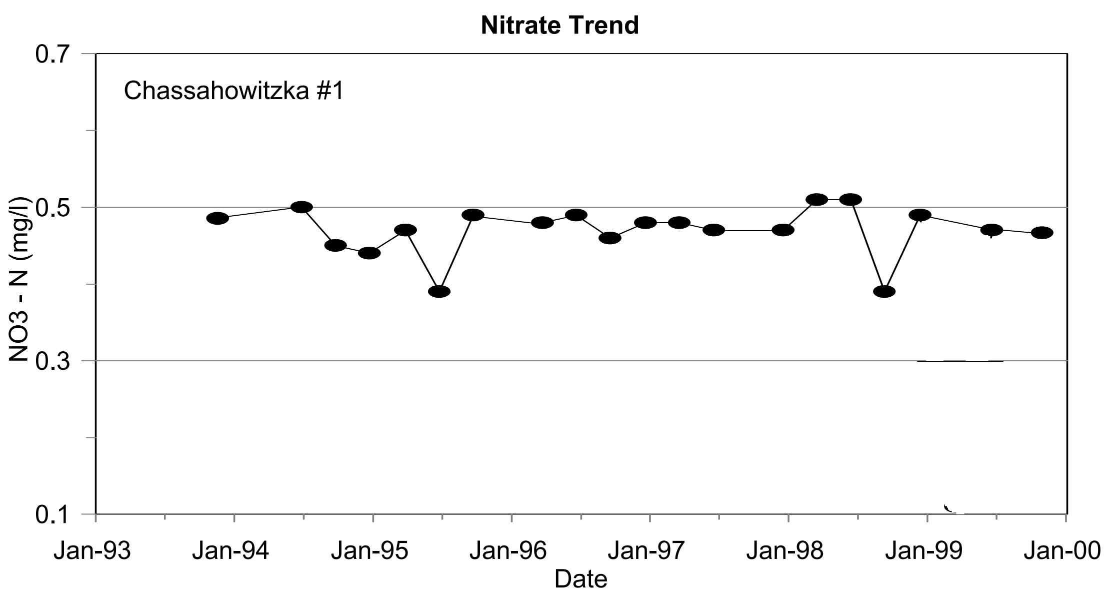
Chassahowitzka #1is located in a small tributary approximately 100 feet upstream from the main spring on the Chassahowitzka River. The vent is located between two large holes (separated by about 15 feet) formed in the limestone floor. Swimmers can often be seen diving into one hole and surfacing from the other several seconds later. The spring is tidally influenced.

Statistical Summary

Latitude: 284258.245
Longitude: 823430.346
County: Citrus
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	7/26/99
Calcium	54.60
Magnesium	19.10
Sodium	86.50
Potassium	2.96
Bicarbonate	146.00
Chloride	162.00
Sulfate	28.50
Nitrate	0.46
Phosphorus	0.02
TDS	459.00
Temp. (^{O}C)	23.40
pH (s.u.)	7.77
Sp. Cond. (µS/cm)	851.00

* (mg/l) unless noted otherwise



Crab Creek Spring

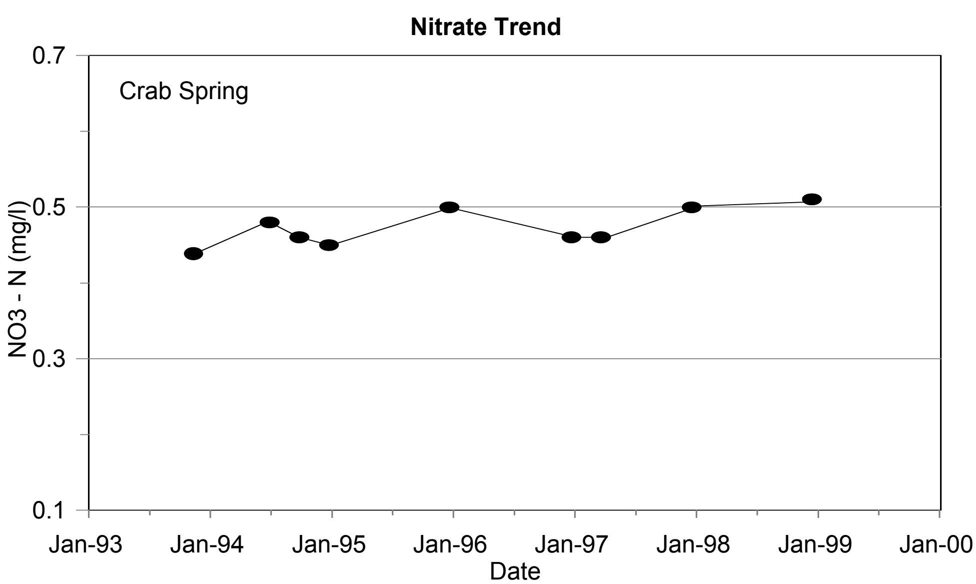
Crab Creek Spring is located about 600 feet north of the main spring area, and forms the headwaters of Crab Creek (which flows into the Chassahowitzka River just downstream from the main spring). The vent is approximately 3 feet in diameter and 15 feet deep. There are several smaller springs located along the run, one of which formed in the 1980's. This spring may be accessed by boat, and is tidally influenced.

Statistical Summary

Latitude: 284302.502
Longitude: 823433.603
County: Citrus
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	1/21/99
Calcium	80.00
Magnesium	86.30
Sodium	685.00
Potassium	27.10
Bicarbonate	145.00
Chloride	1,310.00
Sulfate	183.00
Nitrate	0.51
Phosphorus	0.04
TDS	2,316.00
Temp. (^{O}C)	23.60
pH (s.u.)	7.51
Sp. Cond. (µS/cm)	4,480.00

* (mg/l) unless noted otherwise



Baird Spring

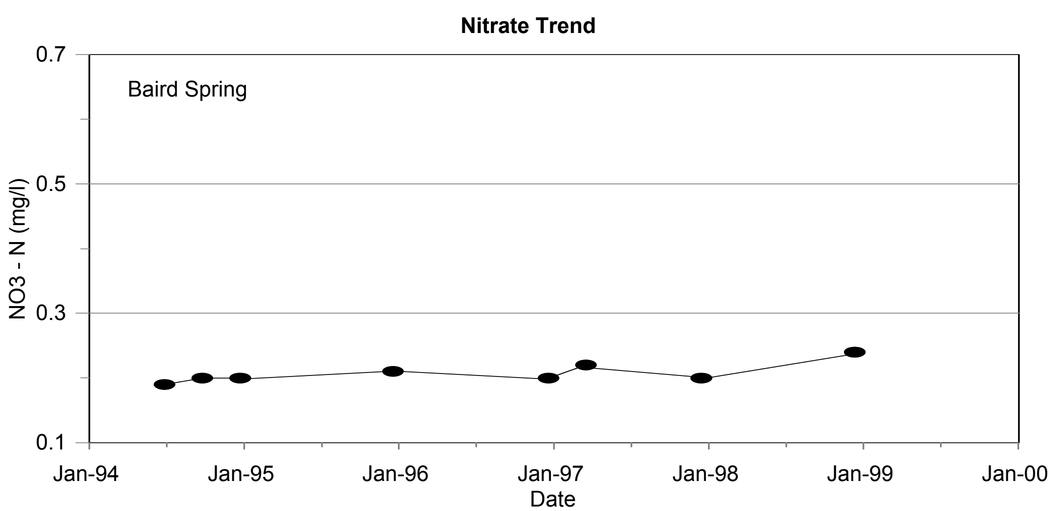
Baird Spring is located approximately 0.5 miles west of the Chassahowitzka Main Spring. The spring forms the headwaters of Baird Creek which flows northward into the Chassahowitzka River. The spring emanates from a large fracture in the limestone. The fracture is 3-5 feet wide and 20 feet in length. This spring is a popular swimming hole for locals and may be accessed by hiking or canoeing. The spring is tidally influenced.

Statistical Summary

Latitude: 284226.786
Longitude: 823441.033
County: Citrus
Basin: Coastal Rivers
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	1/21/99
Calcium	137.00
Magnesium	210.00
Sodium	1,830.00
Potassium	69.50
Bicarbonate	143.00
Chloride	3,450.00
Sulfate	462.00
Nitrate	0.24
Phosphorus	0.03
TDS	5,626.00
Temp. (^{O}C)	23.20
pH (s.u.)	7.47
Sp. Cond. (μS/cm)	10,390.00

* (mg/l) unless noted otherwise



Ruth Spring

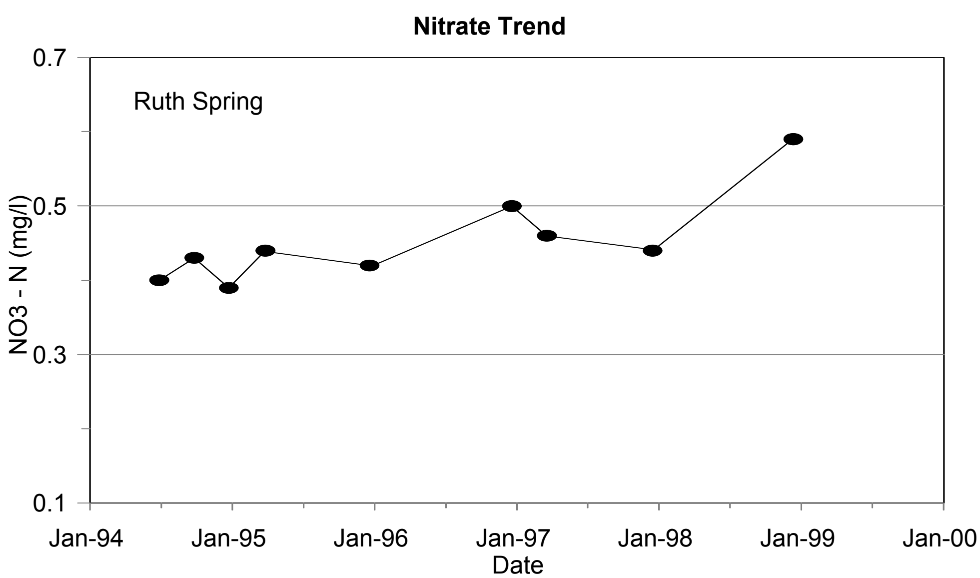
Ruth Spring is located approximately 300 feet east of Potter Creek. Ruth Spring forms a small run that feeds into Potter Creek and the vent is formed from a large fracture in the limestone approximately 10 feet deep and 2-3 feet wide. Potter Creek feeds into the Chassahowitzka River approximately 2 miles west of the main spring. This spring is tidally influenced.

Statistical Summary

Latitude: 284355.183
Longitude: 823543.869
County: Citrus
Basin: Coastal Rivers
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	1/21/99
Calcium	61.10
Magnesium	42.80
Sodium	303.00
Potassium	12.50
Bicarbonate	135.00
Chloride	564.00
Sulfate	84.60
Nitrate	0.59
Phosphorus	0.04
TDS	1,117.00
Temp. (^{O}C)	22.80
pH (s.u.)	7.52
Sp. Cond. (µS/cm)	2,200.00

* (mg/l) unless noted otherwise



Beteejay Spring

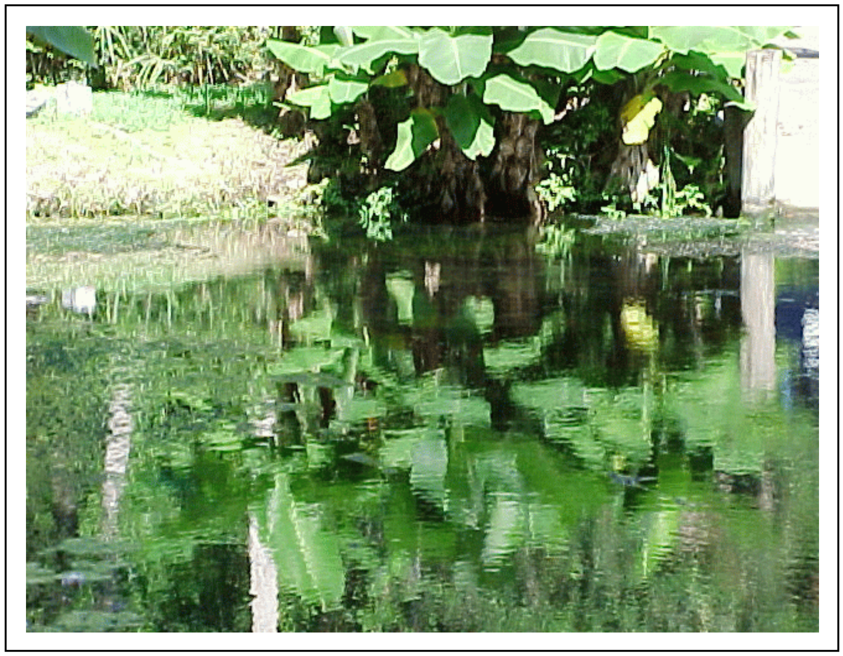
Beteejay Spring, located approximately 2.5 miles west of US 19 in northwest Hernando county, lies at the head of Crawford Creek, a small tributary of the Chassahowitzka River. The spring pool is approximately 100 feet in diameter. The spring vent discharges from the southern edge of the pool in several feet of water. The spring is tidally influenced and situated on private property.

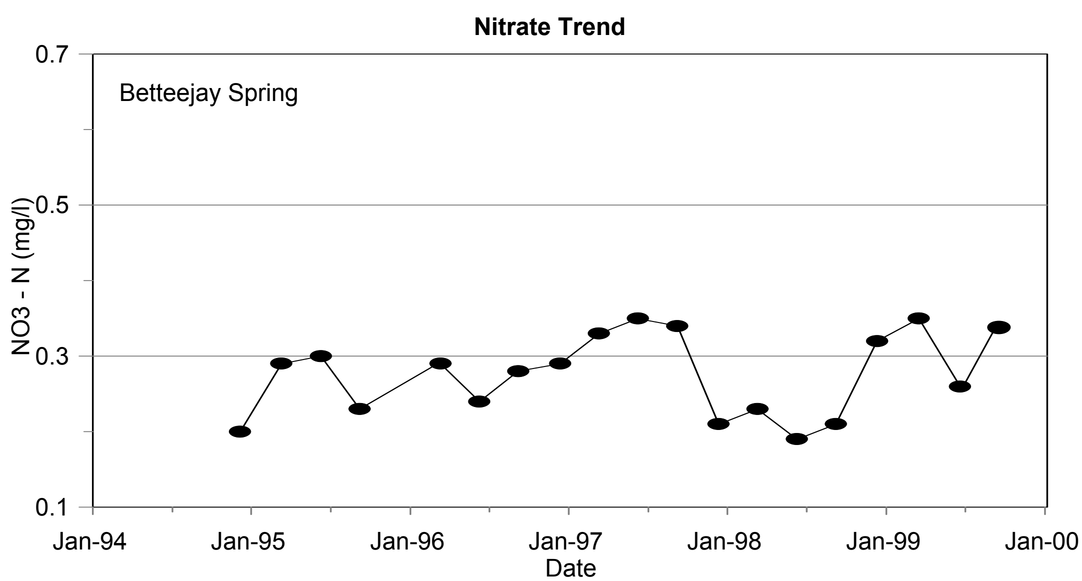
Statistical Summary

Latitude: 284125.394
Longitude: 823529.411
County: Hernando
Basin: Coastal Rivers
Period of Record: 1/95 - present

Parameter*	Value
Sample Date	7/29/99
Calcium	63.00
Magnesium	19.00
Sodium	74.50
Potassium	2.49
Bicarbonate	167.00
Chloride	142.00
Sulfate	26.00
Nitrate	0.26
Phosphorus	0.02
TDS	442.00
Temp. (^{O}C)	23.00
pH (s.u.)	7.44
Sp. Cond. (µS/cm)	821.00

* (mg/l) unless noted otherwise





Blue Run

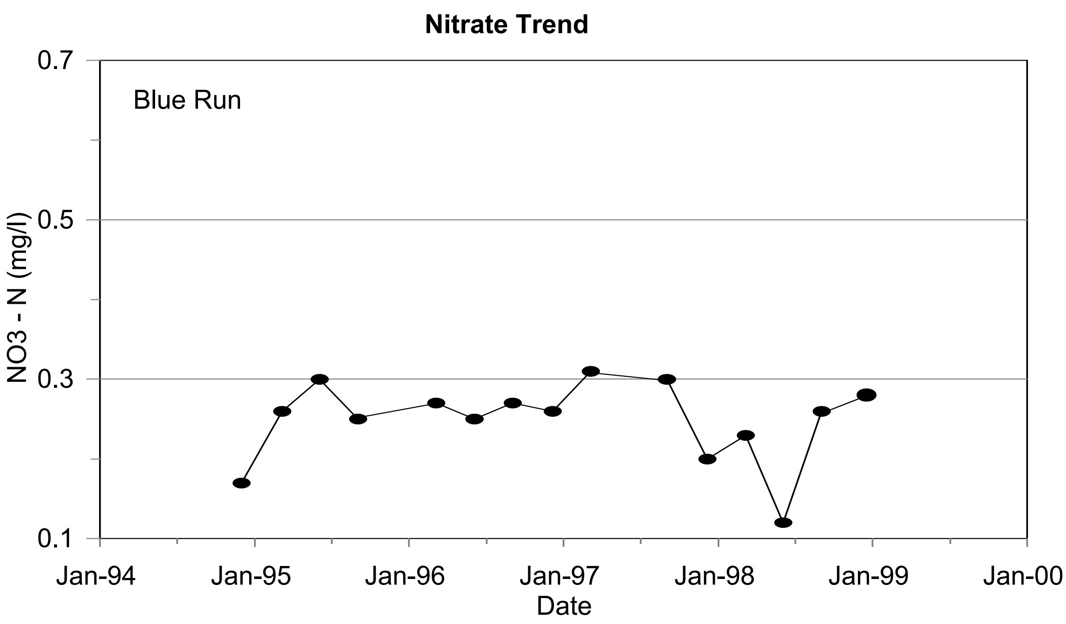
Blue Run is located on state property and may be accessed by boat from the Chassahowitzka River. Blue Run is at the head of a small tributary flowing into Crawford Creek. The vent is a fissure approximately 20 feet deep located in the upstream portion of the pool. The spring is surrounded by undisturbed Florida swampland. This spring is tidally influenced.

Statistical Summary

Latitude: 284112.502
Longitude: 823605.165
County: Hernando
Basin: Coastal Rivers
Period of Record: 1/95 - present

Parameter*	Value
Sample Date	1/18/99
Calcium	140.00
Magnesium	216.00
Sodium	1,770.00
Potassium	70.50
Bicarbonate	155.00
Chloride	3,360.00
Sulfate	470.00
Nitrate	0.28
Phosphorus	0.02
TDS	5,708.00
Temp. (^{O}C)	23.10
pH (s.u.)	7.32
Sp. Cond. (μS/cm)	10,900.00

* (mg/l) unless noted otherwise



SUMTER COUNTY

Lake Panasoffkee Springs Group

The Lake Panasoffkee Springs group is composed of numerous small springs clustered in a nine square-mile area that encompasses the southern half of Lake Panasoffkee, a 4,000 acre lake in west-central Sumter County (Figure 17). Most of the springs in the Panasoffkee group are located in and around Shady Brook, a small spring-fed creek that extends 4-5 miles from its upper reaches to Lake Panasoffkee. The average annual flow in Shady Brook is 25 mgd[73]. Most of this flow is likely derived from the Floridan aquifer as ground-water discharge. At certain times, however, flow in Shady Brook may represent surface-water runoff, or mine drainage from industrial land uses in the area. Significant springs in the Lake Panasoffkee group include: Fenney, Shady Brook Head Spring #2, Maintenance, Belton's Millpond #3, and Hwy 485 Canal Spring 1B.

Discharge

Discharge measurements, whether cumulative or individual, for springs of the Lake Panasoffkee group are limited or nonexistent. Fenney Spring lies at the head of Shady Brook and is the only known spring for which published discharge data could be located[3]. However, within the last several years, the WQMP has measured discharge at several springs in the Panasoffkee group. The discharge measurements were taken using a Marsh McBirney portable water current meter, and should be considered approximate values. Table 4 contains discharge information for the springs in the Lake Panasoffkee group.

Table 4. Discharge Information for Several Springs in the Lake Panasoffkee Group.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN[3,74]
Fenney	28.3	6	1946,1999
Shady Brook #2	5.8	1	1998
Belton's Millpond	36.5 - this is the combined discharge of five springs at Belton's Millpond.	1	1998
Canal Spring 1B	7.1 - this is the combined discharge of five springs at canal 485.	1	1998
Maintenance	0.8	2	1998-1999

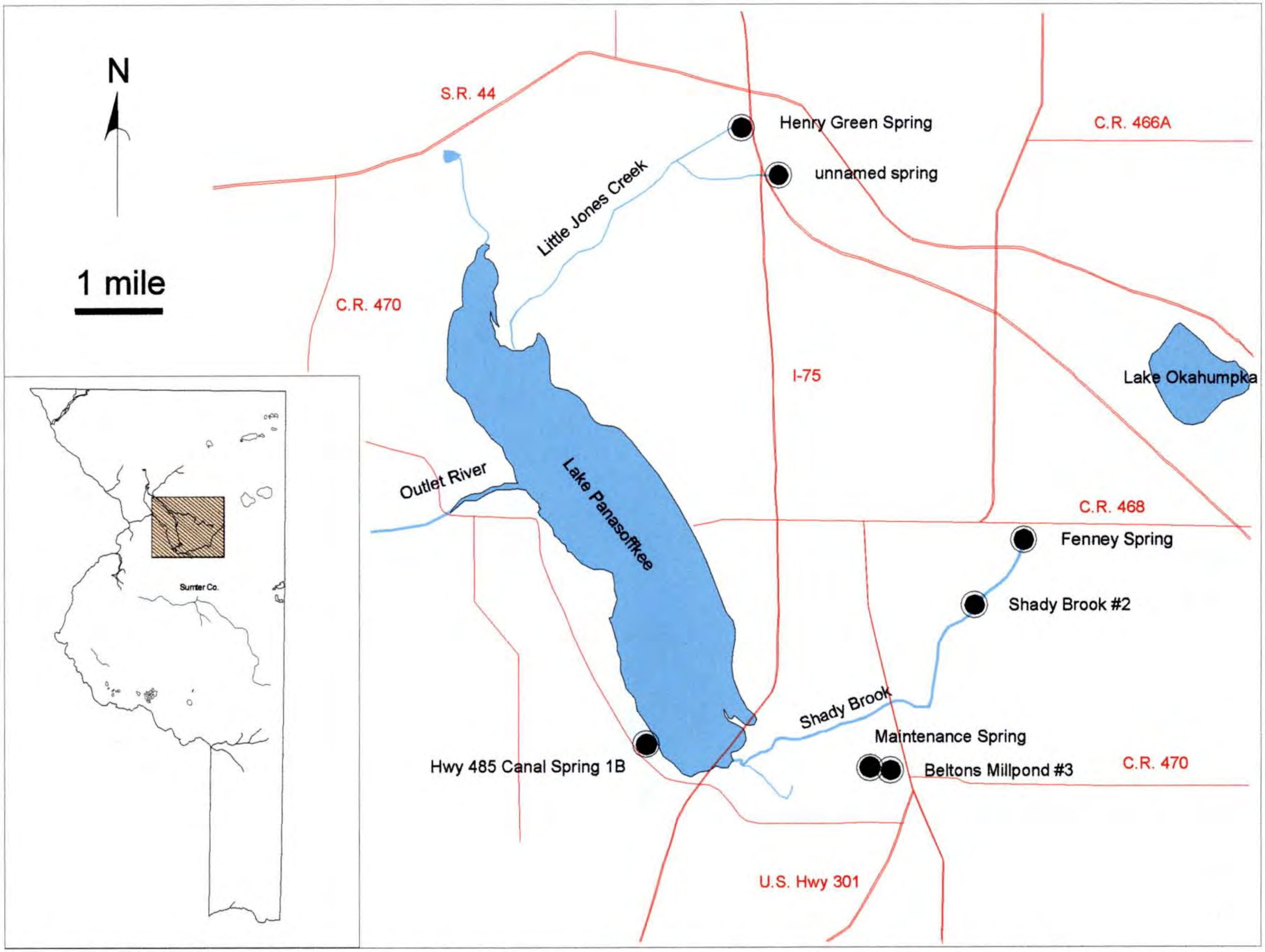


Figure 17. Location and Distribution of Springs in the Lake Panasoffkee Springs Group, Sumter County.

Water Quality

The water quality at the Lake Panasoffkee Springs group reflects the influence of sulfate upwelling along fractures in the limestone bedrock. Ground water discharging at the group is fresh and typically contains less than 350 mg/l TDS. Water quality varies slightly across the spring group with sulfate concentrations increasing from less than 10 mg/l along Shady Brook to greater than 50 mg/l in springs associated with residential canals along the southwestern shore of Lake Panasoffkee. Chloride concentrations in the spring are generally less than 10 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs(75).

Several springs in the Lake Panasoffkee Springs group have nitrate concentrations that are significantly elevated above background concentration measured in the Floridan aquifer. Nitrate concentrations vary among the individual springs of the group and are typically at or above 1 mg/l in springs associated with residential canals along the southwestern shore of Lake Panasoffkee(75).

Fenney Spring

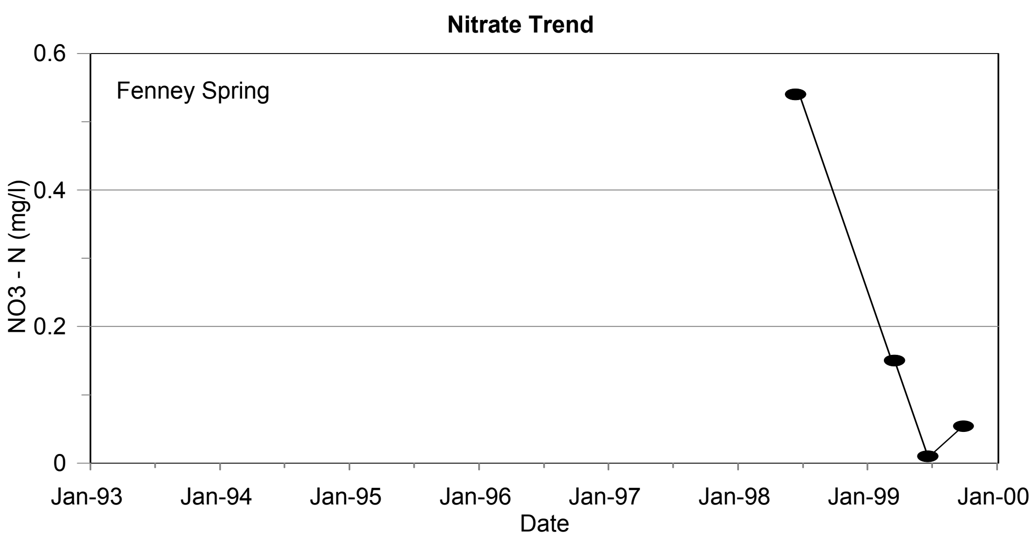
Fenney Spring, situated on private property, is located about 2 miles east of Coleman in Sumter County on Hwy 484. Fenney Spring lies at the head of Shady Brook, in a spring pool 50 feet in diameter. The spring vent is in about 25 feet of water, and after heavy rain events, may discharge tannic water, as was the case during a site visit in July 1999. The spring is surrounded by woodlands and ranch land used to pasture cattle.

Statistical Summary

Latitude: 284741.899
Longitude: 820217.115
County: Sumter
Basin: Withlacoochee
Period of Record: 6/98 - present

Parameter*	Value
Sample Date	10/19/99
Calcium	46.10
Magnesium	3.78
Sodium	7.53
Potassium	2.65
Bicarbonate	102.00
Chloride	14.30
Sulfate	2.82
Nitrate	0.055
Phosphorus	0.147
TDS	217.00
Temp. (^{O}C)	24.20
pH (s.u.)	7.00
Sp. Cond. (µS/cm)	268.00

* (mg/l) unless noted otherwise



Shady Brook Spring #2

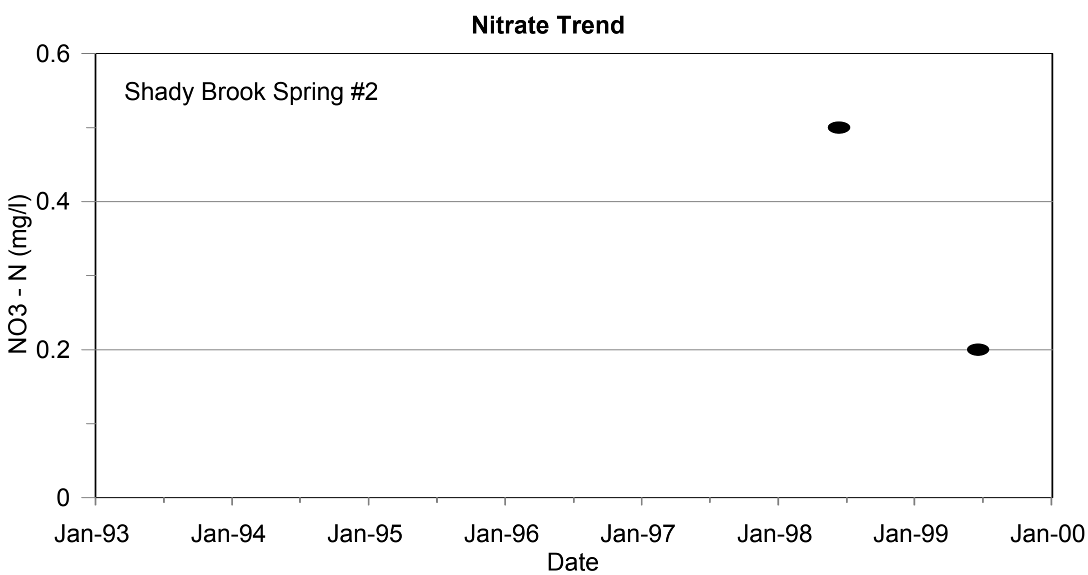
Shady Brook Spring is located in Sumter County approximately 2 miles southeast of Coleman. The spring is about one mile southwest (downstream) of Fenney Spring, and is surrounded by private property. Access to the spring is by foot traffic only. The spring pool is approximately 30 feet in diameter with a maximum depth of 10 feet. The spring produces a noticeable boil on the pool surface.

Statistical Summary

Latitude: 284708.958
Longitude: 820244.133
County: Sumter
Basin: Withlacoochee
Period of Record: 6/98 - present

Parameter*	Value
Sample Date	7/27/99
Calcium	54.70
Magnesium	2.19
Sodium	4.86
Potassium	0.51
Bicarbonate	124.00
Chloride	8.19
Sulfate	5.40
Nitrate	0.20
Phosphorus	0.08
TDS	178.00
Temp. (^{O}C)	23.90
pH (s.u.)	7.44
Sp. Cond. (µS/cm)	288.00

* (mg/l) unless noted otherwise



Maintenance Spring

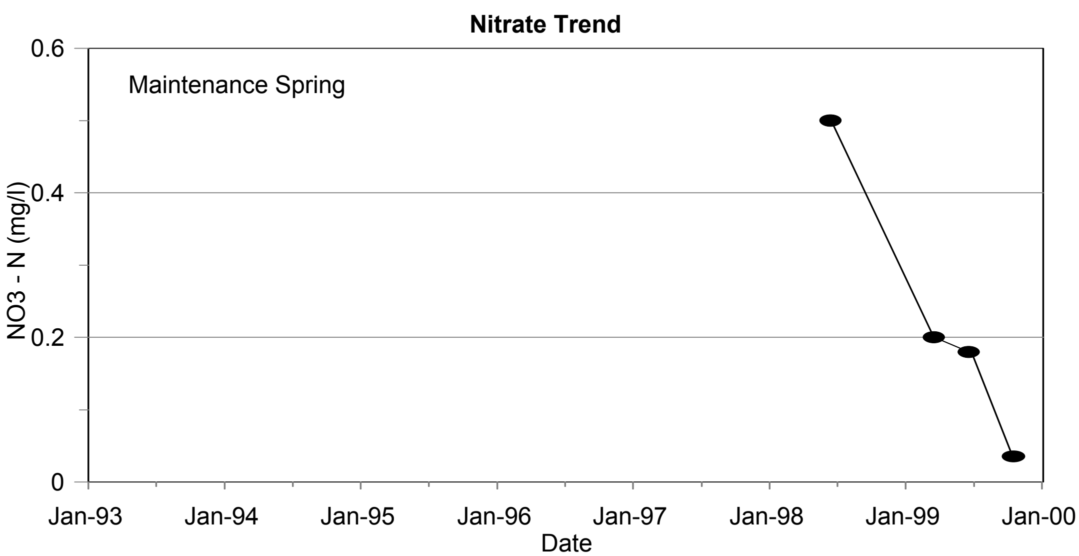
Maintenance Spring is located 1000 feet west of the Beltons Millpond at the Shady Brook Golf Course and R.V. Resort. The pool has been artificially enlarged and is approximately 150 feet in diameter with an average depth of 6 feet. The vent is 3 feet below the surface of the pool and 2 feet in diameter. The area surrounding the vent is covered with eel grass. A small boil is visible at the surface above the vent. Water in the spring pool flows into a 24-inch diameter culvert located in the northwest corner of the pool, and eventually into Shady Brook. The spring is situated on private property.

Statistical Summary

Latitude: 284524.394
Longitude: 820405.364
County: Sumter
Basin: Withlacoochee
Period of Record: 6/98 -present

Parameter*	Value
Sample Date	7/19/99
Calcium	79.70
Magnesium	2.92
Sodium	4.27
Potassium	0.14
Bicarbonate	193.00
Chloride	7.74
Sulfate	9.58
Nitrate	0.18
Phosphorus	0.05
TDS	242.00
Temp. (^{O}C)	25.30
pH (s.u.)	7.23
Sp. Cond. (µS/cm)	427.00

* (mg/l) unless noted otherwise



Beltons Millpond #3

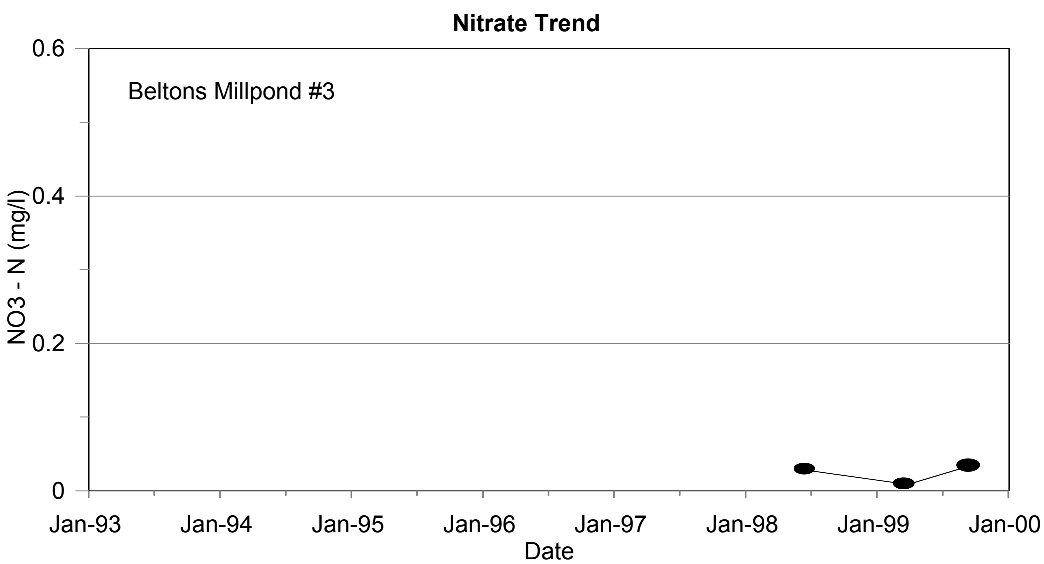
Beltons Millpond #3 is located in the Shady Brook Golf Course and R.V. park approximately 3 miles south of Coleman. The spring pool is heavily vegetated. The spring vent is a 15-foot long and 2-foot wide vertical fracture in the limestone bedrock. The fracture trends in a northeast-southwest direction, and the depth varies from 8 to 12 feet. The spring discharge produces the largest and most visible boil in the Belton's Millpond Group. The spring is situated on private property.

Statistical Summary

Latitude: 284529.672
Longitude: 820345.305
County: Sumter
Basin: Withlacoochee
Period of Record: 6/98 - present

Parameter*	Value
Sample Date	4/19/99
Calcium	79.10
Magnesium	2.09
Sodium	4.79
Potassium	0.21
Bicarbonate	194.00
Chloride	7.90
Sulfate	4.45
Nitrate	-0.01
Phosphorus	0.07
TDS	325.00
Temp. (^{O}C)	21.20
pH (s.u.)	6.91
Sp. Cond. (μS/cm)	425.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



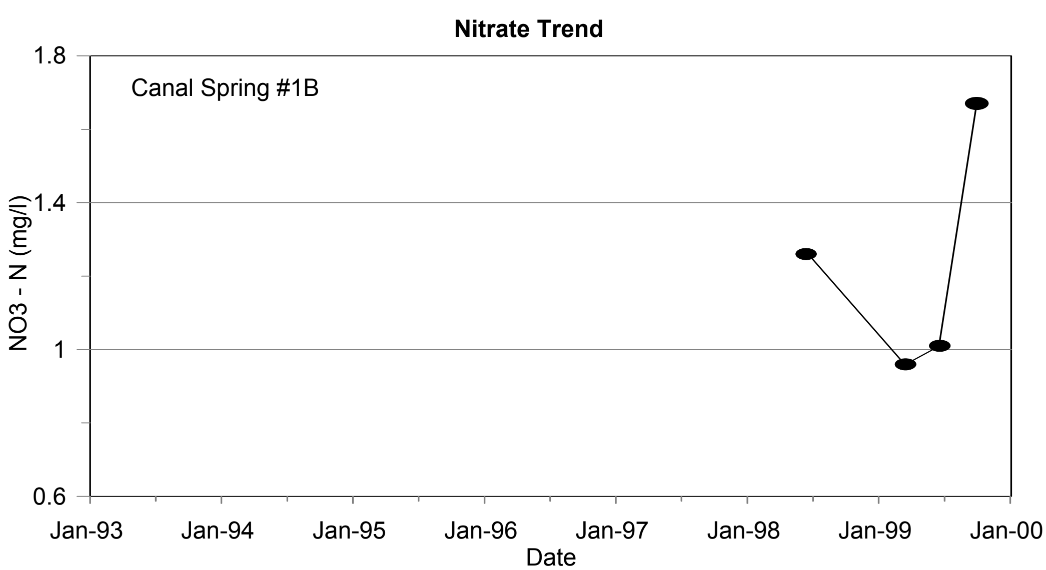
Canal Spring #1B

Canal Spring #1B is located in the southwest corner of Lake Panasoffkee near C.R. 485 and C.R. 485A off County Hwy 470. Spring #1B is composed of two vents on the bottom of the canal channel. Both vents are 2 feet in diameter and are 4 feet apart. One vent is 5 feet deep and the other is slightly deeper at 8 feet. Spring #1B produces a visible boil at the surface of the water. Another spring, Canal Spring #1A, is located 10 feet north of #1B.

Statistical Summary

Latitude: 284610.603
Longitude: 820704.804
County: Sumter
Basin: Withlacoochee
Period of Record: 6/98 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	59.30
Magnesium	4.41
Sodium	3.44
Potassium	0.14
Bicarbonate	102.00
Chloride	7.08
Sulfate	53.50



Gum Slough Springs Group

Located along the Marion/Sumter County line, the Gum Slough Springs are located four miles northeast of the Withlacoochee River, and six miles west of Interstate 75 (Figure 18). The springs lie in a largely undeveloped area, and are surrounded by numerous wetlands and swamps. A moderate amount of residential development lies five miles to the northeast of the springs toward C.R. 484 in Marion County. Wilson Head Spring, located approximately five miles to the west of the Gum Slough Springs, is included in the Gum Slough group due to its close proximity to the springs group. The following paragraphs were taken from a description given by the USGS in 1977[(3)].

"This group of springs reportedly consists of at least seven individual springs distributed from the head of Gum Slough to less than 0.8 mi downstream. The slough is a 4-mi long run that flows southwest through thick semi-tropical swamp forest to discharge into the Withlacoochee River. The springs issue from vents between 10 and 20 ft deep in the bottom of individual pools or in the bed of Gum Slough. Except for the vents from which the springs issue, the pools are 2 to 6 ft deep. The spring run is mostly 1 to about 3 ft deep. Except for a cottage at one of the springs, the owner of the land surrounding the springs has maintained the area in virtually its natural condition for the protection of its wildlife, and calls it 'Seven Springs Wildlife Refuge.'

Only six springs were found and identified on June 13, 1972. For ease of description, they are numbered 1 through 6. Three of the six springs, numbers 1, 2 and 3 in downstream order from north to south, form individual pools within 800 ft of each other aligned northeast to southwest, and together comprise the headwaters of Gum Slough. Flow from the three pools converge westerly down separate short runs to form the southwest-flowing Gum Slough. Three other springs (4,5, and 6 in downstream order) are within about 1,000 ft of each other in the channel of Gum Slough, about 0.6 to 0.8 mi downstream from the confluence of springs 1-3."

Wilson Head Spring

"The spring pool is about 100 ft in diameter in a semitropical, hardwood swamp forest about 0.25 mi N. of the Withlacoochee River. The pool has been artificially enlarged and is enclosed by an earthen dike with a 5-ft wide outlet on its northeast side. The water level in the pool is controlled by a stoplog gate in the outlet. On June 5, 1972, the pool water level was about 2 ft below the top of the dike. The pool is apparently deepest- 8 to 10 ft- in its west-central part. Most of the inflow to the pools seems to come from an inconspicuous opening in the limestone floor of the deepest part of the pool. A slight boil was evident at the surface and a small sand boil was observed nearby on the floor of the pool. From the spring pool water flows about 50 ft eastward then about 0.25 mi S. down a small run to the Withlacoochee River."

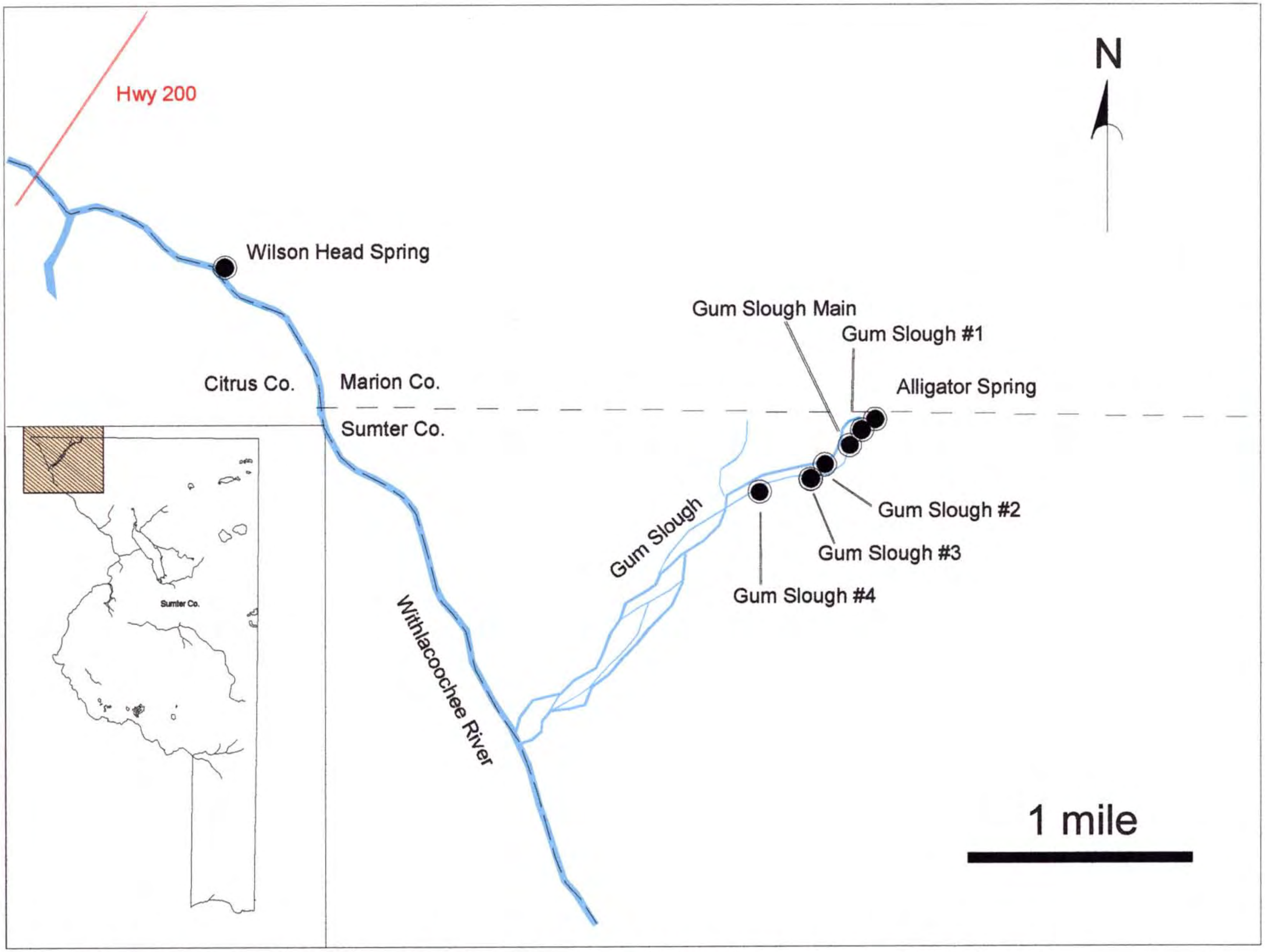


Figure 18. Location and Distribution of Springs in the Gum Slough Springs Group, Sumter County.

Discharge

Discharge measurements, whether cumulative or individual, for springs of the Gum Slough group are limited or nonexistent. Only one discharge measurement for Wilson Head and two cumulative flows for Gum Slough were published by the USGS in the 1970's[3]. However, within the last several years, the WQMP has measured discharge at several springs in the group. The discharge measurements were taken using a Marsh McBirney portable water current meter, and should be considered approximate discharge values. Table 5 contains discharge information for the springs in the Gum Slough group.

Table 5. Discharge Information for Several Springs in the Gum Slough Group.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN[3,74]
Alligator	5.2	3	1999
Gum Slough #1	8.6	3	1999
Gum Slough	42.4 - this is the combined discharge of all springs along Gum Slough.	5	1932,1999
Wilson Head	3.0	3	1972,1999

Water Quality

The water quality at the Gum Slough Springs group has not been extensively studied by WQMP staff. However, cursory review of water-quality data suggests that ground water discharging from the group is influenced by sulfate upwelling along fractures in the limestone bedrock. Ground water discharging at the group is fresh and typically contains less than 250 mg/l TDS[69]. Water quality varies slightly across the spring group with sulfate concentrations increasing from 10 mg/l to greater than 40 mg/l near the main spring. Chloride concentrations in the springs are generally less than 10 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs.

Nitrate concentrations at the Gum Slough group are significantly elevated above background concentration measured in the Floridan aquifer. The concentrations vary among the individual springs of the group, however, are typically around 1 mg/l. Research to determine the source of the nitrate discharging at Gum Slough Springs has not been conducted by the WQMP. However, nitrogen-isotope samples collected in April, 2000 indicate that the springs may be affected by the use of inorganic fertilizers near the springs.[74]

Alligator Spring

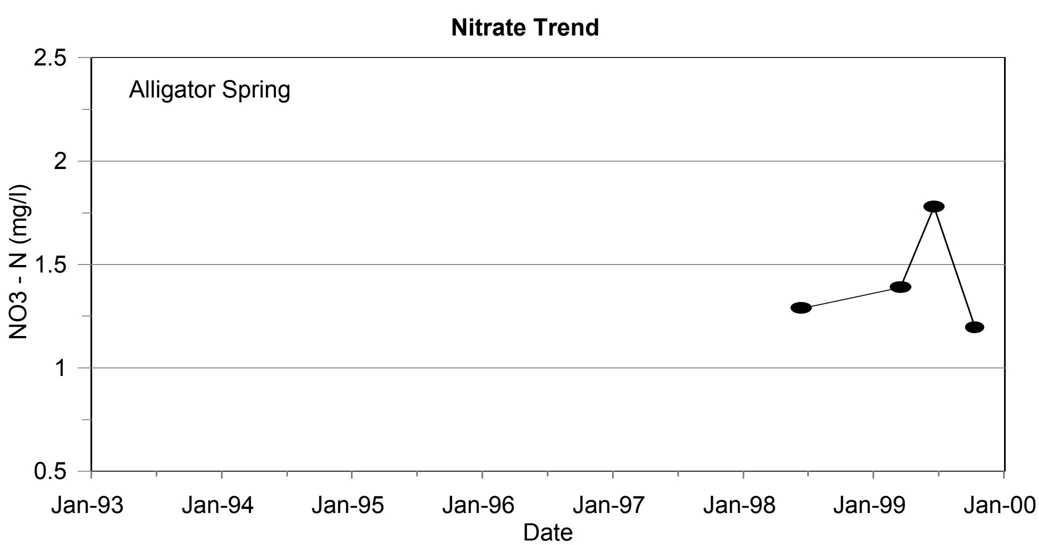
Alligator Spring (Gum Spring 01A) is located in dense swamp woods on the Marion - Sumter County line. The spring pool is about 50 feet in diameter. The edge of the vent is about 6 feet from the pool surface and is 20 feet in diameter. Spring flow emanates from under a rock ledge on the north side and near the bottom of a circular vent in the central part of the pool. The run, which is the uppermost reach of Gum Slough, bends southwest about 500 feet. There is a large 10-foot alligator that lies at the bottom of the pool, and has been there every time the spring has been visited for sampling.

Statistical Summary

Latitude: 285736.817
Longitude: 821345.676
County: Sumter
Basin: Withlacoochee
Period of Record: 3/99 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	53.40
Magnesium	7.26
Sodium	3.58
Potassium	0.11
Bicarbonate	110.00
Chloride	5.99
Sulfate	40.80
Nitrate	1.39
Phosphorus	0.03
TDS	195.00
Temp. (^{O}C)	23.50
pH (s.u.)	7.66
Sp. Cond. (µS/cm)	335.00

* (mg/l) unless noted otherwise



Gum Spring Main

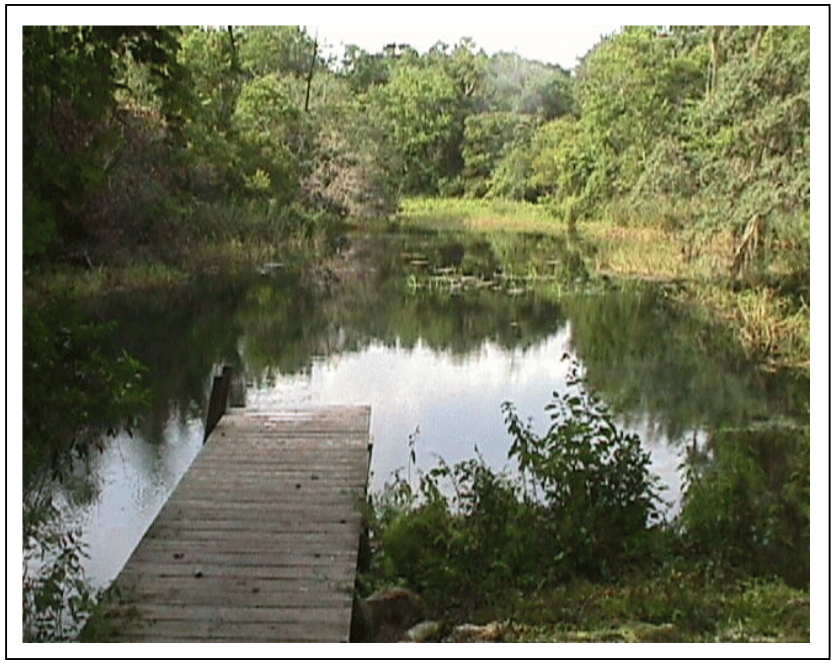
Gum Spring Main is surrounded by private property and is posted for no trespassing. The spring pool is approximately 80 feet in diameter. Flow emanates from a circular rock vent in the central part of the pool. The vent is about 25 feet in diameter at the top edge, which is at a depth of 5 feet, and funnels down to a depth of 13 feet below the pool surface. The owner of the land surrounding the spring has maintained the natural condition of the area for the protection of wildlife, and calls it " Seven Springs Wildlife Refuge."

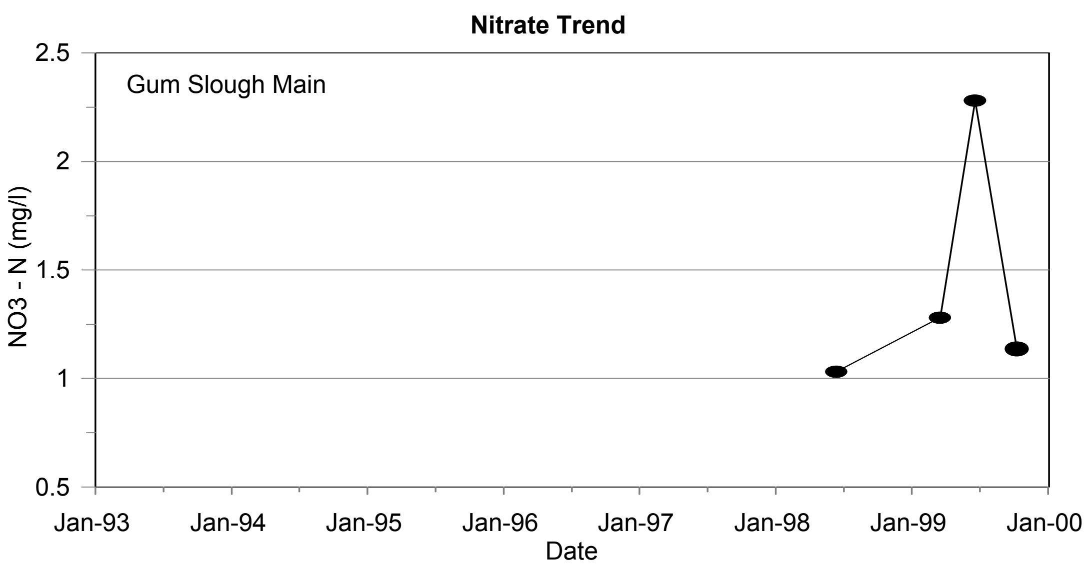
Statistical Summary

Latitude: 285731.391
Longitude: 821353.476
County: Sumter
Basin: Withlacoochee
Period of Record: 7/98 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	51.80
Magnesium	6.91
Sodium	3.42
Potassium	0.09
Bicarbonate	112.00
Chloride	5.78
Sulfate	33.90
Nitrate	2.28
Phosphorus	0.03
TDS	182.00
Temp. (^{O}C)	23.40
pH (s.u.)	7.67
Sp. Cond. (µS/cm)	323.00

* (mg/l) unless noted otherwise





Gum Slough #1

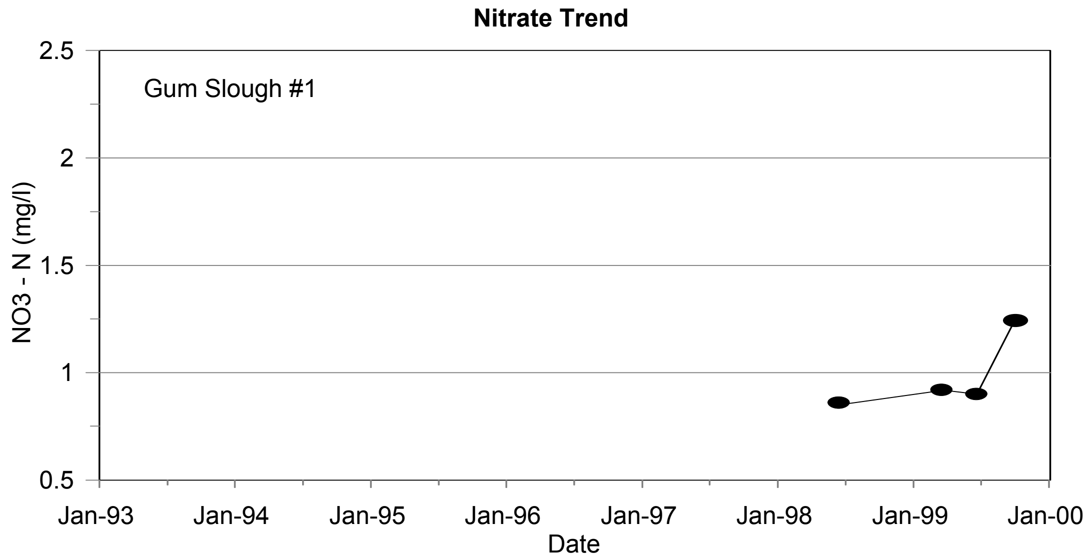
Gum Slough #1 is located approximately 300 feet northeast of Gum Spring Main. It has an irregular shaped pool about 20 feet in diameter and is located in an open, grassy, wooded area. Surrounding land types include swamp forest to the northwest and higher, flat terrain which is sparsely pine-wooded to the southeast. The pool is about 40 feet in diameter, and the vent is approximately 15 feet in diameter at its top, which is about 3 feet below the pool surface.

Statistical Summary

Latitude: 285733.485
Longitude: 821350.825
County: Sumter
Basin: Withlacoochee
Period of Record: 7/98 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	49.70
Magnesium	6.30
Sodium	3.19
Potassium	0.05
Bicarbonate	120.00
Chloride	5.60
Sulfate	19.70
Nitrate	0.90
Phosphorus	0.03
TDS	171.00
Temp. (^{O}C)	23.60
pH (s.u.)	7.64
Sp. Cond. (µS/cm)	328.00

* (mg/l) unless noted otherwise



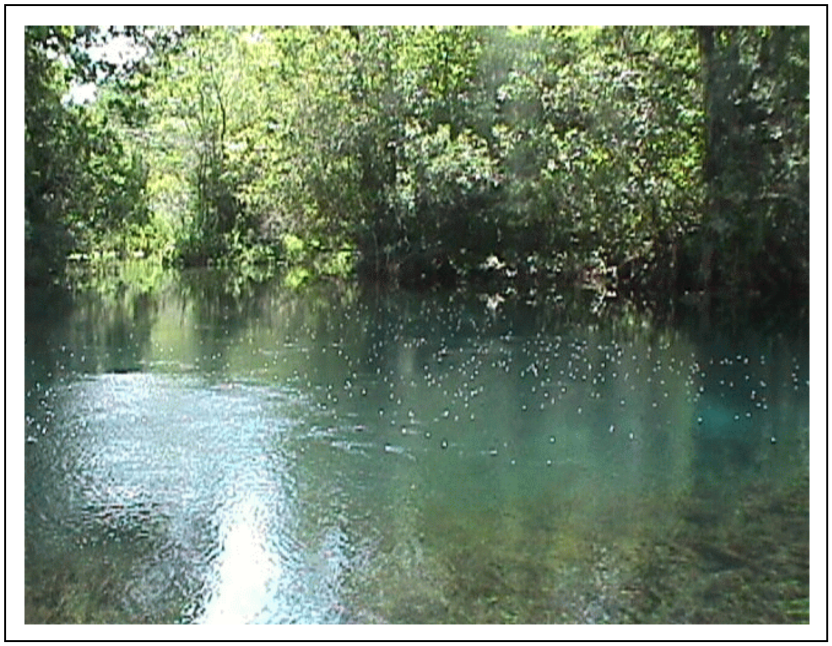
Gum Slough #2

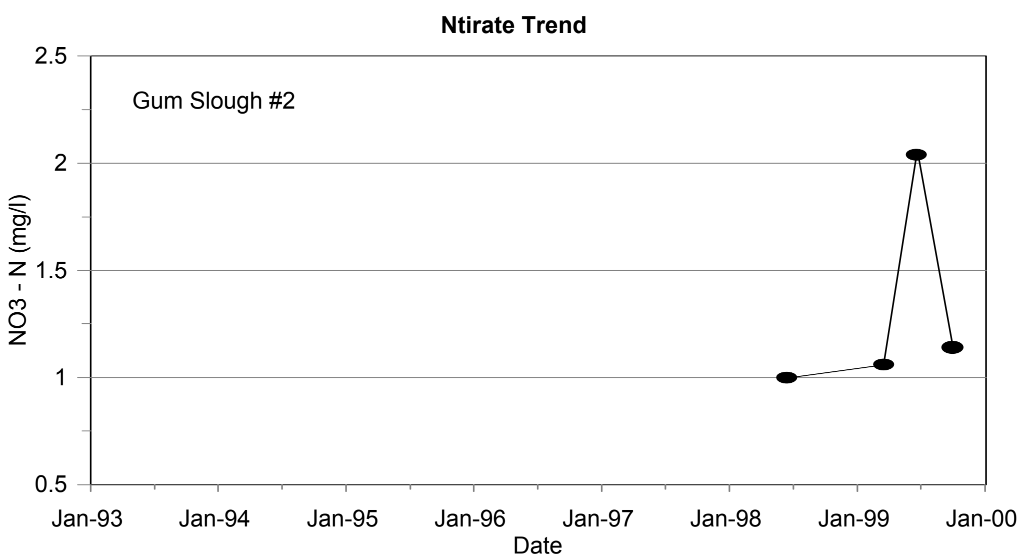
Gum Slough #2 is located approximately 0.5 miles downstream from Gum Spring. The vent is approximately 30 feet in diameter with a maximum depth of 17 feet. A slight boil is visible at the water surface above the vent. The spring vent is located on the north side of the spring run, and there is a small island that borders the south side of the spring. Gum Slough #2 and Gum Slough #3 are less than 100 yards apart from each other. The owners of the property have named the spring "Blue Hole."

Statistical Summary

Latitude: 285713.837
Longitude: 821412.692
County: Sumter
Basin: Withlacoochee
Period of Record: 7/98 - present

Parameter*	Value
Sample Date	7/21/99
Calcium	52.60
Magnesium	7.00
Sodium	3.51
Potassium	0.12
Bicarbonate	111.00
Chloride	5.88
Sulfate	37.10





Wilson Head

Wilson Head is located about 20 miles south of Ocala off State Hwy 200 on private property. The spring pool is about 100 feet in diameter in a semitropical hardwood swamp forest about 0.25 miles north of the Withlacoochee River. The pool has been artificially enlarged and is enclosed by an earthen dike with a 5-foot wide outlet on the northeast side. The pool water level is about 3 feet below the top of the dike. The pool is approximately 10 feet deep in the west central part of the spring. A slight boil is evident at the surface. Spring flow discharges to the Withlacoochee River via a short spring run.

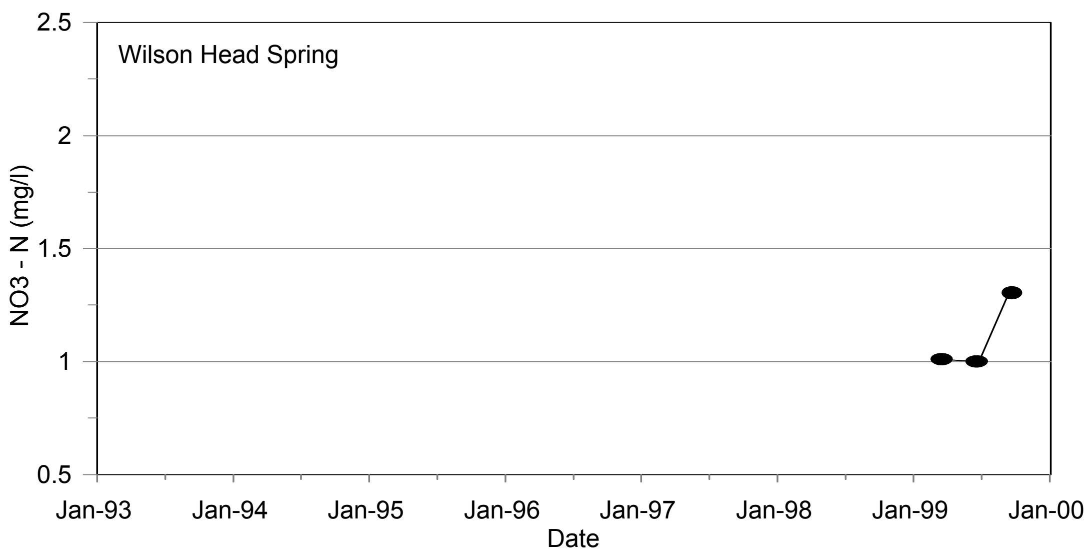
Statistical Summary

Latitude: 285847.232
Longitude: 821916.138
County: Marion
Basin: Withlacoochee
Period of Record: 4/99 -present

Parameter*	Value
Sample Date	7/20/99
Calcium	70.90
Magnesium	1.95
Sodium	2.87
Potassium	0.08
Bicarbonate	163.00
Chloride	6.26
Sulfate	12.40
Nitrate	1.00
Phosphorus	0.08
TDS	212.00
Temp. (^{O}C)	23.30
pH (s.u.)	7.40
Sp. Cond. (µS/cm)	375.00

* (mg/l) unless noted otherwise

Nitrate Trend



HERNANDO COUNTY

Weeki Wachee Springs Group

The Weeki Wachee Springs group lies in western Hernando County, eleven miles southwest of the City of Brooksville, and is composed of a single, large main spring and numerous smaller springs spread over an are of nearly five square miles (Figure 19). The spring is a popular tourist attraction and features mermaid shows and water-ride attractions. The spring lies approximately 500 feet southwest of the U.S. Hwy 19 and S.R. 50 intersection.

Springs in the Weeki Wachee group include Weeki Wachee Main, Salt, and Jenkins Springs. The Weeki Wachee River originates at the main spring and flows westward for approximately five miles before emptying into the Gulf of Mexico. The river receives additional flow from Twin Dees, Salt, and Mud Springs as well as numerous additional small springs.

<u>Discharge</u>

The average discharge of the springs in the Weeki Wachee Springs group is approximately 164 mgd. Table 6 contains discharge information for the springs in the Weeki Wachee group.

Table 6. Discharge Information for Several Springs in the Weeki Wachee Group[12].

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN[3,36]
Weeki Wachee Main	165.0*	364	1917-1974
Twin Dees	11.0	2	1972-1975
Salt	33.0	34	1988-1989
Mud River	45.0	5	1988-1989

*Includes the discharge of Twin Dees.

Figure 4 depicts the mean monthly discharge between 1917 and 1998 at Weeki Wachee Main Spring. Much like Rainbow Springs and other springs throughout the SWFWMD, discharge at Weeki Wachee Main Springs exhibits significant seasonality, reaching a minimum at the end of the dry season in May and peaking in October, after the end of the summer wet season. This pattern indicates that the lag time between seasonal changes in rainfall and the response of the spring system is minimal. The pattern also indicates that the circulation of ground water in the Floridan aquifer is open and vigorous and that the springs are recharged by precipitation falling in close proximity (5 - 10 mile radius) of the springs.

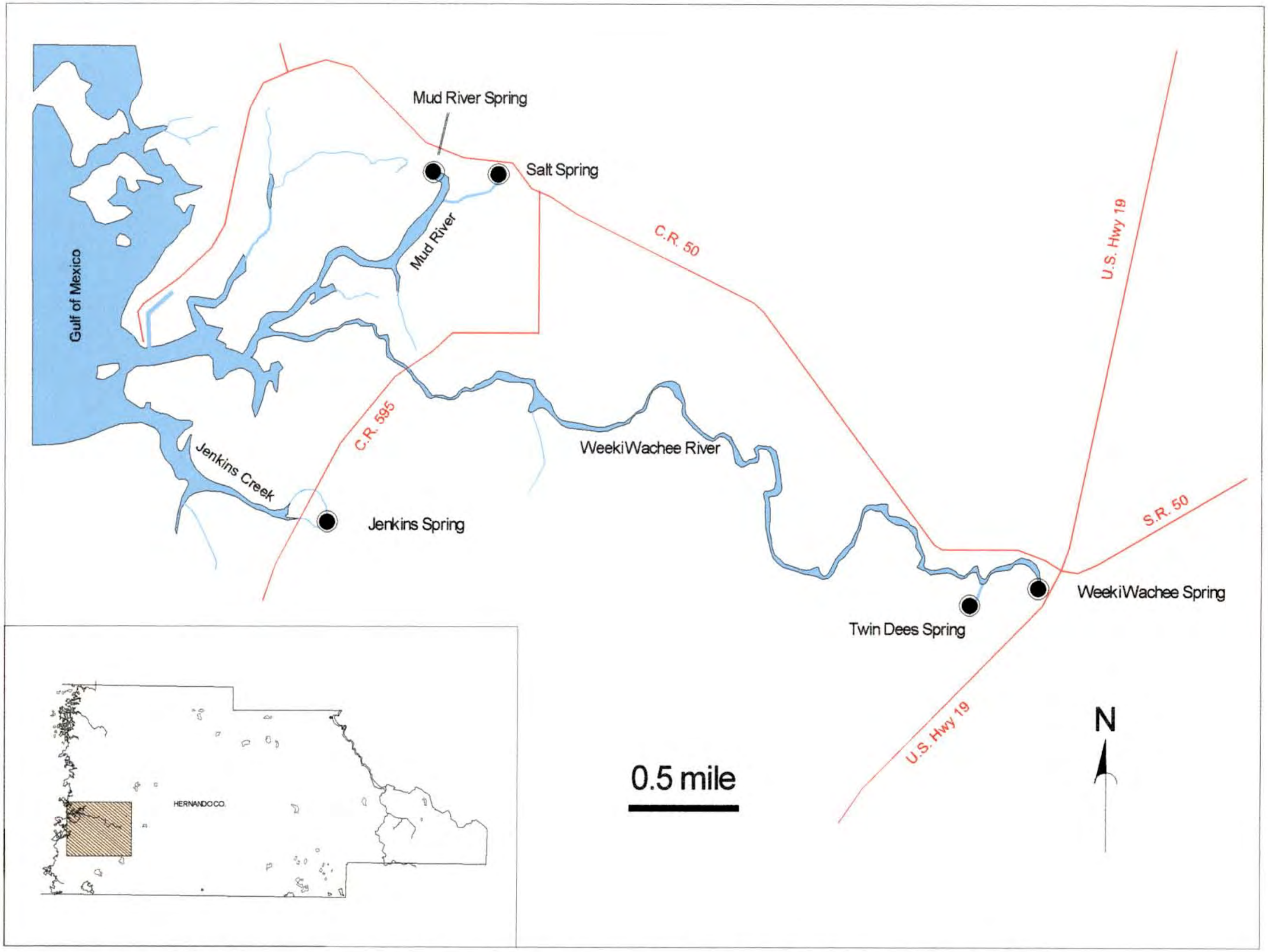


Figure 19. Location and Distribution of Springs in the Weeki Wachee Springs Group, Hernando County.

Water Quality

Ground water discharging at the Weeki Wachee Springs group is fresh inland of the transition zone and brackish closer to the Gulf of Mexico. Water quality varies across the spring group with TDS concentrations increasing from less than 200 mg/l at the main spring to greater than 12,000 mg/l in springs near the Gulf. Chloride concentrations in the springs may range from less than 10 mg/l to greater than 7,000 mg/l, indicating that water quality at the spring group is influenced by the coastal transition zone[(12)].

Nitrate concentrations at the Weeki Wachee Springs group are typically below 0.8 mg/l. The concentrations vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and differences in nitrate within the Floridan aquifer. Research conducted by the WQMP indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs[(12)].

Cavern Features

Main Spring

Weeki Wachee Main Spring forms a large spring pool that is circular in shape, nearly 150 ft in diameter, and 10 feet deep where the main vent begins. The vent is a north-south trending, vertical fracture that narrows progressively to a depth of approximately 185 feet. At this point, the fracture is 20 feet long and only 3 feet wide.

The force of the entire flow of the spring passing the constriction creates a nearly impenetrable barrier to divers. However, on several occasions in 1980, groups of divers passed the constriction with great difficulty. The end of the fracture opened into the ceiling of a large room. The top of a debris cone was discovered approximately 20 feet below the opening in the ceiling at a depth of 205 feet. Exploration revealed passages exiting both ends of the room[(76,77)].

According to divers, the conduits appeared to convey water away from the fracture leading to Weeki Wachee Spring. One of the passages seemed to be flowing very strongly which led divers to conclude that more water was flowing through the large room than was exiting through the fracture to Weeki Wachee Spring. After several dives, an inflowing conduit could not be located[(77)].

Twin Dees

Twin Dees, also known as Little Spring, is located approximately 3,000 feet southwest of the main spring. The spring pool is 25 feet in diameter and water enters the pool through a vertical shaft that is just wide enough for a diver to enter the cave system 50 feet below. Another shaft is present in the pool, but is apparently plugged. Water discharging from the spring flows through a marsh for approximately 0.2 miles to the Weeki Wachee River.

An extensive cave system is accessible through Twin Dees Spring (Figure 20). Since June of 1995, an intensive effort to explore and map the cave system has been undertaken by Karst Underwater Research (KUR); an organization of research divers. Currently, KUR has surveyed 2,500 feet from the entrance to depths of 300 feet and have discovered large chambers and wide, extensive passageways. A large tunnel at the end of the survey indicates that the system could be much more extensive[78].

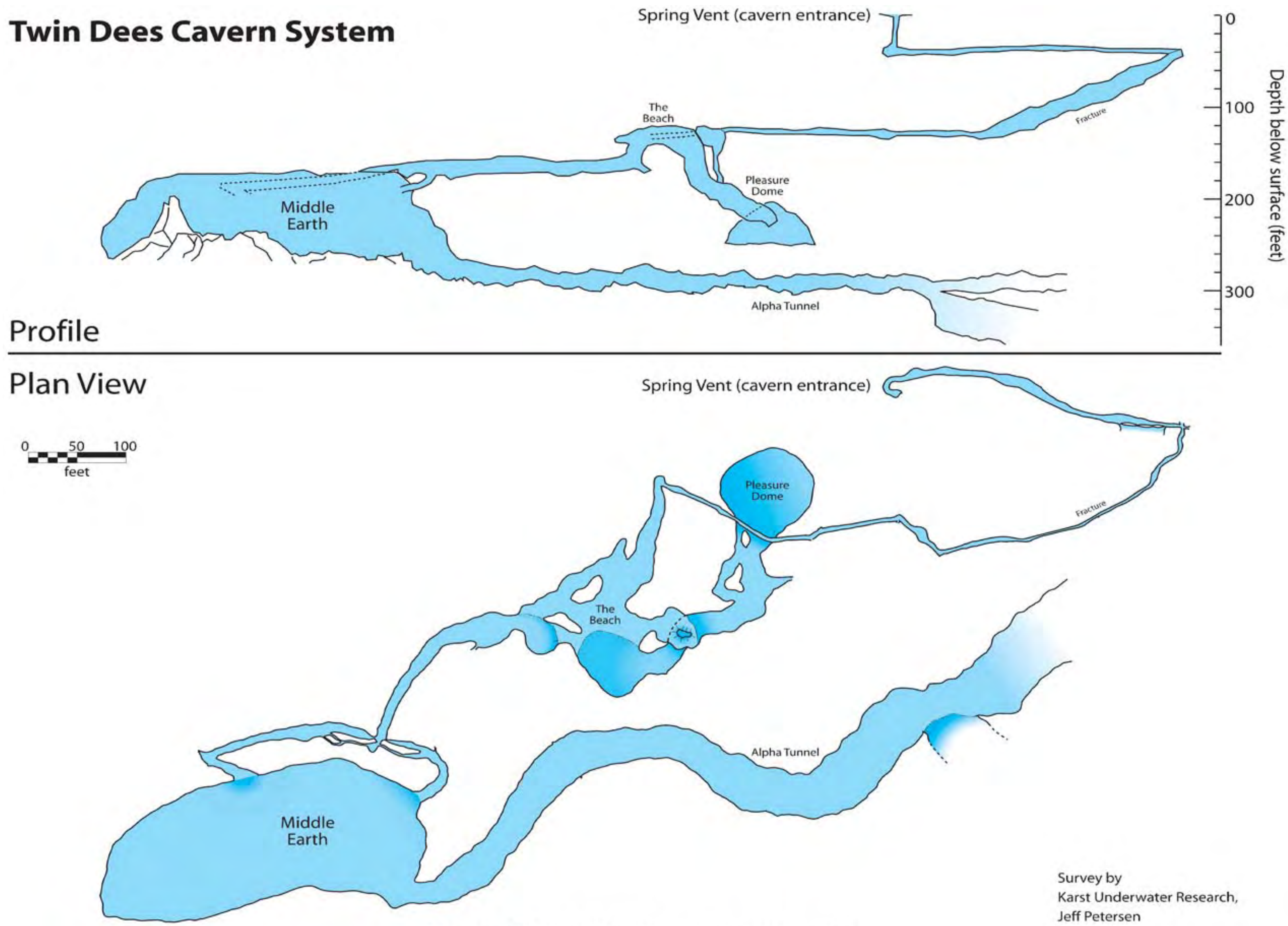


Figure 20. The Twin Dees Cavern System

Weeki Wachee Main Spring

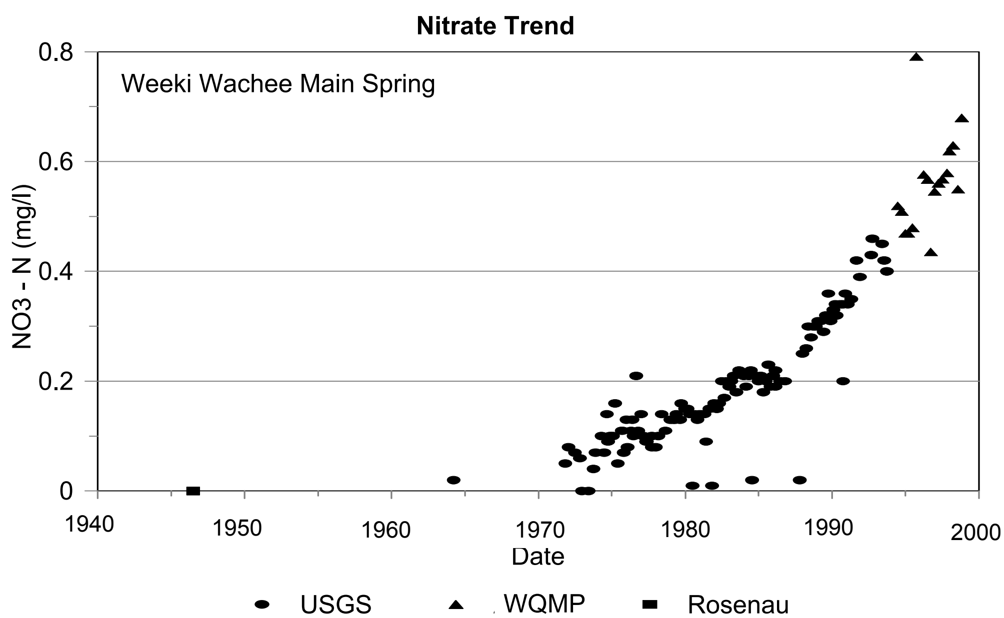
Weeki Wachee Main Spring is located in western Hernando County, and is approximately 500 feet southwest of the U.S. Hwy 19 and State Hwy 50 intersection. The banks of Weeki Wachee Spring have been developed to include a number of buildings, platforms, and a sandy beach area known as Buccaneer Bay. Weeki Wachee Spring is the headwaters of the Weeki Wachee River which flows westward seven miles to the Gulf Mexico. The vent of the spring is a north-south trending, vertical fracture that narrows to a depth of about 185 feet. At this point, the fracture is 20 feet long and 3 feet

Statistical Summary

Latitude: 283102.002
Longitude: 823423.419
County: Hernando
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	7/29/99
Calcium	55.20
Magnesium	6.23
Sodium	3.91
Potassium	0.20
Bicarbonate	138.00
Chloride	6.11
Sulfate	9.59
Nitrate	0.44
Phosphorus	0.01
TDS	186.00
Temp. (^{O}C)	24.50
pH (s.u.)	7.52
Sp. Cond. (µS/cm)	314.00

* (mg/l) unless noted otherwise



Salt Spring

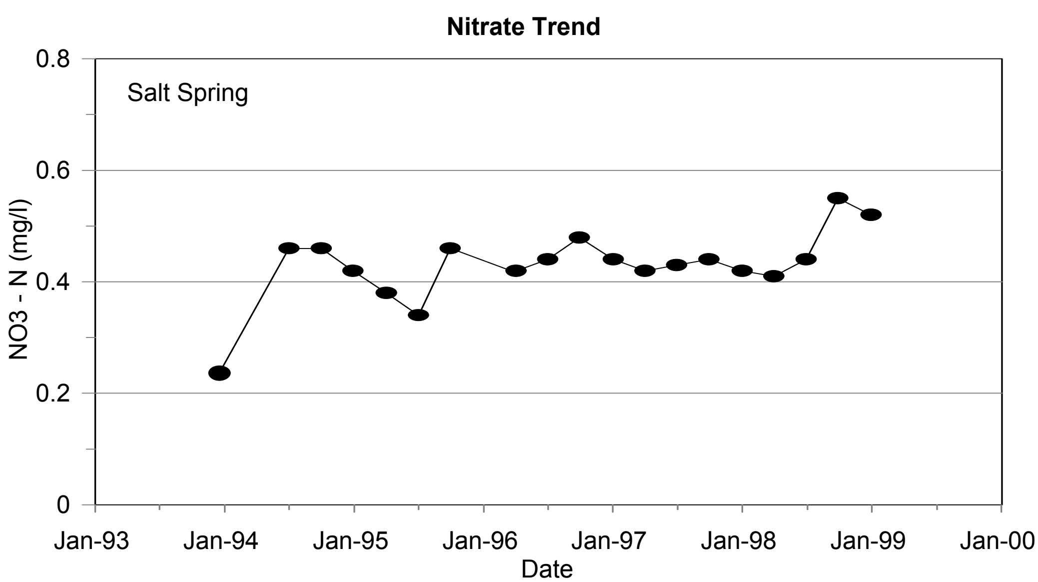
Salt Spring is located on private property approximately 3.6 miles west of the intersection of U.S. Hwy 19 and State Hwy 50, and 100 feet south of Hwy 50. The oval-shaped spring pool is approximately 80 feet in length and 60 feet wide. The spring produces a noticeable boil near the center of the pool, and is surrounded by large cypress trees as well as other vegetation. The spring pool drains through a spring run that flows to the southeast, then southwest, eventually reaching Mud River. This spring is tidally influenced.

Statistical Summary

Latitude: 283246.617
Longitude: 823708.386
County: Hernando
Basin: Coastal Rivers
Period of Record: 10/93 - present

Parameter*	Value
Sample Date	1/18/99
Calcium	83.10
Magnesium	89.30
Sodium	740.00
Potassium	25.80
Bicarbonate	123.00
Chloride	1,370.00
Sulfate	199.00
Nitrate	0.52
Phosphorus	0.01
TDS	2,491.00
Temp. (^{O}C)	23.60
pH (s.u.)	7.12
Sp. Cond. (µS/cm)	4,790.00

* (mg/l) unless noted otherwise



Jenkins Spring

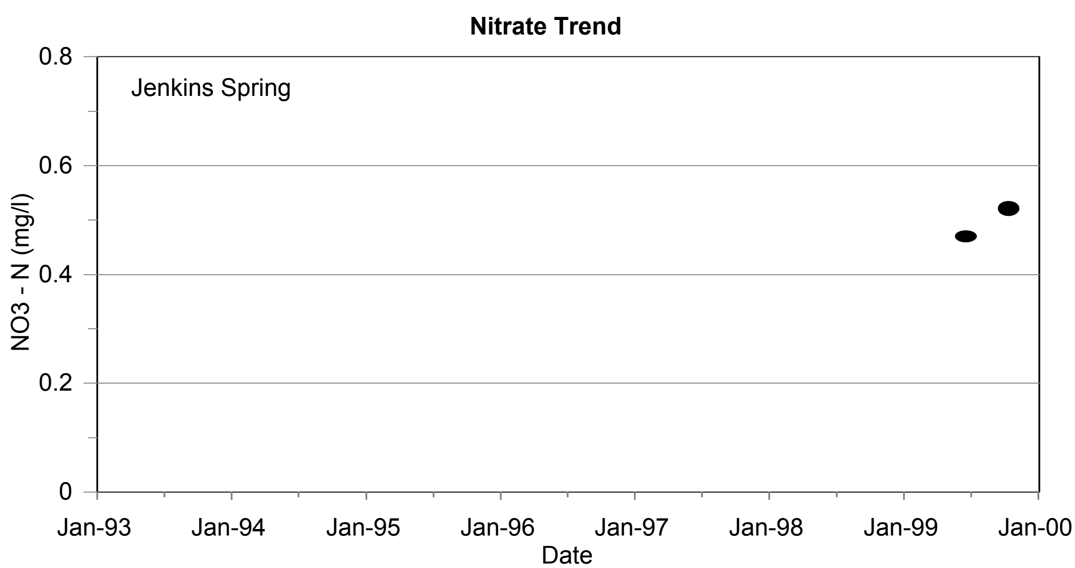
Jenkins Spring is located inside Hernando Beach Park off Shoal Line Rd. in western Hernando County. The spring pool is elliptical in shape; approximately 200 feet in length and 60 feet wide. There are two spring runs - one run flows to the south and the other flows to the northwest. The spring is tidally influenced which can affect the appearance of boils in the spring pool.

Statistical Summary

Latitude: 283119.310
Longitude: 823802.635
County: Hernando
Basin: Coastal Rivers
Period of Record: 7/99 - present

Parameter*	Value
Sample Date	7/29/99
Calcium	210.00
Magnesium	411.00
Sodium	3,650.00
Potassium	137.00
Bicarbonate	122.00
Chloride	7,170.00
Sulfate	908.00
Nitrate	0.47
Phosphorus	0.02
TDS	12,250.00
Temp. (^{O}C)	24.4
pH (s.u.)	7.46
Sp. Cond. (µS/cm)	20,300.00

* (mg/l) unless noted otherwise



Aripeka Springs Group

The Aripeka Springs group lies approximately seven miles southwest of Weeki Wachee Springs and is composed of numerous small springs clustered in a one square-mile area in southwestern Hernando County (Figure 21). Springs in the group include: Boat, Magnolia, and Bobhill Springs. Numerous smaller springs are located in and around Hammock Creek, a small tidal creek that extends one mile from its upper reaches to the Gulf of Mexico.

Discharge

The average discharge of the springs in the Aripeka Spring group is probably less than 6 mgd[12]. Although this discharge is very low compared to the other spring groups, there is probably considerably more water discharging from unknown spring vents, through sediments in the bottom of Hammock Creek, and in the Gulf of Mexico near the mouth of Hammock Creek. Table 7 contains discharge information for the Aripeka group.

Table 7. Discharge information for Several Springs in the Aripeka Group[12].

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN[3,36]
Aripeka #1	Unknown, probably < 5	0	N/A
Aripeka #2	Unknown, probably < 5	0	N/A
Boat	1.25	7	1988-1989
Magnolia	0.69	7	1988-1989
Bobhill	2.56	5	1988-1989

Discharge data collected by the WQMP between 1994-1996 indicated that the discharge at Bobhill Spring had decreased considerably from historical values given by the USGS in 1977[3] and later in 1992[36]. Forty-six discharge measurements taken using a Marsh McBirney portable water current meter show that the flow has decreased to an average of approximately 0.5 mgd (0.7 cfs) over a three year period, 1994-1996[74]. A site visit to Bobhill Spring on May 12, 2000 indicated that the spring had ceased to flow and that the water level in the spring pool was 2-3 inches below the top of the weir at the head of the spring run leaving the pool.

Water Quality

Ground water discharging at the Aripeka Springs group is fresh inland of the transition zone and brackish closer to the Gulf of Mexico. Water quality varies across the spring group with TDS concentrations increasing from less than 200 mg/l to greater than 600 mg/l. Chloride concentrations in the springs may range from less than

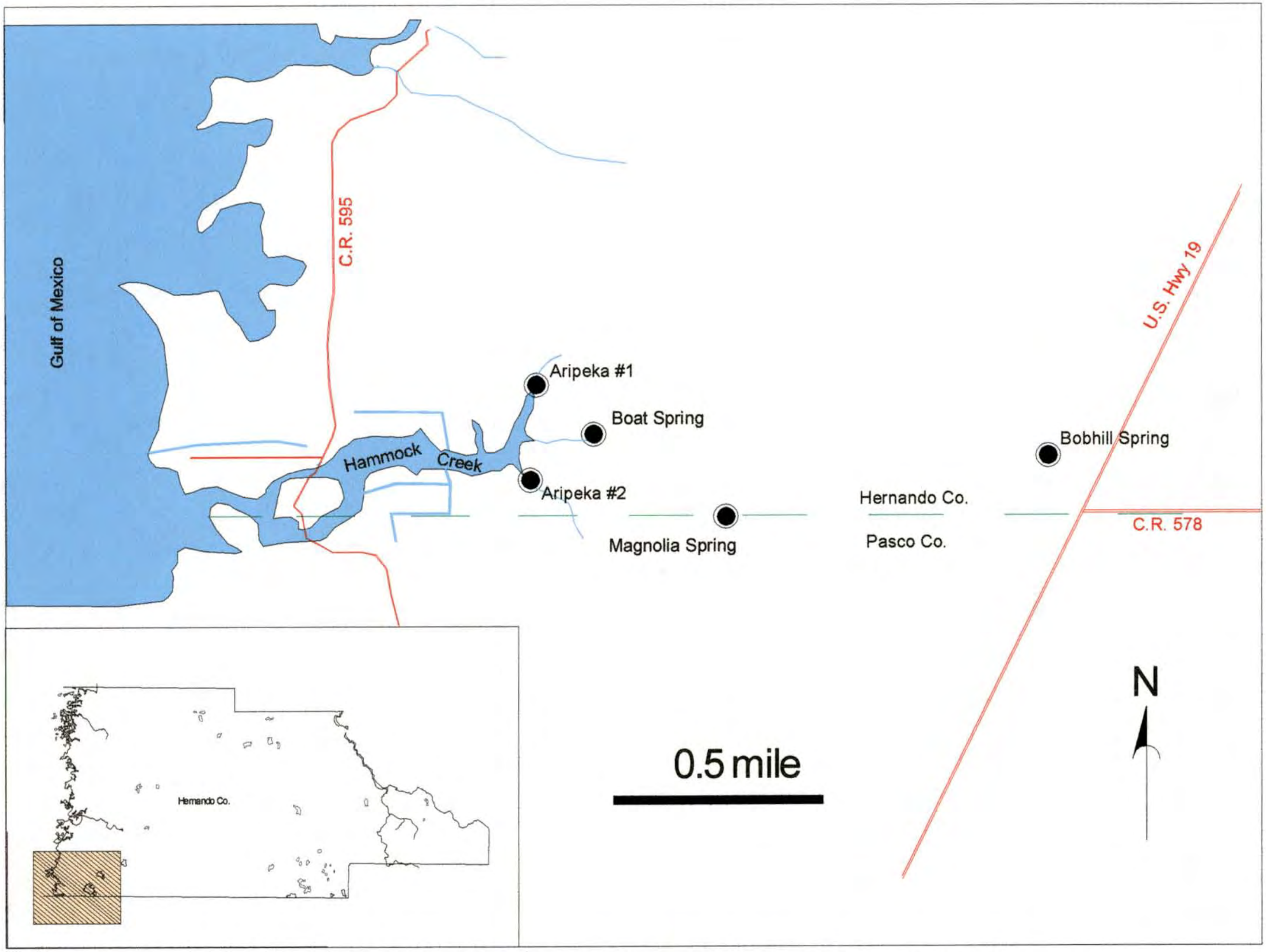


Figure 21. Location and Distribution of Springs in the Aripeka Springs Group, Hernando County.

10 mg/l to greater than 300 mg/l, indicating that the spring group is influenced by the coastal transition zone[12].

Nitrate concentrations at the Aripeka Springs group are typically below 0.5 mg/l, with the highest concentrations detected at Bobhill Spring. The concentrations vary among the individual springs of the group, possibly in response to mixing in the coastal transition zone and variations in nitrate in Floridan aquifer ground water. Research conducted by the WQMP indicates that the nitrate discharging from the springs is derived from an inorganic source of nitrate - inorganic fertilizers applied to residential and golf course turf grass near the springs[12].

Boat Spring

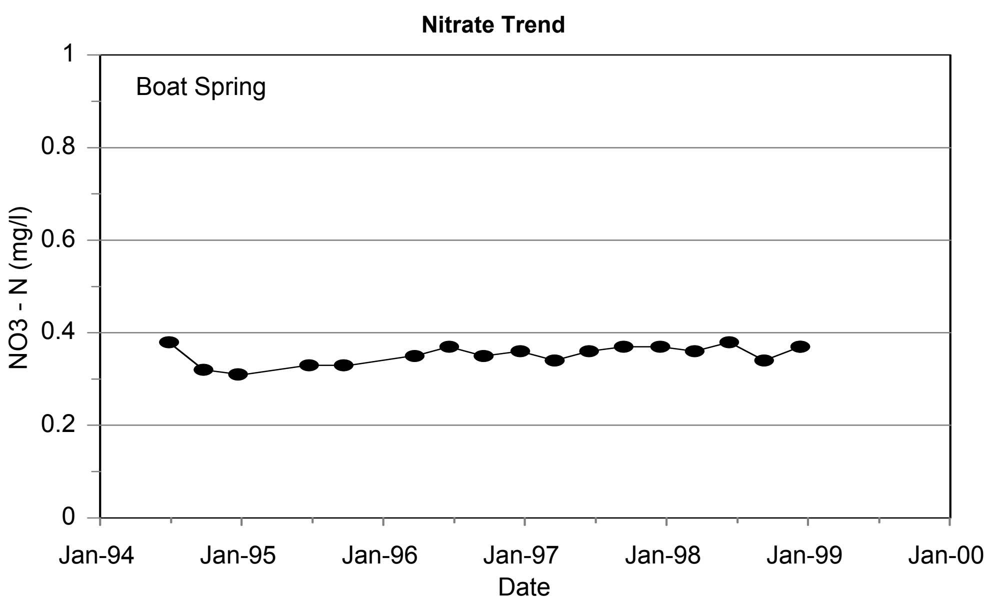
Boat Spring is located on private property west of U.S. 19 off Hwy 595 on Jebert Road in southwestern Hernando County. It consists of five vents in cavernous limestone with a pool approximately 40 feet long and 20 feet wide. It does not have any noticeable boils and the spring is tidally influenced. The spring is surrounded with native vegetation such as cabbage palm, ferns, and magnolia trees. The spring run flows through an adjacent salt-water marsh before reaching Hammock Creek.

Statistical Summary

Latitude: 282611.718
Longitude: 823923.055
County: Hernando
Basin: Coastal Rivers
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	1/21/99
Calcium	54.00
Magnesium	22.10
Sodium	164.00
Potassium	6.64
Bicarbonate	101.00
Chloride	305.00
Sulfate	51.00
Nitrate	0.37
Phosphorus	0.03
TDS	656.00
Temp. (^{O}C)	23.40
pH (s.u.)	7.55
Sp. Cond. (µS/cm)	1,280.00

* (mg/l) unless noted otherwise



Magnolia Spring

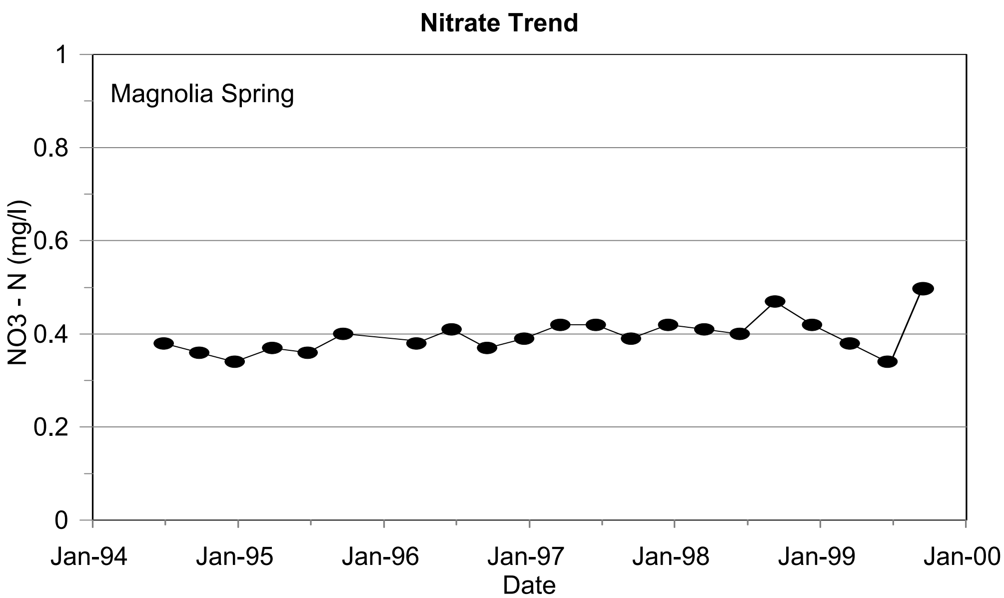
Magnolia Spring is located on private property west of U.S. 19 off CR 595 on Jebert road in southwestern Hernando County. The spring pool is approximately 60 feet in length and 40 feet wide. There are several boils present within the spring; one medium size boil and approximately eleven smaller boils. The spring is surrounded by vegetation which includes cabbage palms, ferns, banana trees, and magnolia trees. The spring forms a run that flows to the southeast, then curves back to the northwest before entering Hammock Creek.

Statistical Summary

Latitude: 282602.111
Longitude: 823908.965
County: Hernando
Basin: Coastal Rivers
Period of Record: 8/94 - present

Parameter*	Value
Sample Date	7/28/99
Calcium	48.20
Magnesium	6.56
Sodium	36.4
Potassium	0.28
Bicarbonate	105.00
Chloride	68.40
Sulfate	17.80
Nitrate	0.34
Phosphorus	0.01
TDS	251.00
Temp. (^{O}C)	24.60
pH (s.u.)	7.64
Sp. Cond. (µS/cm)	467.00

* (mg/l) unless noted otherwise



Bobhill Spring

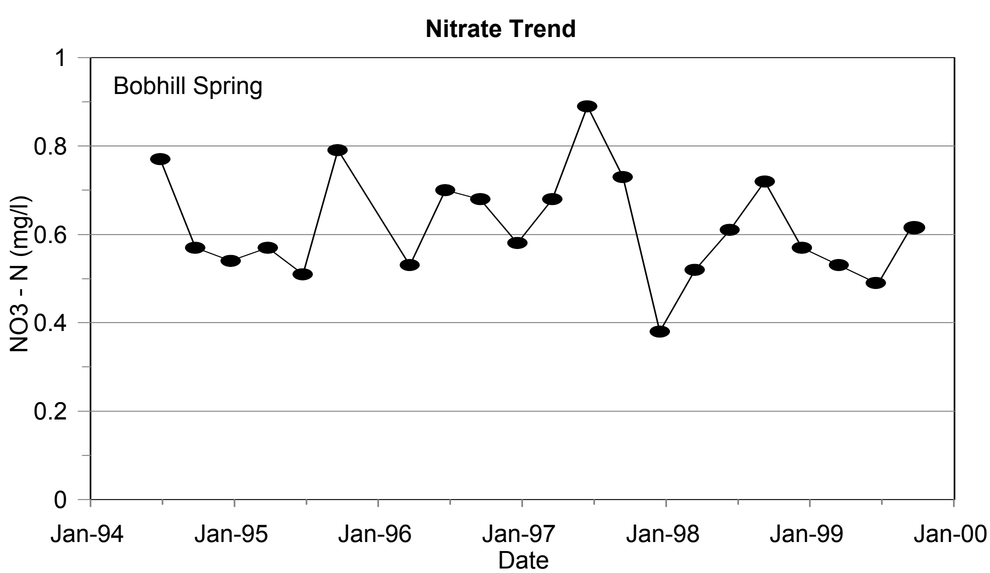
Bobhill Spring is located 400 feet west of U.S. Hwy 19 and County Line Road inside the Holiday Trav-L-Park. The spring vent is on the south side of the spring pool in about 15 feet of water. The spring pool is approximately 100 feet in length and 75 feet wide, and does not have any noticeable boils. A concrete decking has been constructed around the edge of the entire pool area. The spring discharges through Bayou Creek and Bayou Lake westward into the Gulf of Mexico. The spring was not flowing in May 2000.

Statistical Summary

Latitude: 282604.958
Longitude: 823827.975
County: Hernando
Basin: Coastal Rivers
Period of Record: 7/94 - present

Parameter*	Value
Sample Date	7/28/99
Calcium	50.40
Magnesium	3.52
Sodium	3.93
Potassium	0.30
Bicarbonate	115.00
Chloride	6.63
Sulfate	8.66
Nitrate	0.49
Phosphorus	0.01
TDS	158.00
Temp. (^{O}C)	25.00
pH (s.u.)	7.45
Sp. Cond. (µS/cm)	276.00

* (mg/l) unless noted otherwise



PASCO COUNTY

Crystal Springs Group

The Crystal Springs group lies in southeastern Pasco County, three miles south of Zephyrhills along the Hillsborough River (Figure 22). The group is comprised of a single, second-magnitude spring that has historically discharged 36 mgd to the Hillsborough River[(19)], and three additional springs that contribute an additional 4 mgd to the total discharge of the group[(13)]. The main spring contributes significant quantities of water to the Hillsborough River, especially during the dry season when 80% of the flow in the upper portion of the river may be derived from ground-water discharge at the main spring[(58)].

Crystal Springs was modified in the 1940's by damming the spring run upstream of its confluence with the Hillsborough River[(13)]. This modification created a spring pool that quickly became a recreational attraction for many residents in the area. The main spring remained a popular swimming area for visitors and residents until the spring property was closed indefinitely in April 1996.

Discharge

Ground-water discharge at Crystal Springs has been measured regularly by the USGS since the 1930's. Discharge from the main spring is determined by measuring the flow of the Hillsborough River up and downstream of the spring. The difference in flow between these two points on the river represents ground-water discharge from the main spring. Recent review of historical discharge data indicates that the formation of the spring pool may have caused a slight decline in spring flow by increasing water levels immediately adjacent to the spring vent and in the vicinity of the spring[(79,80)].

Figure 7 depicts the mean monthly discharge between 1933 and 1998 at Crystal Springs. Much like Rainbow Springs and other springs throughout the District, discharge at Crystal Springs exhibits significant seasonality, reaching a minimum at the end of the dry season in June and peaking in October, after the end of the summer wet season. This pattern indicates that the lag time between seasonal changes in rainfall and the response of the spring system is minimal. This pattern also indicates that the circulation of ground water in the Floridan aquifer is open and vigorous; and the springs are recharged by precipitation falling in close proximity (5 - 10 mile radius) of the springs.

Spring flow at Crystal Springs has declined over the last several decades. Figure 8 clearly shows that the decline in flow extends across much of the period of record (1933 - 1998) at the springs. Decreased flow at the spring can be attributed to a number of factors including an overall decrease in rainfall in the area and ground-water withdrawals at wells. The withdrawal of water from the spring for bottled-water supplies, however, has only occurred since the mid-1980's[(79)].

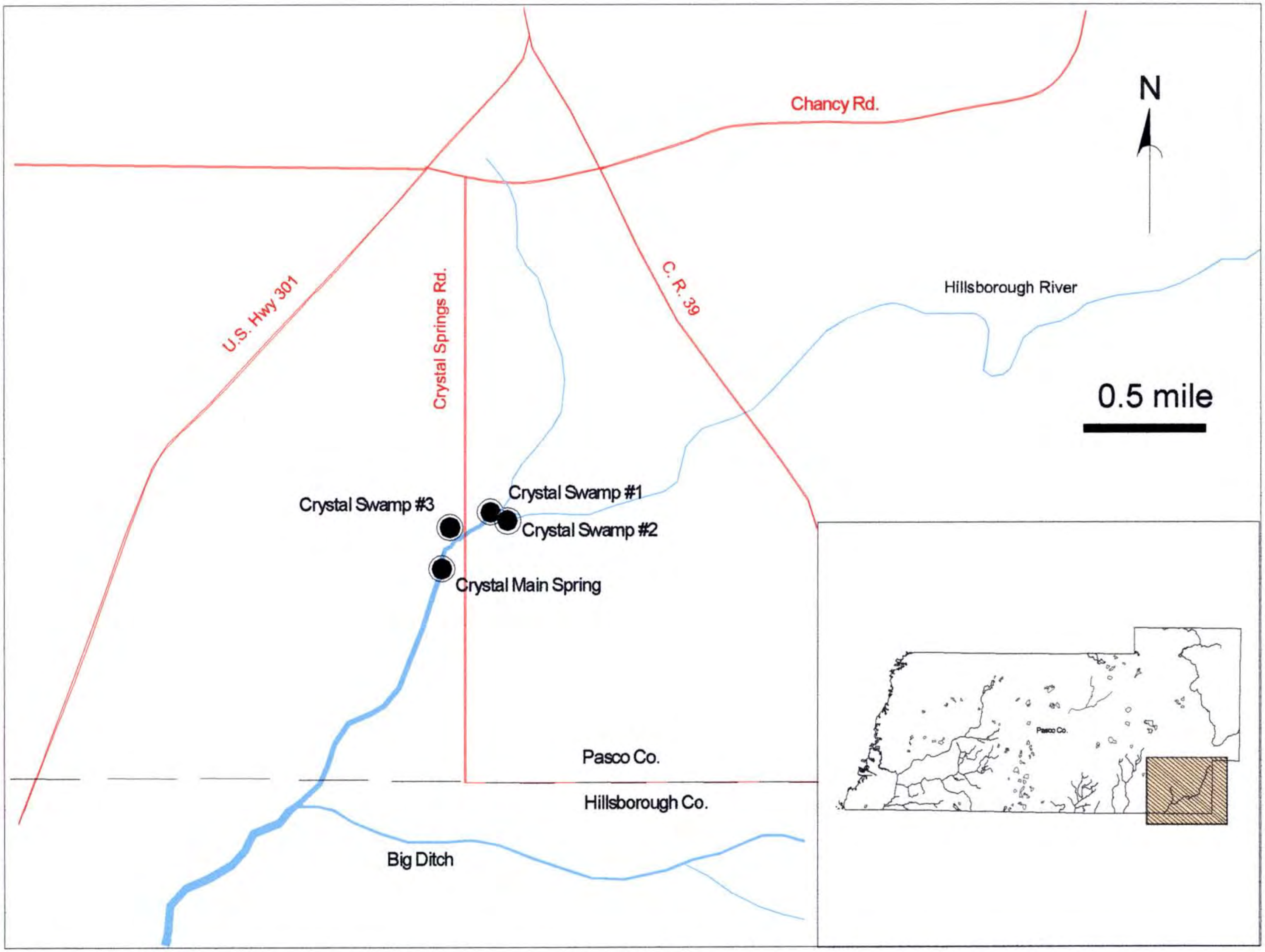


Figure 22. Location and Distribution of Springs in the Crystal Springs Group, Pasco County.

Water Quality

Ground water discharging at the Crystal Springs group is fresh and typically contains less than 250 mg/l TDS. Water quality varies only slightly across the spring group with sulfate concentrations ranging within several milligrams per liter between spring vents. Chloride concentrations in the springs are generally less than 10 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs(13).

Nitrate concentrations at Crystal Springs are significantly elevated above background concentration measured in the Floridan aquifer. The concentrations vary only slightly among the individual springs of the group and are typically around 2 mg/l. Research conducted by the WQMP indicates that the nitrate discharging from the springs is most likely derived from an inorganic source of nitrate - inorganic fertilizers applied to citrus northwest of the springs in the Brooksville Ridge(13).

Crystal Springs Main

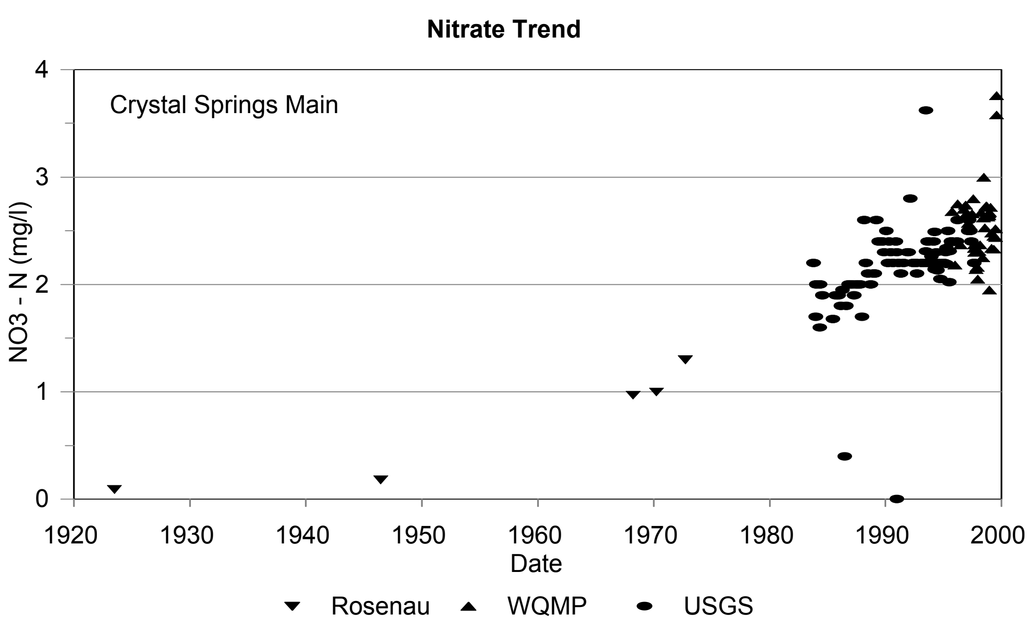
Crystal Springs Main is located in southeast Pasco county along the banks of the Hillsborough River. The main spring contributes a significant amount of flow to the Hillsborough River, especially during the dry season. The spring was open for swimming until 1996 when it was closed to the public and returned to its natural state through a restoration project undertaken by the property owner. A portion of the water discharged by the spring is pumped to a bottling plant in Zephyrhills, and sold as bottled-spring water. The spring is situated on private property.

Statistical Summary

Latitude: 281056.023
Longitude: 821106.028
County: Pasco
Basin: Hillsborough River
Period of Record: 3/95 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	62.90
Magnesium	4.18
Sodium	5.35
Potassium	-0.05
Bicarbonate	142.00
Chloride	9.74
Sulfate	9.08
Nitrate	3.76
Phosphorus	0.04
TDS	205.00
Temp. (^{O}C)	24.50
pH (s.u.)	7.50
Sp. Cond. (µS/cm)	348.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



Crystal Swamp #1

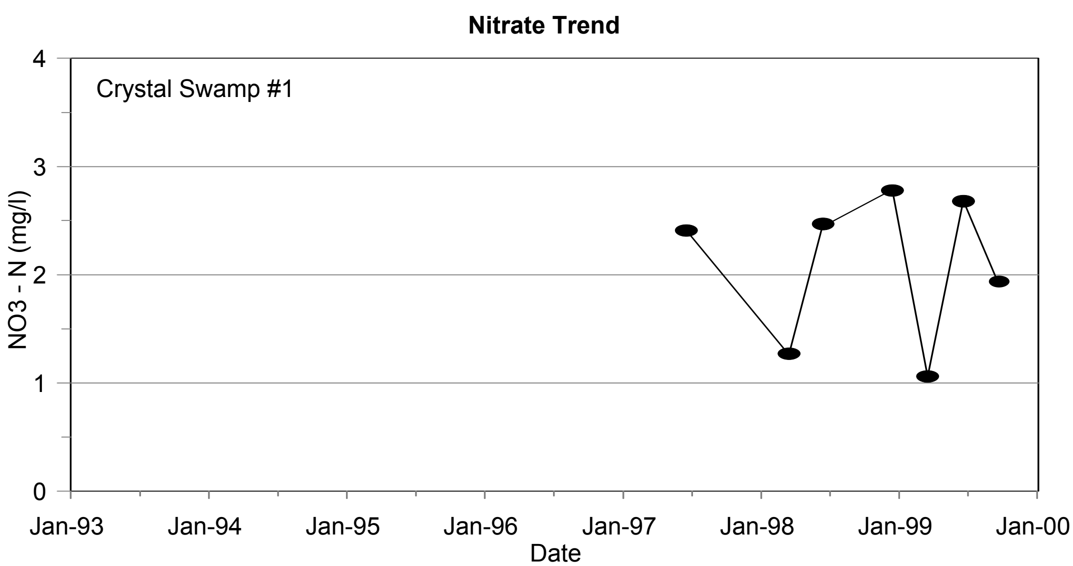
Crystal Swamp #1 is located in southeast Pasco County several thousand feet east of the main spring. The spring pool is approximately 10 feet deep and 25 feet in diameter. Crystal Swamp #1 is located approximately 500 feet north of Crystal Swamp # 2, and approximately 650 feet east of Crystal Springs Rd. The spring, lying within the flood plain of the Hillsborough River, is surrounded by native wetland vegetation, and is subject to frequent flooding by the river.

Statistical Summary

Latitude: 281113
Longitude: 821052
County: Pasco
Basin: Hillsborough River
Period of Record: 6/97 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	63.90
Magnesium	3.87
Sodium	5.52
Potassium	-0.05
Bicarbonate	143.00
Chloride	9.91
Sulfate	8.34
Nitrate	2.68
Phosphorus	0.04
TDS	207.00
Temp. (^{O}C)	24.40
pH (s.u.)	7.63
Sp. Cond. (µS/cm)	350.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



Crystal Swamp #2

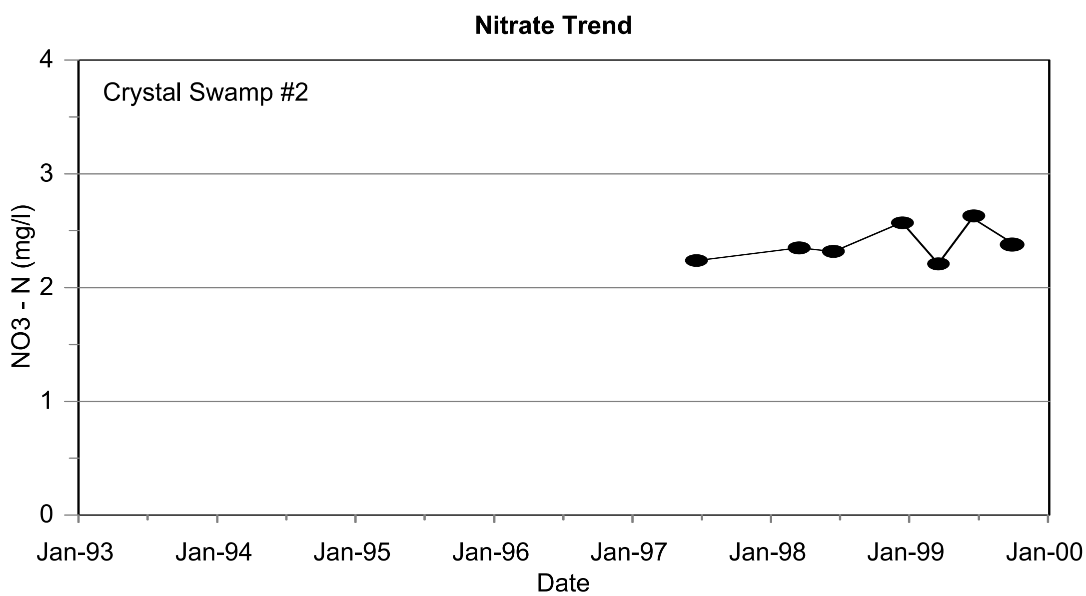
Crystal Swamp #2 is located in southeast Pasco County several thousand feet east of the main spring. The spring pool is approximately 10 feet deep and 25 feet in diameter. Crystal Swamp #2 is located approximately 500 feet south of Crystal Swamp # 1 and approximately 650 feet east of Crystal Springs Rd. The spring, lying within the flood plain of the Hillsborough River, is surrounded by native wetland vegetation, and is subject to frequent flooding by the river.

Statistical Summary

Latitude: 281106
Longitude: 821048
County: Pasco
Basin: Hillsborough River
Period of Record: 6/97 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	64.40
Magnesium	4.06
Sodium	5.55
Potassium	-0.05
Bicarbonate	145.00
Chloride	9.96
Sulfate	8.65
Nitrate	2.63
Phosphorus	0.04
TDS	207.00
Temp. (^{O}C)	24.00
pH (s.u.)	7.43
Sp. Cond. (µS/cm)	356.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



Crystal Swamp #3

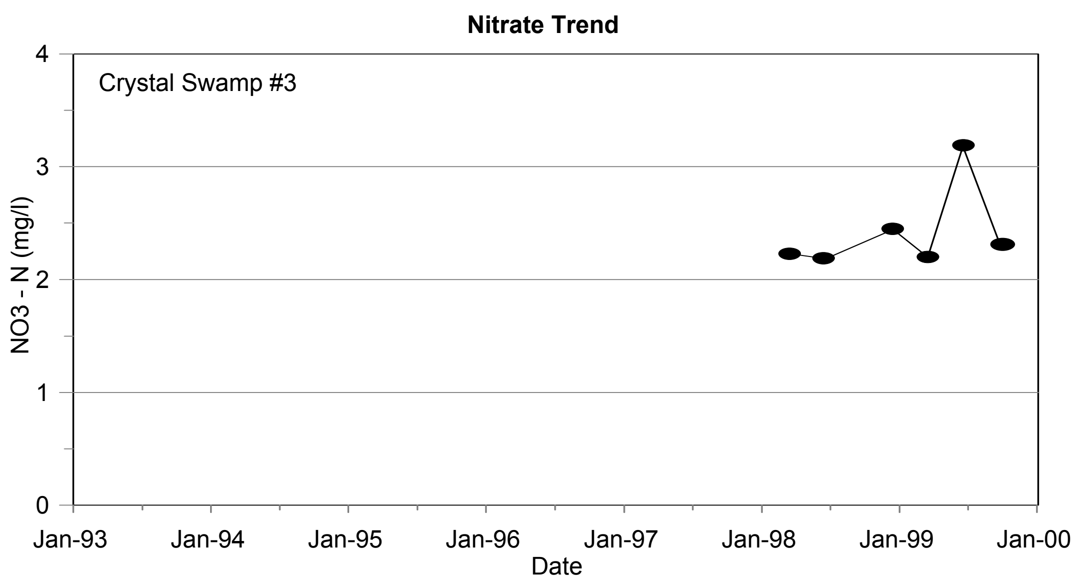
Crystal Swamp #3 is located in southeast Pasco County several thousand feet northwest of the main spring. The spring pool is approximately 2 feet deep and 5 feet in diameter. The spring run is very shallow and rocky. Flow from the spring enters the Hillsborough River approximately 800 feet downstream of the Crystal Springs Rd. bridge.

Statistical Summary

Latitude: 281107
Longitude: 821134
County: Pasco
Basin: Hillsborough River
Period of Record: 3/98 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	62.40
Magnesium	4.43
Sodium	5.01
Potassium	-0.05
Bicarbonate	141.00
Chloride	9.24
Sulfate	7.97
Nitrate	3.19
Phosphorus	0.04
TDS	201.00
Temp. (^{O}C)	24.20
pH (s.u.)	7.54
Sp. Cond. (µS/cm)	346.00

* (mg/l) unless noted otherwise
(-) denotes analyte below detection limit



HILLSBOROUGH COUNTY

Lithia/Buckhorn Springs Group

The Lithia/Buckhorn Springs group lies in central Hillsborough County, three miles south of Brandon along the Alafia River (Figure 23). The group is comprised of two second-magnitude springs that collectively discharge 35 mgd to the Alafia River. A number of smaller, third-magnitude springs in the group contribute an additional 8 mgd to the group's total discharge[(9)]. Bell Creek Spring discharges approximately 0.03 mgd (30,000 gallons per day) to the Alafia River[(54)], and is included in the Lithia/Buckhorn Springs group.

Discharge

Discharge of Lithia Springs is regularly measured by the USGS approximately 500 feet upstream from the Alafia River. Total discharge of the springs consists of discharge from the main spring and a smaller spring (Lithia Minor) that flow through separate runs, and diversion by pumpage from the main spring pool. Diversion of water from Lithia Main Spring is used to supply water to a local industrial facility, and diversion amounts are regularly reported to the USGS by facility operators[(19)].

Figure 7 depicts the mean monthly discharge between 1934 and 1998 at Lithia Main Spring. Much like Rainbow Springs and other springs throughout the SWFWMD, discharge at Lithia Springs exhibits significant seasonality, reaching a minimum at the end of the dry season in May and peaking in October, after the end of the summer wet season. This pattern indicates that the lag time between seasonal changes in rainfall and the response of the spring system is minimal. The pattern also indicates that the circulation of ground water in the Floridan aquifer is open and vigorous and the springs are recharged by precipitation falling in close proximity (5 - 10 mile radius) of the springs.

Water Quality

The water quality at the Lithia/Buckhorn Springs group is influenced by the upwelling of sulfate along the inner margin of the coastal transition zone. Ground water discharging at the group is fresh and typically contains less than 350 mg/l TDS. Water quality varies only slightly across the spring group with sulfate concentrations increasing from 40 to 70 mg/l. Chloride concentrations in the springs are generally less than 30 mg/l indicating that the springs are recharged by precipitation falling in close proximity to the springs and are not significantly affected by higher salinities within the coastal transition zone[(9)].

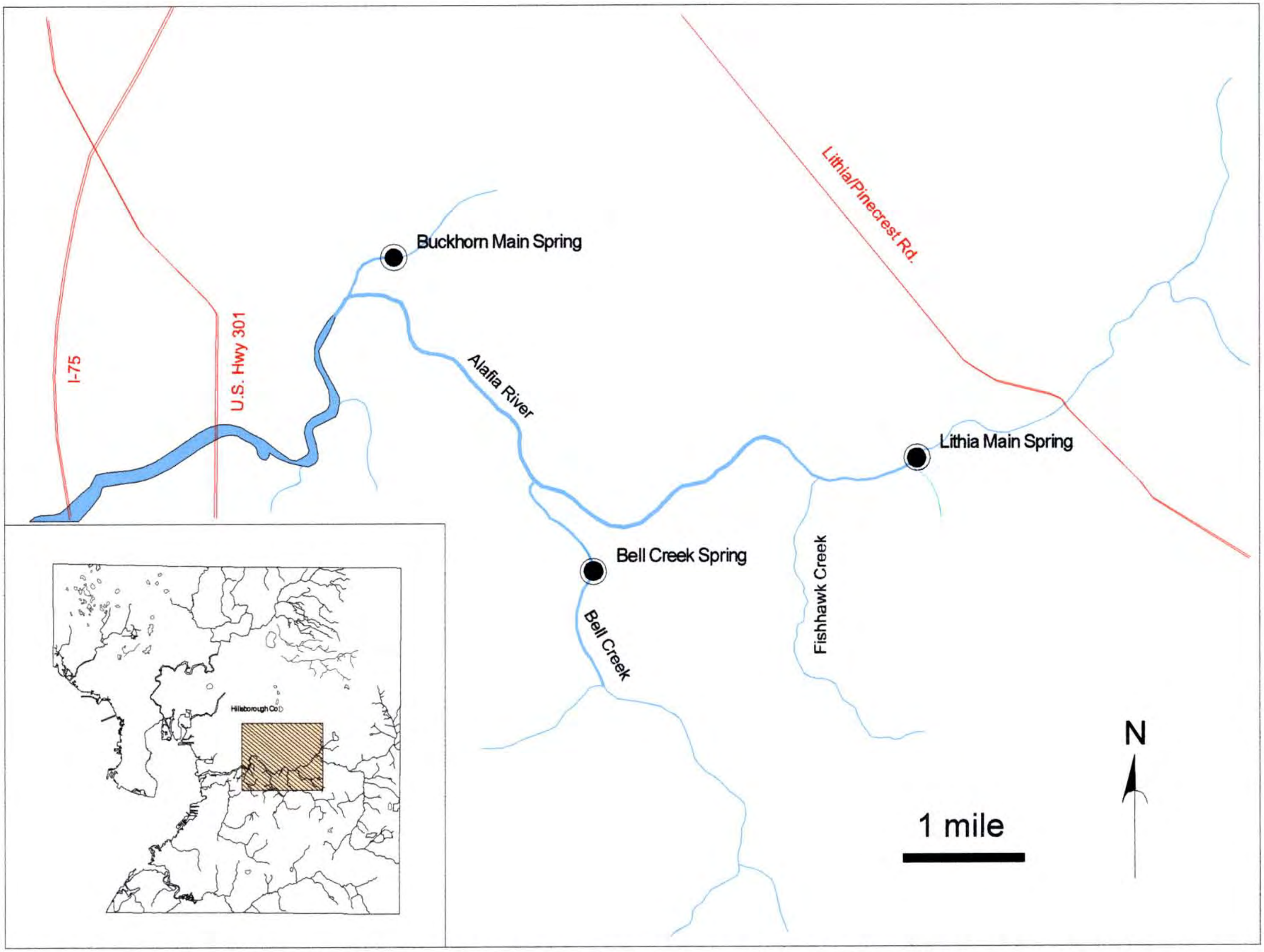


Figure 23. Location and Distribution of Springs in the Lithia/Buckhorn Springs Group, Hillsborough County.

Nitrate concentrations at Lithia/Buckhorn Springs are significantly elevated above background concentrations measured in the Floridan aquifer. The concentrations vary among the individual springs of the group and are typically around 3 mg/l. Nitrate concentrations at Bell Creek typically exceed the Primary Drinking Water Standard for Nitrate (10 mg/l as N) established by the FDEP(53). Research conducted by the WQMP indicates that the nitrate discharging from the springs is derived from an inorganic source of nitrate - inorganic fertilizers applied to citrus near the springs(9).

Lithia Main Spring

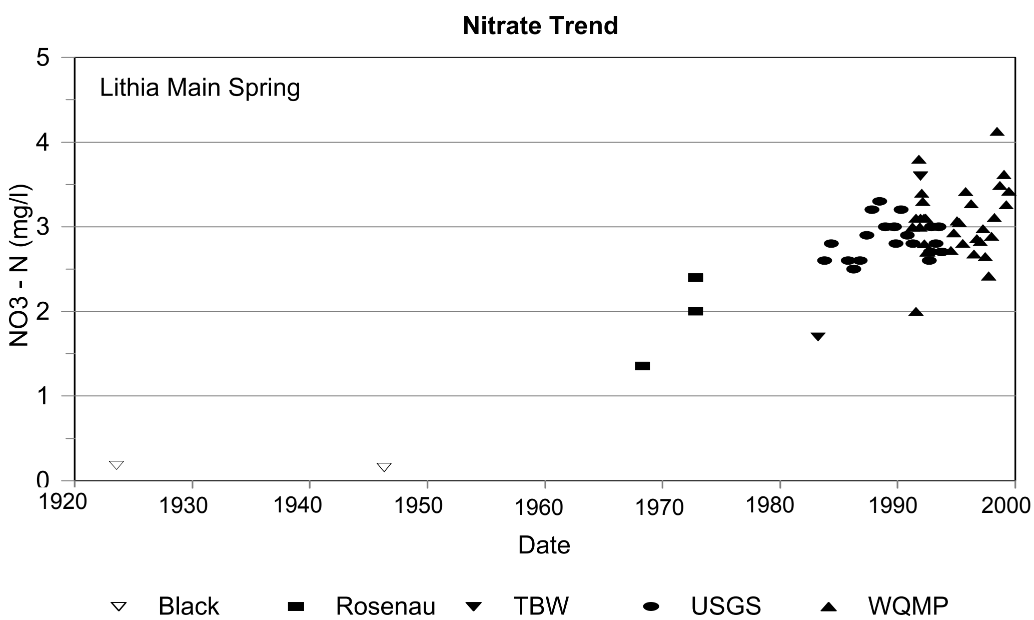
Lithia Main Spring is located in central Hillsborough County along the southern banks of the Alafia River. The spring is located in a county-owned and operated park which is open to the public for swimming, canoeing, and picnicking. The spring vent lies in 10-15 feet of water, underneath an outcropping of limestone (Arcadia Formation). The spring flows from a nearly horizontal vent near the pool center, and is blocked by a large steel grate.

Statistical Summary

Latitude: 275159.163
Longitude: 821353.460
County: Hillsborough
Basin: Alafia River
Period of Record: 4/91 - present

Parameter*	Value
Sample Date	7/20/99
Calcium	66.00
Magnesium	11.00
Sodium	13.00
Potassium	0.32
Bicarbonate	112.00
Chloride	27.60
Sulfate	69.20
Nitrate	3.37
Phosphorus	0.10
TDS	286.00
Temp. (^{O}C)	26.60
pH (s.u.)	7.48
Sp. Cond. (µS/cm)	483.00

* (mg/l) unless noted otherwise



Buckhorn Main Spring

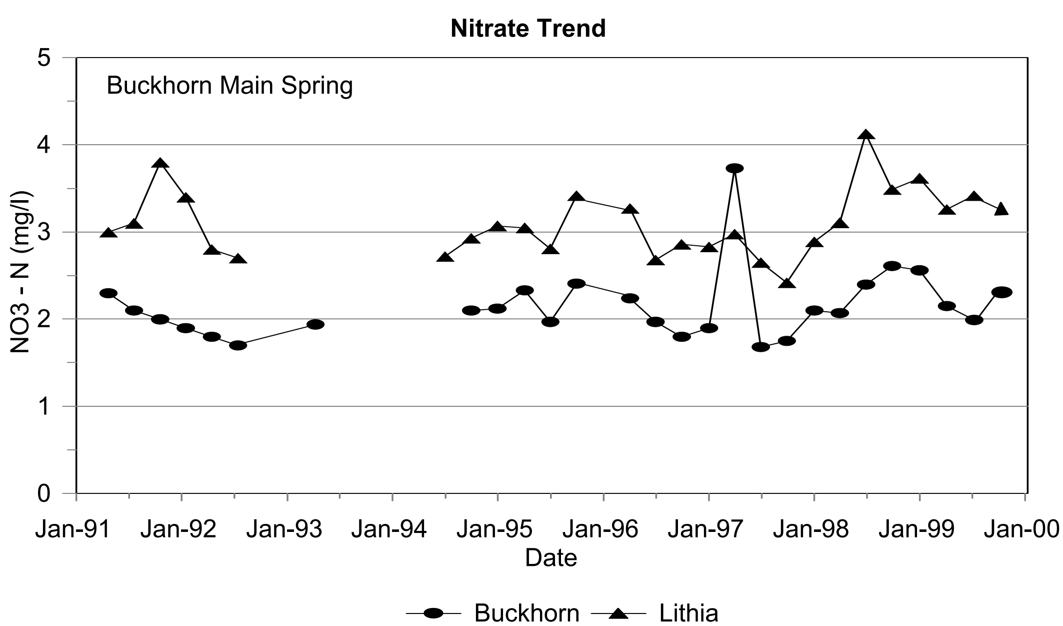
Buckhorn Spring is located in central Hillsborough County four miles west of Lithia Springs near the Alafia River. The spring is on private property, and is used as an industrial water supply. A large steel structure in the spring pool supplies water to a local pumping station which then transports spring water to a phosphate processing facility located on U.S. Hwy 41. The spring pool feeds directly into Buckhorn Creek, a small stream that enters the Alafia River southwest of the spring.

Statistical Summary

Latitude: 275321.731
Longitude: 821809.770
County: Hillsborough
Basin: Alafia River
Period of Record: 4/91 - present

Parameter*	Value
Sample Date	7/19/99
Calcium	61.50
Magnesium	12.40
Sodium	14.10
Potassium	0.30
Bicarbonate	116.00
Chloride	28.70
Sulfate	65.00
Nitrate	2.81
Phosphorus	0.04
TDS	271.00
Temp. (^{O}C)	24.80
pH (s.u.)	7.63
Sp. Cond. (μS/cm)	474.00

* (mg/l) unless noted otherwise



Bell Creek Spring

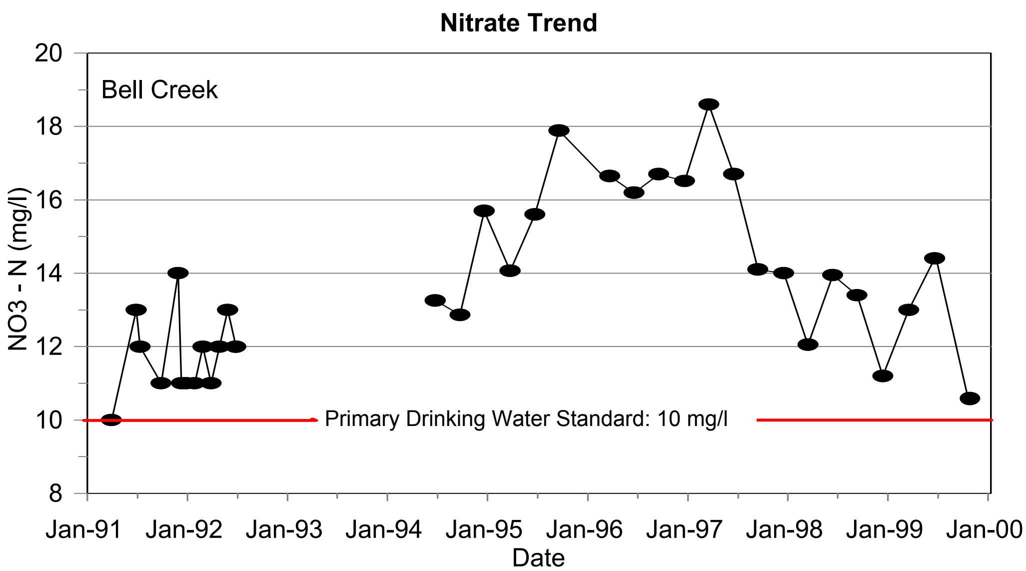
Bell Creek Spring (also known as Boyette Spring) is located in central Hillsborough County on the west bank of Bell Creek, approximately two miles west of Lithia Springs. The spring lies adjacent to a rapidly expanding residential community south of Brandon. Land uses surrounding the spring were primarily agriculture until the early 1990's when the region surrounding the spring began to experience the southward expansion of urban land uses from Brandon/Valrico.

Statistical Summary

Latitude: 275113.204
Longitude: 821626.520
County: Hillsborough
Basin: Alafia River
Period of Record: 4/91 - present

Parameter*	Value
Sample Date	7/19/99
Calcium	49.20
Magnesium	20.60
Sodium	15.60
Potassium	22.10
Bicarbonate	128.00
Chloride	23.60
Sulfate	46.70
Nitrate	14.40
Phosphorus	0.11
TDS	342.00
Temp. (^{O}C)	24.20
pH (s.u.)	6.66
Sp. Cond. (µS/cm)	555.00

* (mg/l) unless noted otherwise



Sulphur Springs

Rising 300 feet north of the Hillsborough River, Sulphur Springs lies well within the urbanized area of the City of Tampa. The spring is located approximately 200 feet southwest of the intersection of Nebraska Avenue (U.S. Hwy 41) and Sitka Street (Figure 24). The spring is surrounded by a mixture of residential and commercial land uses. The spring pool has been developed into a 50 ft circular swimming pool with concrete walls. The pool has a maximum depth of about 30 ft and water level is controlled by two toboggan flumes with fixed crest elevations on each side of a large moveable steel stop-gate at the outlet. The run exits the pool to the south, then flows southwest to the Hillsborough River 500 feet below the pool(3).

Once popular with tourists and residents of the area, Sulphur Springs has been closed to swimming and recreational activities since the mid 1980's. High levels of bacteria in the spring discharge facilitated its closure as a recreational facility(81). Bacteria contamination of the spring is believed to result from the flushing of storm water into sinkholes located several miles north of the spring. Ground-water studies performed by the USGS and ground-water consultants have verified a direct connection between the spring and several sinks to the north(38,82,83). Based on dye-tracer experiments conducted at Curiosity, Blue and Jasmine Sinks, it is estimated that storm water entering these sinks may reach Sulphur Springs within 48 hours(38,82).

Discharge

The discharge at Sulphur Springs is measured regularly by the USGS in the Spring run about 300 feet below the spring pool. The average annual discharge of Sulphur Springs is approximately 25 mgd(19). Water is occasionally diverted from Sulphur Springs to augment the water in the Hillsborough Reservoir, a large impoundment of surface water three miles east of the spring behind the City of Tampa Dam.

Spring flow at Sulphur Springs has declined over the last several decades. Figure 8 clearly shows the decline of flow at Sulphur Springs from 1960 to 1997. This decline can be attributed to a number of environmental and anthropogenic factors including an overall decrease in rainfall in the area, ground-water withdrawals in the region, and alteration of the spring’s conduit system. Alteration of the spring’s conduit system was noted by investigators when the subterranean connection between Curiosity Sink and Sulphur Springs could not be verified by the consultants and City of Tampa employees(82).

Water Quality

The water quality at Sulphur Springs has not been extensively studied by WQMP staff. However, cursory review of water-quality data suggests that ground water discharging at Sulphur Springs is brackish and typically contains greater than 1,000 mg/l TDS(69). Chloride concentrations in the spring are generally greater than 500 mg/l indicating that the spring is affected by higher salinity in the coastal transition zone.

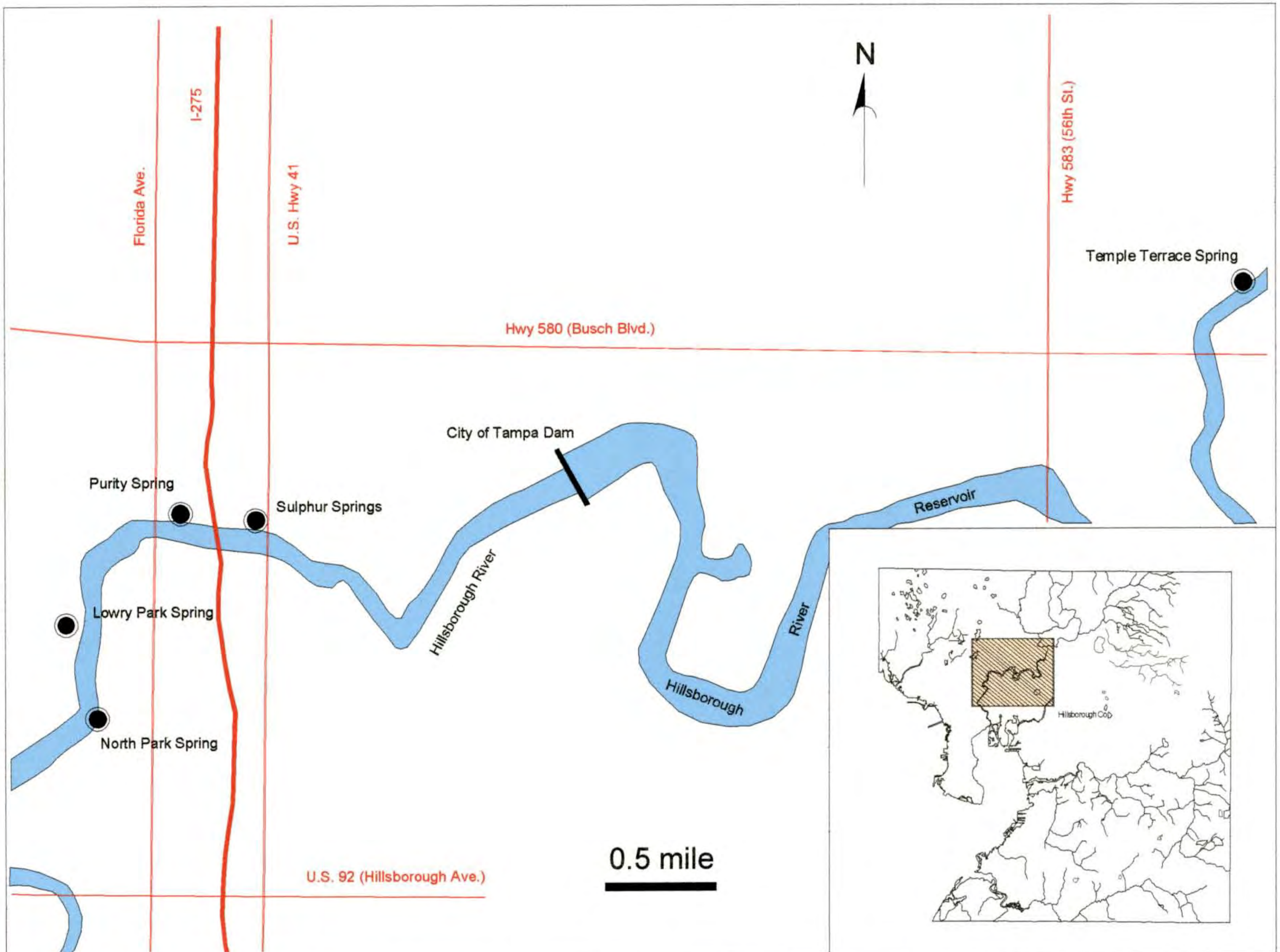


Figure 24. Location and Distribution of Springs in the Sulphur Springs Group, Hillsborough County.

Nitrate concentrations at Sulphur Springs have varied over the period of record at the spring and since 1989 have generally been below 1 mg/l. Research to determine the source of the nitrate discharging at Sulphur Springs has not been conducted by the WQMP, but may be related to storm water flushed into the aquifer north of the spring.

Sulphur Springs

Sulphur Springs lies approximately 200 feet southwest of the intersection of Nebraska Ave. (U.S. Hwy 41) and Sitka Street, and 300 feet north of the Hillsborough River. The spring, until the mid 1980's, was a popular recreational area; however, bacterial contamination of the spring water eventually caused the spring to be closed indefinitely. The spring pool is a concrete structure, 50 feet in diameter and about 30 feet deep. The spring produces a noticeable boil on the surface of the pool, especially when the water level in the pool is dropped.

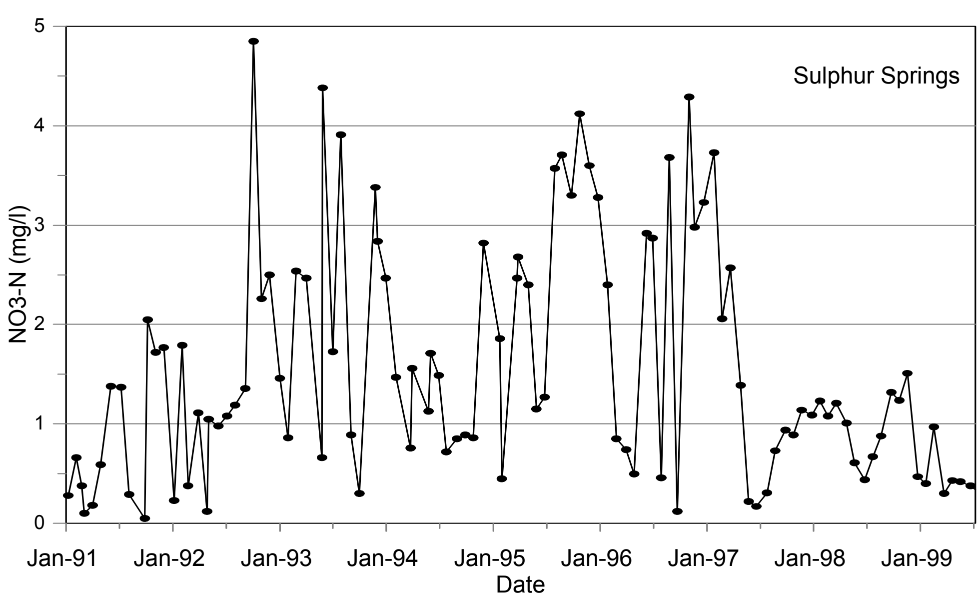
<u>Statistical Summary</u>

Latitude: 280114.690
Longitude: 822705.214
County: Hillsborough
Basin: Hillsborough River
Period of Record: 7/96 - present

Parameter*	Value
Sample Date	07/24/96
Calcium	141.00
Magnesium	36.60
Sodium	320.00
Potassium	9.71
Bicarbonate	149.00
Chloride	580.00
Sulfate	200.00
Nitrate	0.89
Phosphorus	0.11
TDS	1,600.00
Temp. (^{O}C)	25.80
pH (s.u.)	7.12
Sp. Cond. (µS/cm)	2,520.00

* (mg/l) unless noted otherwise

Nitrate Trend



Lettuce Lake Springs Group

The Lettuce Lake Springs group lies in central Hillsborough County to the east of the City of Tampa, and Sulphur Springs (Figure 25). The group is comprised of six spring vents spread over an area of approximately one square mile. The springs lie in the upper reaches of Six Mile Creek which was channelized in the 1970's to form the Tampa Bypass Canal. Flow from Lettuce Lake Spring group declined considerably after the construction of the Tampa Bypass Canal[84]. Intercepting ground-water flow to the springs, the canal redirected ground water into the excavated channel, thus effectively “short circuiting” the spring discharge. A large spring boil occurs just to the south of a water-control structure (S-159) and several hundred feet south of the Harney Road bridge over the bypass canal and may represent this intercepted and redirected spring flow. The Lettuce Lake Spring group is represented by Eureka, Lettuce Lake, and Six Mile Creek Springs. Because it still retains a considerable amount of flow, only Lettuce Lake Spring is covered in this section of the report. Eureka and Six Mile Creek Springs are covered in a later section of the report entitled INACTIVE SPRINGS.

Discharge

Lettuce Lake Spring lies along the northern property boundary of the Tampa Service Office of the SWFWMD, and the western bank of the bypass canal. The spring pool is approximately 100 feet in diameter and flow from the spring is derived via culverts to the bypass canal. The discharge from Lettuce Lake Spring was measured in March, 2000 by staff of the WQMP using a Marsh McBirney portable current meter. Flow from the spring was estimated to be approximately 1.1 mgd. This amount of flow, however, is considerably less than historical values given by the USGS in 1977. Historical discharge measurements[3] are listed below:

April 28, 1969	12.5 cfs (cubic feet per second)
September 17, 1969	*21.8
March 25, 1970	*19.8
November 12, 1970	*12.1
May 21, 1971	6.86
October 31, 1971	10.2
June 1, 1972	7.60
October 20, 1972	9.40
May 18, 1973	9.58

* Includes flow of the Six Mile Creek

Water Quality

The water quality at the Lettuce Lake Springs group has not been extensively studied by WQMP staff. However, cursory review of water-quality data suggests that ground water discharging at Lettuce Lake Spring is fresh and may contain less than 400 mg/l TDS. Sulfate concentrations in the spring are greater than 80 mg/l, while chloride concentrations are generally less than 25 mg/l[69]. This indicates that the spring is recharged by precipitation falling in close proximity to the spring and that sulfate is

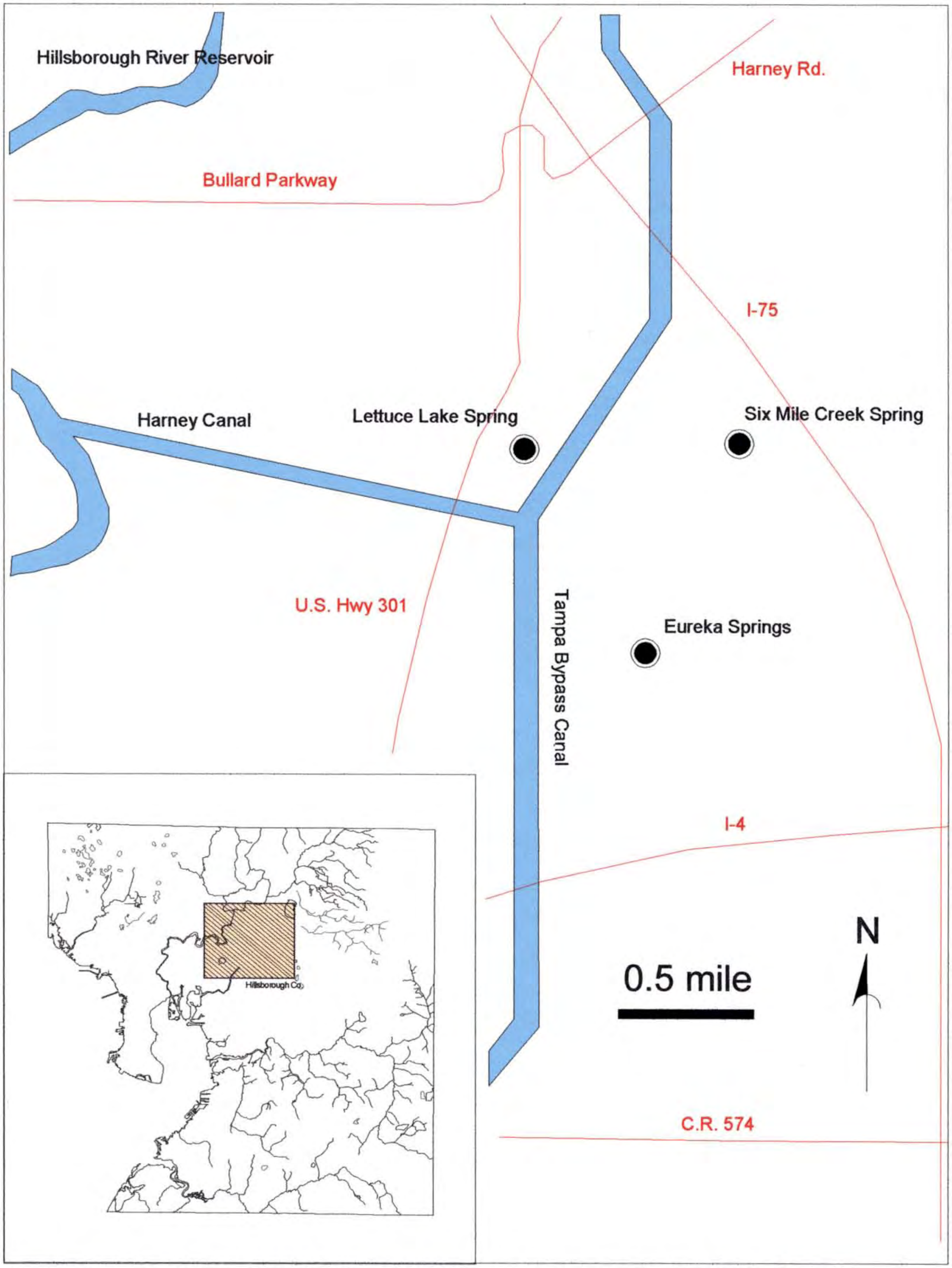


Figure 25. Location and Distribution of Springs in the Lettuce Lake Springs Group, Hillsborough County.

upwelling in the vicinity of the spring vent.

Nitrate concentrations at Lettuce Lake Spring are significantly elevated above background concentration measured in the Floridan aquifer. Concentrations measured at the spring are typically above 1 mg/l. Research to determine the source of the nitrate discharging at Lettuce Lake Spring has not been conducted by the WQMP. However, nitrogen-isotope samples collected in April, 2000 indicate that the spring may be affected by animal and/or human wastes near the spring.

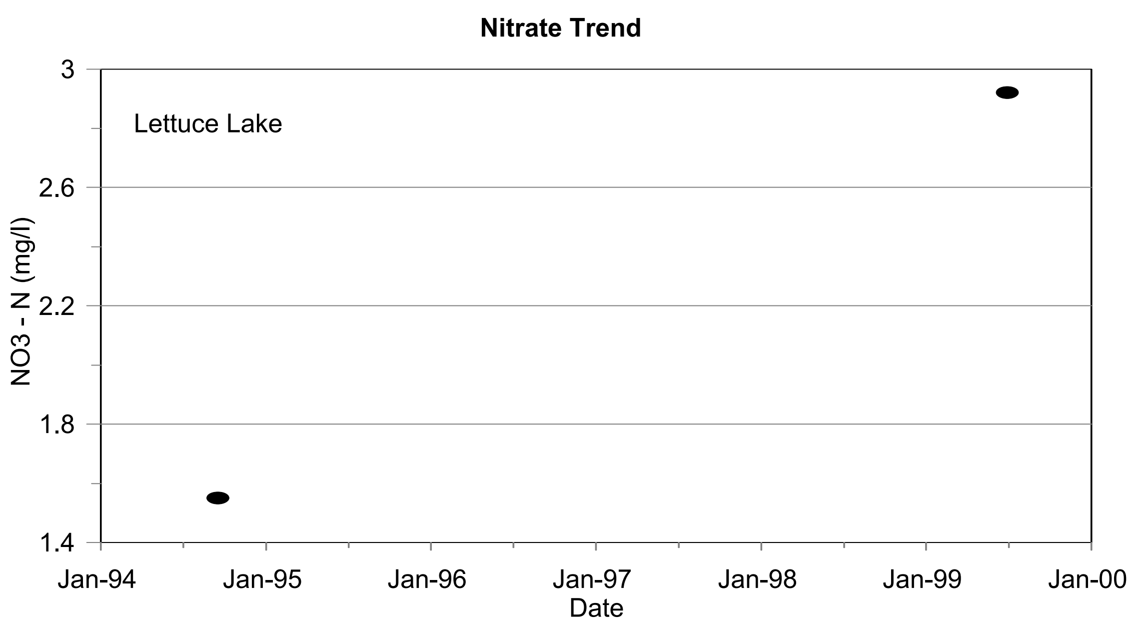
Lettuce Lake Spring

Lettuce Lake Spring is located four miles east of Tampa along the western bank of the Tampa Bypass Canal. The spring is situated along the northern property boundary of the Tampa Service Office of the SWFWMD. Flow from the spring was measured in March, 2000 and was approximately 1.1 mgd. Discharge at the spring decreased significantly upon construction of the bypass canal along Six Mile Creek.

Statistical Summary

Latitude: 280104.381
Longitude: 822100.258
County: Hillsborough
Basin: Tampa Bay
Period of Record:10/94-present

Parameter*	Value
Sample Date	7/22/99
Calcium	103.00
Magnesium	8.19
Sodium	12.40
Potassium	2.36
Bicarbonate	158.00
Chloride	22.80
Sulfate	87.80
Nitrate	3.05
Phosphorus	0.06
TDS	354.00
Temp. (^{O}C)	24.70
pH (s.u.)	7.11
Sp. Cond. (µS/cm)	571.00



SARASOTA COUNTY

Warm Mineral Springs Group

The Warm Mineral Springs group is located in southern Sarasota County near the Charlotte County line (Figure 26). Warm Mineral Springs rises two miles northeast of the Myakka River, and one mile north of U.S. Highway 41 in the community of Northport. The spring is surrounded on all sides by residential development, and is currently the site of the "Warm Mineral Springs Resort and Spa." The group is the most southerly of all large springs groups in both the SWFWMD and the State of Florida. Its unique geologic location, pre-historic artifacts and fossils makes the spring group of interest to the geologist and archeologist alike. The following paragraphs were taken from a description given by the USGS in 1977[3]:

> "The area surrounding Warm Mineral Springs is flat and about 10 ft above mean sea level. The soil is sandy and vegetative cover is sparse. Limestone crops out at the edge of the spring pool. Discharge is southwestward through a 20 ft wide run to Salt Creek and about 2 mi more to the Myakka River. The water is salty and has a sulpherous odor and taste. The spring pool has a surface diameter of about 250 ft, and water-surface elevation is about 6 ft above mean sea level. The bottom of the pool slopes gently to a depth of 17 ft, about 40 ft from shore, and then drops off sharply to a debris cone and depths of 124 ft to more than 200 feet below water surface.
>
> A cave or recessed area containing large stalactites underlies a 43 ft ledge that extends around the full perimeter of what originated as a sink, owing to collapse of a cavern in the Tampa Limestone. The 43 ft ledge and cave area is underlain by a sandy limestone and dolomite clay to 65 ft where there is a second ledge with small stalactites hanging to a depth of about 75 feet into the chamber. Clausen and others[85] cite the presence of stalactites at the level as establishing a low water level during the Pleistocene glacial epoch, to at least the 75 ft depth. The area below the orifice widens into a cathedral-shaped chamber with a diameter of about 400 ft at the 200 ft depth. Total depth of the spring appears to exceed 240 ft along the north wall, where according to Clausen and others[85], temperature of the springflow is 23°C to 37°C."

<u>Archeological Significance</u>

Prehistoric remains found underwater at Warm Mineral Springs makes the spring group unique among springs of the SWFWMD. Investigated by a team of divers in the early 1970's, the remains indicate human habitation of the area since at least 12,000 years ago[3]:

> "W. R. Royal recovered human remains from the 43ft ledge of Warm Mineral Springs which were radiocarbon dated at 10,000 $\pm$ 200 years. Florida State archeologist have excavated animal and human skeletal remains and artifacts from the spring that were similarly dated by associated leaf material[86].

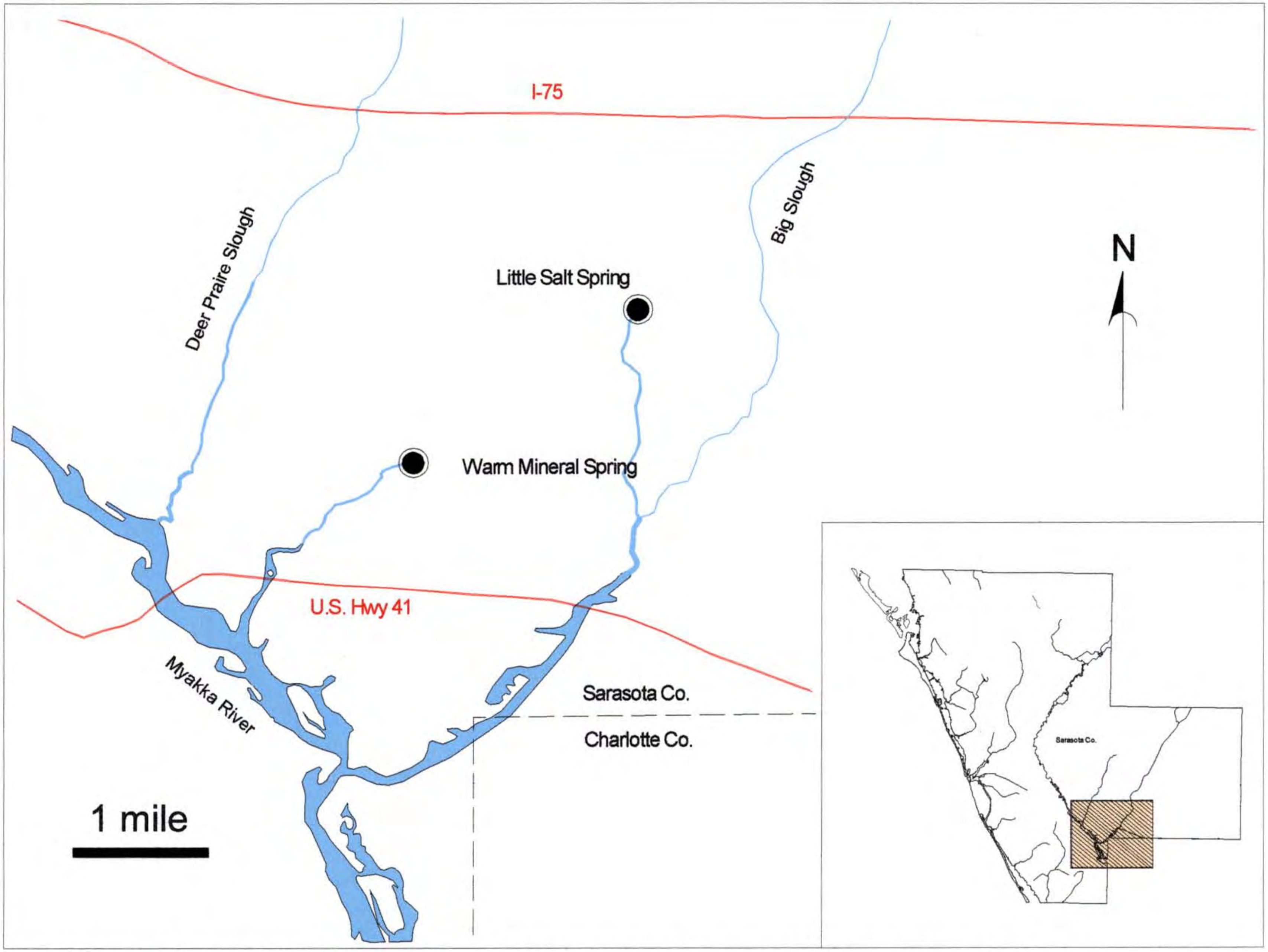


Figure 26. Location and Distribution of Springs in the Warm Mineral Springs Group, Sarasota County.

Underwater archeologists of the Bureau of Historic Sites and Properties recovered human and other skeletal remains from the easterly side of the 90 ft ledge[85]. The human remains were radio-carbon dated to an age of 5220 $\pm$ 90 yrs. Wood pins were recovered from the 35 ft depth where they had been driven into the limestone at the edge of the drop-off. Clausen and others[85] reasoned that these pins (radio-carbon age 9645 $\pm$ 160 yrs) and the presence of human remains suggested water levels were below present levels in Little Salt Spring and Warm Mineral Springs; and that these southern coastal springs are two of but a few places where fresh water was available to the inhabitants of a once dry land."

Discharge

A number of discharge measurements were taken at Warm Mineral Springs between 1942 and 1974. Those discharge measurements, listed in previous spring studies, are given below:

Warm Mineral Springs[3]

October 1, 1942	11.0 cfs
April 29, 1946	10.8
April 24, 1956	9.53
December 14, 1960	9.02
February 22, 1962	9.40
April 9, 1962	10.0
June 7, 1962	9.25
November 21, 1971	11.2
May 31, 1972	9.24

Water Quality

The water quality at Warm Mineral Springs has not been extensively studied by WQMP staff. However, the USGS does provide a brief review of water-quality data collected at the spring in July, 1992. The USGS has determined that Warm Mineral Springs discharges from the lower portions of the Upper Floridan aquifer and that the spring is a mixture of freshwater and seawater[51]. Ground-water discharge at Warm Mineral Springs is saline and typically contains greater than 10,000 mg/l TDS. Chloride concentrations in the spring are generally greater than 400 mg/l. Sulfate concentrations, however, are more than double the chloride values and may be greater than 1,000 mg/l. This indicates that the spring is affected by the inner margin of the coastal transition zone where sulfate is upwelling from deeper portions of the Floridan aquifer.

Warm Mineral Springs

The area surrounding Warm Mineral Springs is flat, and about 10 feet above mean sea level. Limestone crops out at the edge of the spring pool. Discharge is southwestward through a 20 foot wide run to Salt Creek and about 2 miles more to the Myakka River. The spring pool has a surface diameter of about 250 feet, and water-surface elevation is about 6 feet above mean sea level. The bottom of the pool slopes gently to a depth of 17 feet, about 40 feet from shore, and then drops off sharply to a debris cone and depths of 124 feet to more than 200 feet below water surface(3).

Statistical Summary

Latitude: 270334.467
Longitude: 821537.414
County: Sarasota
Basin: Manasota
Period of Record: 6/95 -present

Parameter*	Value
Sample Date	07/01/98
Calcium	488
Magnesium	517
Sodium	4,750
Potassium	166
Bicarbonate	135
Chloride	488
Sulfate	1,500
Iron	0.130
Silica	8.65
TDS	17,080
Temp. (^{O}C)	29.1
pH (s.u.)	7.12
Sp. Cond. (µS/cm)	25,700

* mg/l unless noted otherwise

INACTIVE SPRINGS

POLK COUNTY

Kissengen Spring

Located in central Polk County, Kissengen Spring lies approximately four miles southeast of Bartow on the western bank of the Peace River (Figure 1). The land surrounding Kissengen Spring is dominated by phosphate mining, some of which has been deactivated and reclaimed. Citrus production occurs sporadically in the area and is interspersed with low-density residential land uses.

Once popular with tourists and residents of the Bartow area, Kissengen Spring has been abandoned for nearly 50 years. The spring and associated recreational structures (e.g., buildings, dock and beach area) have been destroyed and/or overgrown, and are no longer recognizable. However, a berm and remnants of a spillway that enclosed the spring can still be found at the spring (Figure 27). The spring pool, now filled with clayey sediment and organic debris, is dry and may no longer be able to function as a spring.

Figure 27. Kissengen Spring during a site visit in May, 1999. The remnants of the spillway can be seen on the extreme left of the photo (next to the arrow). Also notice the dry depression in the foreground where the spring once was located.

A brief description of the decline, and eventual cessation of flow at Kissengen Spring was provided by the USGS in the late 1970's[(3)]. A portion of that description is reproduced below:

"Kissengen Spring was the first known major spring to cease flowing in Florida because of ground-water withdrawals from wells. Kissengen Spring ceased flowing in February 1950 after a 40-year low record of 15 ft^3/s or more. Although declining in average annual flow when described by Ferguson and others in 1947[(87)], the spring was an active recreational facility. Three years later the spring was dry. H.M. Peek[(88)] ascribed the cessation of flow to increased pumping of water from the Floridan aquifer-'an example of the capture of natural discharge of ground water by the withdrawal of water from wells.' The spring site is no longer (1975) recognizable owing to phosphate mining. Kissengen Spring discharge measurements have been made by the U.S. Geological Survey[(89)]. The maximum known discharge of 28.2 Mgal/d (43.6 ft^3/s) occurred in October 1933."

HILLSBOROUGH COUNTY

Eureka Springs

Eureka Springs lies approximately four miles east of Tampa near the eastern bank of the Tampa Bypass Canal (Figure 24). Flow at Eureka Springs decreased significantly with construction of the Tampa Bypass Canal, eventually ceasing to flow as ground water discharged into the canal. The land surrounding Eureka Springs is predominantly residential, but some light industrial and aquaculture land uses are located near the springs. The interchange of I-4 and U.S. Hwy 301 lies about a half a mile southwest of the springs.

Rosenau and others[(3)] described Eureka Springs in 1977:

"There are 4 springs in the group and all are within the upper reach of Six Mile Creek basin. They are designated as Eureka Tributary Springs 1, 2, 3, and 4. The springs are in a flat, low canaled area; their pools discharge through short spring runs, and merge into one major run. This major run flows south, and a short distance downstream joins the flow from the Tampa Bypass Canal, formerly Six Mile Creek. None of the springs were flowing when visited on May 21, 1971 and on June 1, 1972.

Tributary Springs:	1	2	3	4
		Discharge (cfs)		
April 28, 1969	2.11	0.46	0.81	-
September 17, 1969	2.60	0.14	0.22	-
March 25, 1970	2.68	0.55	0.49	-
November 12, 1970	1.86	0.12	0.00	-
October 13, 1971	1.51	0.30	0.62	0.29
October 20, 1972	0.63	0.006	0.00	0.00
May 18, 1973	1.26	0.12	0.02	0.17

Eureka Springs are part of a County Park featuring a botanical garden of tropical plants from around the world. Tropical fish farms were once abundant in the area outside the park where fish were raised in shallow pools fed by water from flowing wells tapping the same aquifer that feeds the springs."

Six Mile Creek Spring

Six Mile Creek Spring was located in a low swampy area when described by the USGS in the 1970's. The spring flowed west to Lettuce Lake Spring and then south to Eureka Springs. Construction of the bypass canal altered this flow regime, and like other springs in the group, flow was decreased due to ground-water flow into the canal. A county sanitary landfill (now closed) is immediately south of the spring. Discharge measurements reported by the USGS indicate that the spring had an average discharge of approximately 1 mgd historically[(3).]

Two other springs in Hillsborough County, Palma Ceia and Purity Springs, are reported to be inactive. Palma Ceia Spring was located in the upper portion of Hillsborough Bay near Bayshore Boulevard and Barcelona Street. A small County park is currently situated on the site of the spring; however, no visible sign of the spring basin remains. Purity Springs was located several hundred feet west of Sulphur Springs in north Tampa on the northern bank of the Hillsborough River. The spring was enclosed in a protective structure in the early 1900's and ceased flowing as development encroached on the spring basin. Both springs were discharging at 42 gallons per minute on May 1, 1946[(3)].

PASCO COUNTY

Seven Springs

Seven Springs (also known as Sisters Spring) in western Pasco County is no longer active. Historically, the spring discharge was between 2 and 20 gallons per minute; however no flow was reported in April 1962 and later in May and October 1972[(3)]. A site visit in May 2000 revealed that a concrete bunker and discharge pipe constructed over the spring (date of construction unknown) were still intact more than twenty years after site visits by the USGS in the mid to late 1970's. As expected, no flow was observed at the spring.

PINELLAS COUNTY

Phillippi Spring

Rosenau and others[(3)] described Phillippi Spring in 1977:

> “This offshore spring is about 200 ft E. of the west shore of Safety Harbor, about 5 mi E. of Dunedin, 0.2 mi S.E. of the north gate of Phillippi Park and 1.2 mi SE. of the junction of State Hwy 580 and State Hwy 590. A concrete curb 3 ft in diameter and 2 ft high has broken off on the shoreward side to about 0.4 ft above the filled land surface. The spring ceased flowing because persistent vandalism filled the opening with rocks and trash more frequently than park personnel could remove it. The spring flowed as late as 1940 at about 10 gal/min.; the water tasted salty.”

SUMMARY

Hundreds of springs lie within the boundaries of the Southwest Florida Water Management District (SWFWMD or District)[3]. While some of these springs are isolated features, many are clustered into groups, or spring groups, of varying size and areal extent. Large spring groups, such as Rainbow Springs in southwestern Marion County, drain large areas, often draining tens or even hundreds of square miles. In addition, springs throughout the SWFWMD create an ideal environment by which to study and monitor ground-water quality in the Upper Floridan aquifer.

The largest concentration of springs in the SWFWMD can be found in the northern half of the District, where the Upper Floridan aquifer is unconfined and relatively close to the land surface. Because soluble limestones of the Upper Floridan aquifer occur close to the land surface and are not covered by continuing clay layers, the northern half of the District has developed into a karst landscape. This landscape is characterized by an abundance of sinkholes, sinking streams, underground caverns, and springs. Five of Florida's first magnitude largest springs lie within the SWFWMD. Rainbow Springs is, in fact, one of the largest springs in the world[3]

Prior to development, much of the springs region was covered by high pine forests, hammock forests, and pockets of scrub[7]. Over time, this natural vegetation was replaced by agricultural lands, including livestock pastures, row crops, and citrus. However, over the last several decades, urban development has increased dramatically in the region and altered much of the rural landscape. Thousands of acres of commercial and urban development, including residential areas and golf courses, are spreading rapidly across the region as population continues to grow in the vicinity of the springs.

Water-quality studies conducted within the SWFWMD have shown that nitrate concentrations have been increasing in a number of springs throughout the northern portions of the District. This nitrate, derived primarily from inorganic fertilizers, has leached into the Upper Floridan aquifer within the last 20 years and is now being discharged at springs across the region[9,10,11,12,13]. With population in the SWFWMD expected to reach 4.6 million by the year 2010[8], this situation can only become more serious.

It is estimated that springs in the SWFWMD discharge more than 1,000 mgd (one billion gallons per day) of water from the Floridan aquifer[3], and that prior to development, accounted for over 80% of the ground-water discharge from the Floridian aquifer. As development has occurred, however, this percentage may have decreased due to ground-water withdrawals in the region[43]. Ground-water discharge from the Floridan aquifer is important to springs in the region for several reasons: 1) it provides the springs with adequate ground-water supplies to maintain flow; 2) it is an important component of many aquatic and terrestrial ecosystems throughout the region; and 3) it is an ideal barometer by which to gage the water quality of the Floridan aquifer over large areas (tens to hundreds of square miles).

Springs throughout the District exhibit seasonality in discharge as rainfall recharges the Floridan aquifer inland of the springs. This recharge causes water levels in the aquifer to rise and the spring discharge to increase. Studies by the USGS have shown that spring flow along the coast of Citrus and Hernando Counties can vary considerably during the year[(46)]. A number of other springs throughout the SWFWMD exhibit similar variations in discharge as well, with lowest flows occurring late in the dry season (May/June) and highest flows occurring late in the wet season (Sept./Oct.).

From numerous water-quality samples collected since 1991, it is apparent that the springs can be divided into two major groups: group A and group B. Group A springs discharge a variety of water types including: 1) calcium-bicarbonate rich ground water derived from aquifer recharge, 2) sodium-chloride rich ground water derived from salt-water influences, and 3) mixtures of fresh and saline ground water. Group A springs discharge ground water that is strongly influenced by the dissolution of limestone inland of the salt-water transition zone; however, as ground water nears and moves into the transition zone, mixtures of fresh and saline ground water are produced. Group A springs may eventually discharge saline ground water that has intruded inland toward the springs.

Group B springs discharge sulfate-rich ground water. This enrichment reflects the upwelling of sulfate along the inner margin of the coastal transition zone and in highly fractured areas inland of the coast. Group B samples occur sporadically throughout the SWFWMD, but are concentrated at Gum Slough Springs and Lithia/Buckhorn Springs, and to a lesser extent at Rainbow and Panasoffkee Spring groups. Ground water discharging from Warm Mineral Springs is enriched in sulfate due to the deep flow path taken by the ground water through the Floridan aquifer prior to reaching the spring[(51)].

Spring waters throughout the District reflect the dissolution of limestone in the Floridan aquifer. Ground water discharging from the springs is generally dominated by calcium-bicarbonate, except along the coast where the coastal transition zone becomes an important influence on water quality. In addition, the pH of spring water typically varies between 7 and 8, indicating that the ground water is at or near chemical equilibrium with limestone in the Floridan aquifer.

Except near the salt-water transition zone, springs throughout the District have chloride concentrations that reflect rapid recharge to the Floridan aquifer. As one approaches the coast, however, the transition zone increases chloride in the ground water dramatically. A good example of this may be found at the King's Bay Springs group where chloride concentrations in the springs may range from less than 10 mg/l to greater than 1,000 mg/l across the bay at low tide.

Sulfate concentrations in most spring waters are low enough to indicate that the flow system in the Floridan aquifer is shallow (probably within the upper 200-300 feet of the aquifer). In addition, the residence time of ground water in the system is short, and upwelling from the deeper flow system is not occurring in many springs. Several inland spring groups, however, discharge ground water that contains elevated amounts of sulfate. This sulfate is most likely derived from localized upwelling of sulfate in the immediate vicinity of the springs.

TDS concentrations vary among spring groups in the District as well as within a given spring group. This is especially important in coastal springs where the freshwater/saltwater transition zone strongly influences ground-water quality (e.g., King's Bay Springs). TDS concentrations also vary significantly in tidally influenced springs where TDS may vary several thousand milligrams per liter over a given tidal cycle[36].

Nitrate concentrations in spring waters have been a concern in the SWFWMD (as well as other regions of Florida) for a number of years. Increased levels of nitrate are detected at many springs in the District, and may be responsible for the increased growth of nuisance aquatic vegetation such as Lyngbya (a filamentous cyanobacteria) in spring runs throughout the region. Since 1991 a number of ground-water studies have been conducted throughout the northern portions of the SWFWMD in an effort to determine the source(s) of nitrate in the spring water[9,10,11,12,13]. These studies have shown that most of the nitrate discharging from springs in the SWFWMD is derived from inorganic fertilizers. This nitrate was applied to a variety of land uses inland of the springs decades ago as fertilizer for pastures, residential lawns, golf courses, and/or citrus groves.

Nitrate concentrations in spring water throughout the District range from below detection limit (<0.01 mg/l) to slightly greater than 3.0 mg/l. All of the spring samples are well below the primary drinking water standard established by the FDEP for nitrate, 10 mg/l[53]. One exception, however, is Bell Creek Spring in central Hillsborough County. This spring discharges ground water that typically contains nitrate levels in excess of the 10 mg/l drinking water standard. Bell Creek Spring discharges approximately 0.03 mgd and is affected by nitrate derived from a local animal-waste source[9,54].

The temperature of spring water throughout the district should reflect the average annual air temperature in the vicinity of the springs. Mean annual air temperatures in the District range from 22-23°C (71-74°F) from north to south across the SWFWMD[16,57]; springs in the District typically have temperatures that range 23-25°C. The lowest spring temperatures are often found in the extreme northern portions of the District (e.g., Rainbow Springs) where recharged may be rapid and somewhat cooler in temperature. The warmest spring temperatures, not counting Warm Mineral Springs in southern Sarasota County, occur in Central Hillsborough County at Sulphur and Lithia Springs. These springs have temperatures that are typically near 25°C which is slightly elevated above the mean annual air temperature measured in Hillsborough County, 22°C (72°F)[58]. This difference in temperature may reflect slightly deeper flow paths taken by ground water through the Floridan aquifer.

Ground water discharging from Warm Mineral Springs is typically near 30°C[3,51], while the mean annual air temperature in Sarasota/Charlotte County is 25°C[57]. Therefore, the anomalously warm ground water flowing from Warm Mineral Springs does not reflect the average annual air temperature in southern Sarasota County. Studies have shown that Warm Mineral Springs is a deep-seated spring that discharges water from more than 1,200 feet below the land surface[51]. Its spring water has traveled deep into the Floridan aquifer and has been warmed by the geothermal gradient within the limestone.

Most of the springs in the SWFWMD have not been sampled for tritium. This is because a number of investigations have already determined that ground water in the shallow portion of the Floridan aquifer has entered the aquifer very recently(11,59,60). In the Rainbow Springs area, for example, tritium activities in wells and springs were as high as 174 TU at the same time (1966-68) that rainfall contained activities as high as 158 TU. In addition, tritium activities in Rainbow and Silver Springs ranged from 38 to 85 TU and 25 to 150 TU, respectively. This indicates that a large percentage of the water discharging from Rainbow and Silver Springs in 1966-68 could not have been in the flow system for more than 16 years(11).

Studies conducted by the USGS in the late 1980's indicate that tritium activities in the Floridan aquifer ground water in the northern half of the SWFWMD reflect relatively recent recharge, with activities of 8 to 10 TU common. The studies strongly implicate rapid recharge to the Floridan aquifer, with subsequent flow of ground water toward the coastal springs(60).

Twenty-nine springs in the SWFWMD were sampled for uranium isotopes between 1992 and 1999. Most of the spring samples have the low activity ratios (<1.0), and high concentration signatures (>0.1) characteristic of ground water that has recharged rapidly and traveled a relatively short distance (more than several thousand feet) in a shallow flow system. This is consistent with the tritium interpretations which indicate shallow, rapid flow in the karst limestones of the Floridan aquifer.

Based on uranium concentrations and similar activity ratios, spring samples in Citrus and Hernando Counties were grouped into two main clusters; a northern cluster (Citrus County), and a southern cluster (Weeki Wachee and Aripeka). The differentiation of springs along the coast is possibly related to differences in the uranium content of the Hawthorn Group sediments in the northern and southern portions of the Brooksville Ridge(12). A similar differentiation was identified at Rainbow Springs in Marion County where three separate geographic regions appeared to contribute ground water to the spring group(11,65).

Twenty-four springs in the SWFWMD were sampled for nitrogen isotopes between 1991 and 1999. The nitrogen isotopic ratios found in spring waters throughout the District range from 0.7 and 18.1 $^{\circ}/_{\circ\circ}$. As stated previously, ratios that fall between the +2 to +8 $^{\circ}/_{\circ\circ}$ range could be attributable to natural oxidation of organic materials in soil(68). However, this is unlikely because the nitrate concentrations in the springs are too high to have originated from natural sources.

Over 80% of the nitrogen-isotopic ratios reported in the SWFWMD since 1991 are below 6.2 $^{\circ}/_{\circ\circ}$. This indicates that inorganic fertilizers are the most significant source of nitrate in the springs region. Much of the fertilizer appears to be derived from: 1) subdivisions and golf courses near the coastal springs(13), 2) pasture fertilization in the vicinity of Rainbow Springs(11), and 3) fertilization of citrus in the vicinity of Crystal, Lithia and Buckhorn Springs(9,13). Less than 10% of the nitrogen-isotopic ratios are between

6.2 and 9.3 °/∘∘. These ratios indicate that a mixing of inorganic fertilizer nitrogen and animal waste nitrogen, with animal waste nitrogen being the dominant component, is likely occurring at some springs. Three samples collected at Bell Creek Spring in central Hillsborough County were consistently above 10 °/∘∘ (the lower end of the animal waste range[66,67]), indicating that this spring is influenced by nitrate derived from animal-wastes sources[9,54].

Based on increasing nitrate trends and nitrogen isotopic data, it should be apparent that water quality in the Upper Floridan aquifer is already affected by land-use practices within the springs region. Fertilizers that have been applied to urban and agricultural land-use settings near the springs have leached nitrate into the Floridan aquifer. This nitrate has traveled slowly through the aquifer and is now beginning to impact water quality at the springs. In addition, due to the slow movement of ground water through the aquifer (diffuse flow), water-quality changes have been subtle, and even though land uses may have changed in the intervening decades, nitrate continues to discharge from the springs.

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