Blue Spring – Volusia County Water Quality Summary

"Blue" is the most common name given to springs in Florida, due to their naturally clear blue water. Blue Spring in Volusia County (also known as Volusia Blue) is the largest of the state's springs named "blue." The only natural winter refuge for the federally endangered West Indian manatee on Florida's east coast, the spring has been designated by the U.S. Fish and Wildlife Service as a critical habitat for the species.

Spring Location and Characteristics

Volusia Blue Spring lies six miles southwest of DeLand, in Volusia County. It is located in Blue Spring State Park, which covers 2,600 acres. The springshed covers an area of 130 square miles and encompasses portions of five cities in Volusia County. This first-magnitude spring and the largest spring on the St. Johns River, Blue Spring discharges an average of 102 million gallons of water each day. The spring is about 20 feet deep over its single vent. The spring pool is nearly circular, with a visible boil in the center (Figure 1). It is flanked by dramatically steep banks on three sides, with an overlook constructed near the vent. The water is clear and blue with a greenish tinge, and algae are ubiquitous in both the spring and spring run. Both the spring pool and spring run bottoms are mostly limestone and sand, with limited vegetation along the shoreline. The spring run has steep, sandy banks and flows almost half a mile to the St. Johns River through a thick native forest of cabbage palms and oaks.

An underwater cave system has been mapped at Blue Spring, but it is very difficult and dangerous for divers to enter the cave through the spring due to the strong outward flow of ground water.

For centuries, the spring area was home to Native Americans. It contains a prehistoric shell midden that was used as a house site by European settlers in the late 1800s. In 1776, the explorer and botanist John Bartram wrote that the water in the spring run "smelled like bilge water, tasting sweetish and loathsome, warm and very clear . . . [T]he springhead is about 30 yards broad, and boils up from the bottom like a pot . . ." Other early visitors also described the water as sulfurous.

Scientists now understand that Blue Spring, along with other springs on the St. Johns River, is fed by relict seawater in the region's ground water. The resulting water discharging from the spring vent is a combination of relatively young fresh water and older salt water; current water quality may thus be affected by water that entered the aquifer as much as 100 years earlier.

Biology

Blue Spring is the only natural winter refuge for the federally endangered West Indian manatee on Florida's east coast and has been designated by the U.S. Fish and Wildlife Service as a critical habitat for the species. The manatees congregate in large numbers in the spring and spring run during the winter months, when the spring water is considerably warmer than the water of the St. Johns River (Figure 2). These huge, gentle animals, averaging 1,000 pounds, eat only aquatic plants. They cannot survive for extended periods in water colder than about 63℉. From mid-November to mid-March, the spring and run are closed to swimming and boating. The boardwalk that parallels the spring run provides one of the best views in Florida of manatees in their natural habitat. Since the mid-1980s, the winter population of manatees has increased almost fivefold, from fewer than 60 to more than 250 individuals in both the 2005–06 and 2006–07 winter seasons. The manatee count reached as high as 371 individuals during the 2010 hard freeze, giving park visitors a spectacular viewing experience.

In addition to manatees, two species of aquatic snails (the Blue Spring silt snail) found in the spring and spring run are endemic, meaning that they exist nowhere else in the world.

Nutrient enrichment in the spring and spring run have led to eutrophic conditions, or accelerated aging. Filamentous algae such as the blue-green cyanobacteria *Lyngyba* have replaced a majority of the native submersed aquatic vegetation (SAV). These organisms can release toxic substances, deter grazing, and smother vegetation and macroinvertebrate habitat. Overall habitat assessment scores for the spring and spring run are suboptimal, and the Stream Condition Index score, a measure of biological health, ranges from "poor" to "very poor."

Land Use

Land use in the springshed has changed substantially in the last 50 years, from a predominantly rural and agricultural area to one with increasing high-intensity development. The human population has grown about 25% since 2000 and is currently about 155,000. In 2000, almost 60% of the springshed that provides the ground water for Blue Spring was urban, with forested areas covering about 24%. Concurrently with the shift in land use, the spring has experienced an overall decrease in spring flow, increased nitrate concentrations, diminished water clarity, and degraded aquatic habitat.
In 2010, the swimming area at Blue Spring State Park was closed for almost two weeks because of elevated levels of *E. coli* and total coliform bacteria. The closure—the first in five

years—was thought to be caused by rainfall flushing bacteria from the springshed into the swimming area.

Restoration/Protection Efforts

Given the importance of this spring for both human and nonhuman visitors (especially manatees), efforts are under way to protect and restore both the quality and quantity of water discharging from the spring. The St. Johns River Water Management District formed the Blue Spring Minimum Flow Interagency Working Group, which in 2006 developed a minimum flow regime for Blue Spring designed to protect and preserve the amount of water needed for manatees to shelter during cold spells. Long-term average spring flows are being raised at five-year intervals to accommodate an increase in the manatee population of about 7% each year, until a goal of 157 cubic feet per second in spring discharge is reached in 2024.

As part of the implementation of minimum flows, the water management district is carrying out a number of different activities to inventory ecological resources in the spring and spring run, to better understand the dynamics of the manatee population, and to document the effects of human land uses and other factors influencing water quality and quantity.

Because the minimum flow regime limits the amount of ground water that can be used in the springshed, residents and businesses alike are looking at alternative sources of water and at increased water conservation. As part of this effort, Volusia County's water authority is planning to construct at least one surface water treatment plant on the St. Johns River to meet new water supply needs. It will also enforce consumptive use permit rules to ensure that minimum flows are maintained in the spring and spring run.
The Florida's Wildlife Legacy Initiative of the Florida Fish and Wildlife Conservation Commission, supported by the Florida Department of Environmental Protection ("Department"), formed the Volusia Blue Springs Alliance working group in 2008. Local governments and other stakeholders in the springshed have met quarterly since then to provide a forum for stakeholders to learn about the spring ecosystem and threats to its health, to understand why the local community values the springs, and to work together on projects to conserve and restore the spring and the spring-run stream.

In 2005, the U.S. Environmental Protection Agency verified that Blue Spring was impaired for nutrients—meaning that increased nutrient concentrations were causing an imbalance in natural populations of aquatic plants and animals. The EPA established a Total Maximum Daily Load for the spring in the form of a 91% reduction in nutrients. A TMDL is the maximum amount of a given pollutant that a waterbody can assimilate and still meet water quality standards. The restoration of ecological health in the spring and spring run depends heavily on the active participation of stakeholders in the springshed, who are required to develop projects to reduce nutrient concentrations.

In 2014, a revised TMDL document addressing nutrient impairment in Blue Spring and Blue Spring Run was developed by Department staff (Holland et al, 2014). The Department is currently developing a Basin Management Action Plan for Blue Spring that includes nutrient reduction allocations among stakeholders in the springshed, projects to achieve specific reductions, timelines for initiating and completing projects, identification of funding opportunities, agreements, local ordinances, local water quality standards and permits, and follow-up monitoring.

In 2004, the Department replaced the septic system at the park ranger residence with a connection to the local municipal sewer system to reduce the amount of nutrient contamination reaching the springs.

Water Quality

Volusia Blue Spring is a first-magnitude spring, discharging ground water from the upper Floridan aquifer system. It has been sampled for major ions and nutrients at least as far back as 1960 by the U.S. Geological Survey (USGS), more recently by the St. Johns River Water Management District (SJRWMD), and quarterly by the Department and SJRWMD since 2002 for a large number of analytes, including major ions, nutrients, field analytes, and salinity indicators. Table 1 summarizes these results for selected analytes.

Like many Florida springs, nitrate levels in Blue Spring have been trending upward over the last half century, with mean values increasing from around 0.15 milligrams per liter (mg/L) in the late 1970s to around 0.50 mg/L during the 2000s. During the same period, the predominant land use in the Blue Spring springshed has transitioned from primarily silviculture to single-family residential. The Department has determined that nitrate concentrations above 0.35 mg/L indicate potential waterbody impairment; this number is based on recent research conducted in Florida spring waters, which found that some of the most prevalent species of algae proliferate when nitrate levels exceed that concentration. Excessive amounts of algae can smother essential habitat for fish and other wildlife, displace native plants, and deplete the amount of DO in the water.

Nitrate + nitrite concentrations have shown considerable variability in the range of measured values since 2002, likely due to aquifer recharge effects during periods of above-average rainfall. This can be seen when one superimposes nitrate + nitrite values with monthly precipitation measured at DeLand, the closest rainfall station to Blue Spring. This relationship is illustrated in Figure 3, which clearly shows the correlation between high rainfall events and spikes in nitrate concentrations. High rainfall events can carry additional nutrients from surface sources down into the Floridan aquifer system, and from there to the spring vent. This relationship also indicates that a significant percentage of the discharge waters emanating from Blue Spring comprise relatively young ground water; this conclusion is also supported by isotopic age-dating (SJRWMD, 2013).

Plotting the ratios of nitrogen isotopes versus oxygen isotopes in nitrate measured from ground water can reveal whether the likely nitrate sources are inorganic (chemical fertilizers) or organic (wastewater, septic discharge, animal waste) (Roadcap *et al.* 2002). Nitrogen and oxygen isotopes were analyzed from samples collected quarterly from Blue Spring in 2011 and early 2012; the results show a distinct denitrification trend, accompanied by low DO values measured in the field at the same time the samples were collected (mean DO value = 0.38 mg/L). From these data, the predenitrification isotopic signature indicates a predominantly inorganic nitrate source.

The other macronutrient of concern in Florida surface waters, orthophosphate, is only present in low concentrations at Blue Spring (Figure 3). Based on data presented by the SJRWMD, long-term trends indicate that concentrations have not increased over time. Elevated orthophosphate levels are problematic in many of Florida's lakes and rivers due to surface runoff; however, orthophosphate is generally not an issue in springs due to its attenuation within limestone aquifers. Given enough time, orthophosphate reacts with calcium carbonate to produce low-solubility calcium phosphate minerals that remain within the host rock (Brown, 1981). This effectively removes orthophosphate from the waters within the aquifer, and is the probable geochemical mechanism by which "hard rock" phosphate deposits have developed in the state.

Salinity indicators (sodium, chloride, sulfate, and specific conductance), while showing an apparent increasing trend during the last decade (Figure 4), have not significantly increased over the longer period from the 1960s to the present (SJRWMD). Long-term data show years to decade-long periods of cyclic increases and decreases in salinity indicators, but overall mean concentrations have remained fairly steady over the last half century.

Area long-term precipitation data for the period from 1950 to 2012 show a slightly increasing trend at DeLand of about 0.125 inches per year (1950 to 2008) but a slightly decreasing trend during the last decade (Florida Climate Center 2012).

Long-term increases in salinity indicators reflect the potential upconing of deeper, more saline ground water due to increasing fresh ground water withdrawals from shallower portions of the Floridan aquifer system, decreasing precipitation patterns, or a combination of these two causes. The shorter-term precipitation trends shown in Figure 3 appear to be inversely correlated with the salinity indicator trends shown in Figure 4, with high rainfall episodes resulting in depressed salinity indicator values. This relationship reflects higher aquifer recharge from the land surface during periods of heavier precipitation, indicative of fresh water from rainfall comprising a larger portion of Blue Spring discharge following these rainfall events.

DO levels are important for fish and other biota, and are generally measured at levels below 5 mg/L in fresh ground water issuing from spring vents. The levels measured in Blue Spring (Table 1) are within this normal ground water range. Some fish species can tolerate lower DO levels, and thrive in spring vent environments. DO levels generally rise rapidly in surface waters downstream from spring vents, due to plant respiration; however, Blue Spring Run is largely devoid of submerged aquatic vegetation (SAV) other than some species of filamentous algae.

Boron, not known to occur naturally in high concentrations in fresh Floridan aquifer system ground water, has recently been sampled as a possible wastewater tracer in wells and springs, due to its widespread use in laundry detergents. Low concentrations of boron do occur in seawater; therefore, the ratio of boron to chloride (which is constant in seawater) is observed to determine if elevated boron is present. This is based on the assumption that chloride concentrations measured in springs are of oceanic origin.

The boron – chloride ratio from Blue Spring (Table 1) calculated from 16 boron samples collected vs. the historic mean chloride value was 0.000237. This value is very close to the mean boron/chloride ratio measured in Atlantic Ocean seawater sampled along the U.S. coastline from south of Cape Cod to Bermuda, which is 0.000240 (Rakestraw et al, 1935). If one assumes that boron/chloride ratios in the Atlantic Ocean are similar to the boron/chloride ratios of the relict seawater entrained in Floridan aquifer system ground water, these numbers indicate no enrichment of boron in Blue Spring ground water. The measured boron concentrations in Blue Spring are likely due to elevated salinity indicators, resulting from relict seawater trapped within the Floridan aquifer system during the last interglacial high sea stand during the mid-Pleistocene, about 120,000 years ago (Muhs *et al.* 2009). Most low-elevation springs discharging into the St. Johns River Basin have elevated salinity indicators compared with other non-coastal Florida springs.

Sucralose is used as an artificial sweetener. Because it passes through water treatment systems largely intact, it has recently been used as a potential human wastewater tracer. Low levels of sucralose detected in samples from Blue Spring collected during 2012 are indicative of possible wastewater influences within the springshed.

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Figure 1: Blue Spring main vent – view west (Tom Scott – FGS/FDEP)

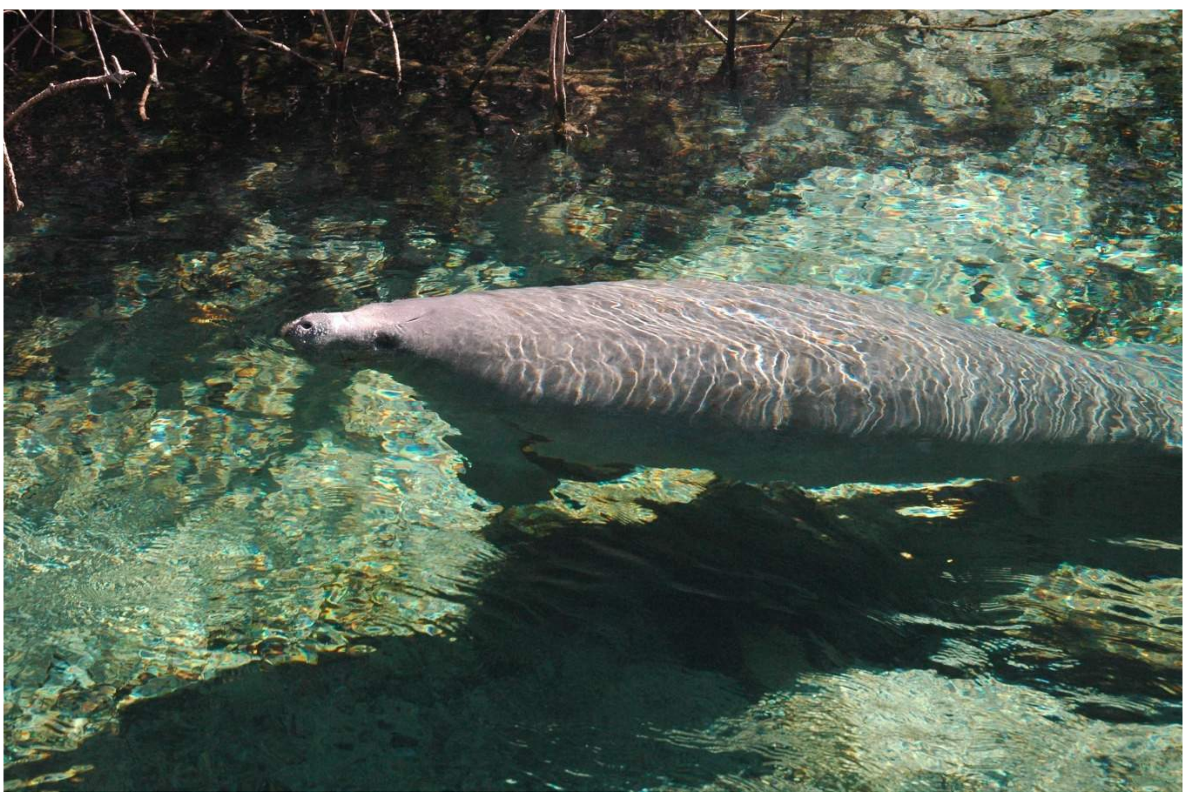
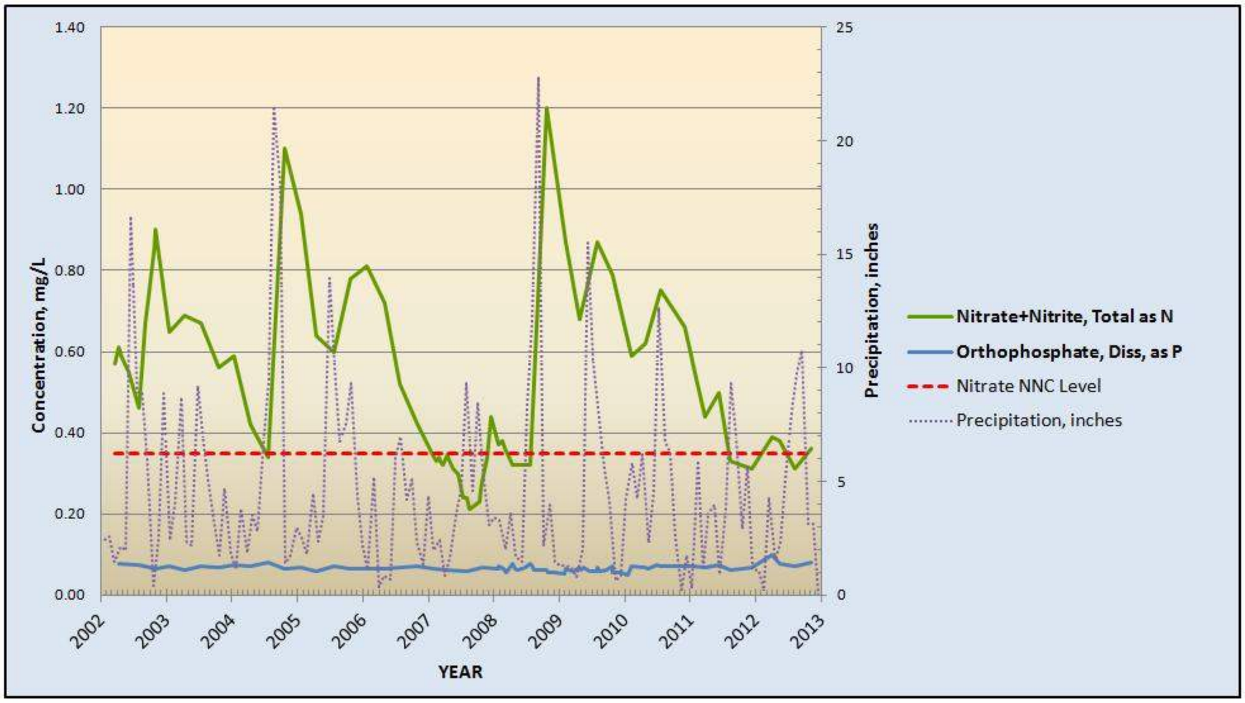


Figure 2: West Indian Manatee in Blue Spring Run (FGS/FDEP)



µmhos/cm = Micromhos per centimeter
NNC = Narrative nutrient criterion

Figure 3: Macronutrient trends in Blue Spring, shown with DeLand monthly precipitation, 2002–12

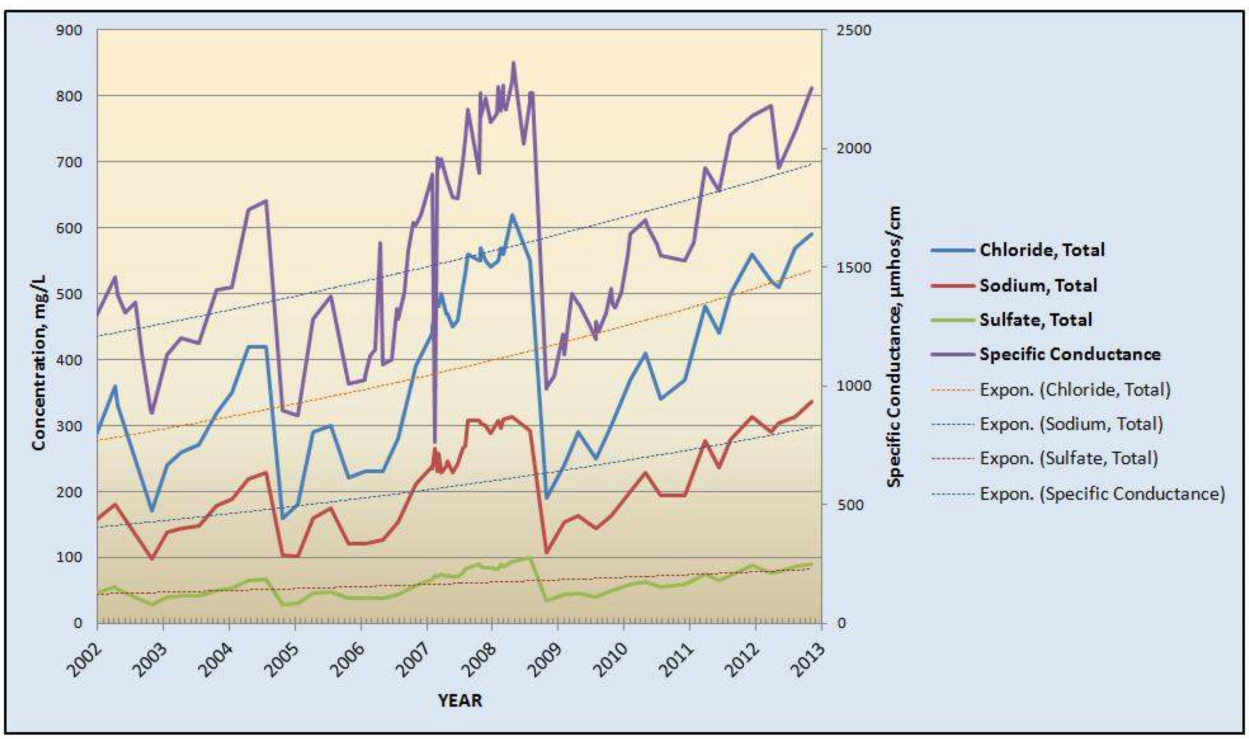


Figure 4: Salinity indicator trends in Blue Spring, 2002–12

	ANALYTE	PERIOD OF RECORD	UNITS	NUMBER OF SAMPLES	HISTORICAL MEAN	HISTORICAL MEDIAN	RECENT MEAN (LAST 4 QTRS)	RECENT MEDIAN (LAST 4 QTRS)
Macronutrients	**Nitrate+Nitrite, Total (as N)**	2002 - 2012	mg/L	64	0.515	0.440	0.360	0.370
	Orthophosphate, Diss (as P)	2002 - 2012	mg/L	69	0.066	0.066	0.082	0.078
Salinity Indicators	**Sodium, Total**	2002 - 2012	mg/L	57	222	229	312	309
	Chloride, Total	2002 - 2012	mg/L	59	411	440	548	545
	Sulfate, Total	2002 - 2012	mg/L	58	64.0	66.5	83.0	82.5
	Specific Conductance	2002 - 2012	µmhos/cm	100	1605	1584	2107	2128
	Dissolved Oxygen	2002 - 2012	mg/L	97	0.71	0.48	0.47	0.46
Wastewater Tracers	**Boron, Total**	2002 - 2012	µg/L	16	97.6	103.0	121.0	120.0
	Sucralose, Total	2012	µg/L	4	NA	NA	0.124	0.110

NA = *Not analyzed*

Data from Florida Department of Environmental Protection & Volusia County Environmental Health Laboratory (STORET)

Table 1: Summary of selected water quality results for Blue Spring