Volusia Blue Spring Restoration Plan

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Executive Summary

Florida springs are among Florida's most valued natural resources and protection of these water bodies is a benefit shared by the environment and the people who visit and live amongst theses natural wonders (German, 2008). Alterations of spring habitat and changes in water quality affect the appearance and function of springs. Florida springs have an important role in recreation but are also unique and valuable ecosystems that are found nowhere else in the world. The goal of this restoration plan is to mitigate the impaired condition of Blue Spring by implementing feasible management practices that ultimately benefit the general population and return Blue Spring to its historical condition.

Water quality in a spring generally will reflect the overall conditions of the underlying aquifer and can be altered by the quality of water recharging the aquifer (Cervone, 2003). Water quality parameters of significance include; water temperature, pH, dissolved oxygen, specific conductance, total nitrogen, and total phosphorus.

One of the most famous inhabitants of Blue Spring State Park is the West Indian Manatee (_Trichechus manatus latirostris)_**. The constant water temperature of the spring attracts hundreds of manatees every winter seeking warm water refuge. Blue Spring is considered the only natural winter refuge for manatees on the east coast of Florida and the United States Fish and Wildlife has designated the spring as a critical manatee habitat (SJWMD, 2010).**

Over time spring ecosystems had evolved into efficient steady state ecosystems with a variety of indigenous flora and fauna residing in crystal clear spring water. As the population of Florida grew, developments, tourism and human alterations have changed the appearance, function and quality of most of Florida's springs.Indicators of impaired spring ecosystems include reduced spring flow, increasing nitrate levels, salt water intrusion, increased abundance of filamentous algae, and higher bacterial counts. Currently there is a combination of efforts from the federal, state and local level that are trying to preserve Blue Spring water quality and habitat. The MFL defines the limit of flow which further reductions would be significantly harmful to the water resources or ecology of the area (SJWMD, 2010). The MFL's protect the manatee habitat by ensuring there is adequate water volume in Blue Spring run and also support 7 other water resource values. The U.S. Environmental Protection Agency has mandated a Total Maximum Daily Load for Blue Spring in 2005 (EPA, 2005).). The TMDL target is to lower nitrate concentration in Blue Spring to levels observed in unimpacted springs with a median concentration of 0.11 mg/L. To reach the target level, a percent reduction of 91% was calculated for allocated loads and total maximum daily loads based on the current conditions (EPA, 2005).

In addition to the current management strategies further actions could be taken to mitigate the impairment to Blue Spring. Other actions may

include; sediment and filamentous algae removal, reintroduce and propagate native submerged aquatic vegetation, reduced fertilizer applications in residential areas, strict storm-water management protocols, limiting the number of visitors to the spring at any given time and to designate more protected areas, and promoting incentives for homeowners and business in the spring basin to adopt water saving designs and appliances.

The key stakeholders in the Blue Spring basin include the cites of Deland, De Bary, Deltona, Lake Helen, and Orange City, St Johns Water Management District, Florida Department of Environmental Protection, US Fish and Wildlife, State of Florida Parks System, and Volusia County. All of these entities represent a stake in the protection efforts of Blue Spring and should therefore share the responsibility of implementing the necessary actions integral to reduce impairment.

Introduction

Purpose

The purpose of the Blue Spring Restoration Plan is to ensure the historic standards of water quality and health of the Blue Spring ecosystem despite growing population demands anthropogenic impacts. Florida springs are among Florida's most valued natural resources and protection of these water bodies is a benefit shared by the environment and the people who visit and live amongst theses natural wonders (German, 2008). Alterations of spring habitat and changes in water quality affect the appearance and function of springs. Florida springs have an important role in recreation but are also unique and valuable ecosystems that are found nowhere else in the world. The goal of this restoration plan is to mitigate the impaired condition of Blue Spring by implementing feasible management practices that ultimately benefit the general population and return Blue Spring to its historical condition.

Location

Blue Spring is located in western Volusia County east of the St Johns River. Volusia Blue Spring is located 2.5 west of Orange City, Florida and 5 miles south of Deland, Florida at latitude 28°56'41.912", longitude 81°20'21.123 (www.floridawater.com). The spring and spring run are owned and operated by the state of Florida as Blue Spring State Park. The spring pool can be accessed by a wooden boardwalk that runs along the east bank of the spring run (FGS, 2004)

History

The springs of Florida have been important focal points of life attracting a variety of animals as well as human settlements (German, 2008). Fossil remains and archeological evidence provide proof that the springs of Florida are significant areas of activity from prehistoric times to present (German, 2008).

The renowned botanist John Bartram visited the spring in 1766 but it was not settled until 1856 by Louis Thursby and his family (wikipedia.com). The Thursby plantation house was built in 1872 upon a large relic Indian shell mound (wikipedia.com). The Thursby's cultivated citrus and later took advantage of the beauty of Blue Spring by encouraging tourism (wikipedia.com). The historic Florida East Coast Railway was constructed near the current park and a small railway connected Orange City to the dock at Blue Spring (wikipedia.com). In 1972, The Florida Department of Environmental Protection acquired the park as part of the manatee protection program (wikipedia.com).

Description

Figure 1.1 Blue Spring State Park (WSI, 2009)

Volusia Blue Spring is considered the largest spring along the St Johns River (SJWMD, 2010). The main spring pool at Blue Spring State Park is 135 ft by 100ft with a sandy limestone bottom and steep sandy banks, presented in Figure 1(SJWMD, 2010). The main spring vent is a narrow cave opening that drops vertical 60 feet and then continues at a 45 degree angle to a depth of 120 ft (USGS, 2008). Cave divers are allowed to dive the first 60 ft and then access is restricted (USGS, 2008). There are numerous tunnels that extend from the main vent with no outlets, as depicted in Figure 1.2 (SJWMD, 2010). The southern end of the spring pool opens into Blue Spring run which flows 0.5 miles south southwest into the St Johns River (SJWMD, 2010). The width of the spring run is 80-100 ft and is surrounded by hardwood and palm forest (FGS, 2004).

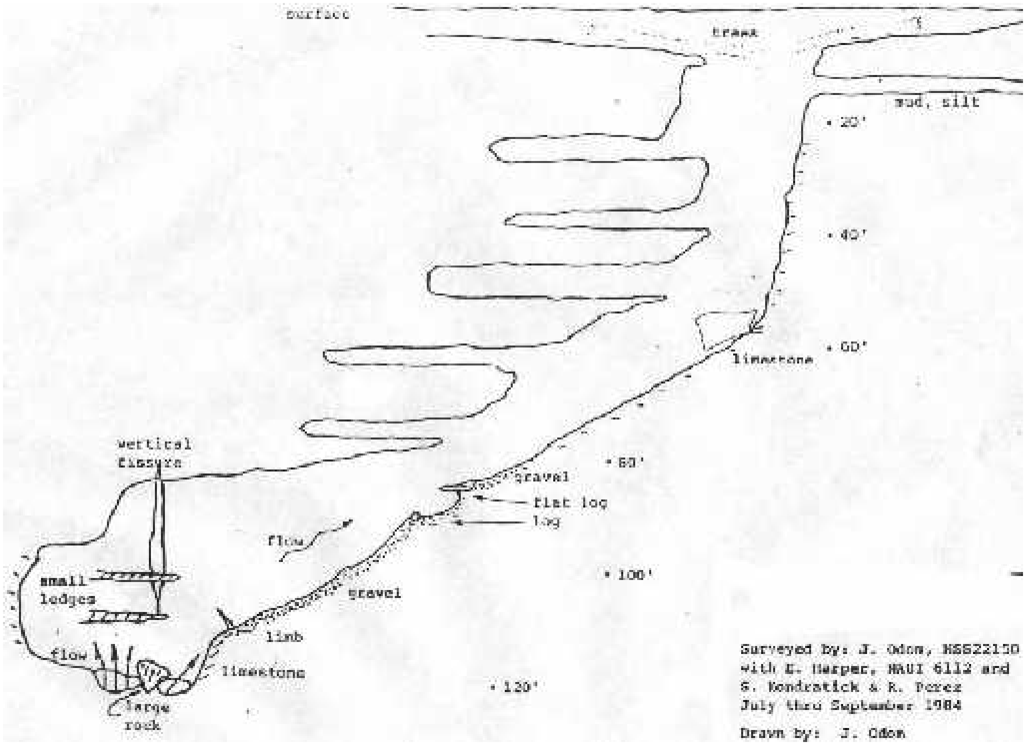


Figure 1.2 Profile of the Blue Spring main vent drawn by J. Odom (WSI, 2009)

Volusia Blue Spring is considered a first magnitude spring with an average mean flow of 157cfs (SFWMD, 2010). Discharge measurements have been recorded as early as the 1930's and provide a detailed summary of the history of flows. Between 1932 and 2005 the maximum discharge of 218 cfs occurred in February 1983 and the lowest discharge measured 87 cfs occurred in November 2001 (SJWMD, 2010). These variable flow rates are affected mainly by localized rain events and groundwater consumption.

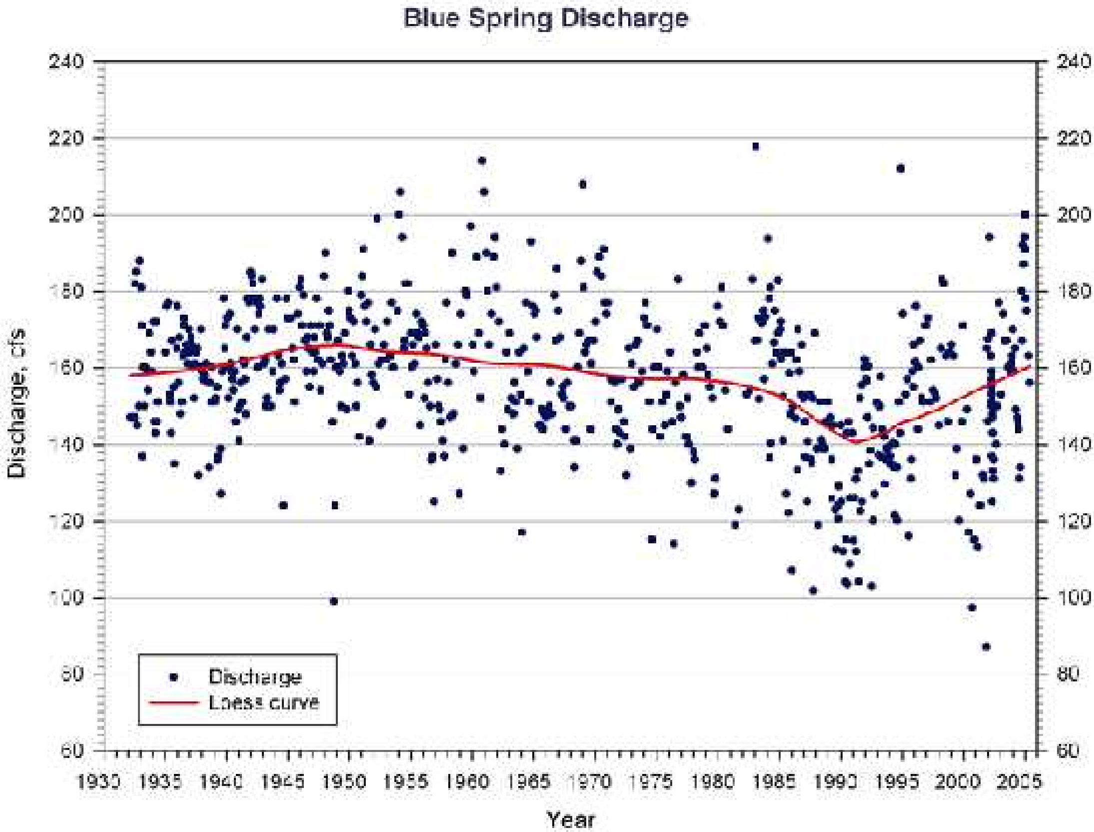


Figure 1.3 Discharge in cubic feet per second from 1932 to 2005 (SJWMD, 2010)

Water Quality

Water quality in a spring generally will reflect the overall conditions of the underlying aquifer and can be altered by the quality of water recharging the aquifer (Cervone, 2003). Water quality parameters of significance include; water temperature, pH, dissolved oxygen, specific conductance, total nitrogen, and total phosphorus. The water temperature remains fairly constant from the spring boil with an average of 23.2 degrees C and a max and minimum of 24.5 and 21.5 respectively from 1960-2005 (SJWMD, 2010). Dissolved oxygen measurements when sampled from 2007-2008 at the main vent are extremely low on average with concentrations of 0.2mg/L, and generally increase to an average of 4.4 mg/L further downstream (WSI, 2009). Measurements of specific conductance averaged 1550 $u$mhos/cm in the field in the years samped between 1984-2005 and ranged from 2320 – 729 $u$mhos/cm (SJWMD, 2010). From 1976 to 2005 Nitrate and Nitrite concentrations ranged from 0.04 mg/L to over 1.0 mg/l (SJWMD, 2010). Orthophosphate measured from 1972-2005 remained fairly constant and ranged from 0.05mg/L to 0.10mg/L (SJWMD, 2010). Average concentrations from 2007-2008 of total nitrogen ranged from 0.58-0.67 mg/L, of which an average of 62% was found to be nitrate 0.35-.40 mg/L, 17% ammonia 0.10-0.11 mg/L, and 22% organic

nitrogen 0.08-0.23 mg/L (WSI, 2009). Total phosphorus ranged from 0.079-0.092 mg/L during the sampled period 2007-2008 with a majority of the total, 85%, as dissolved ortho-phosphate.

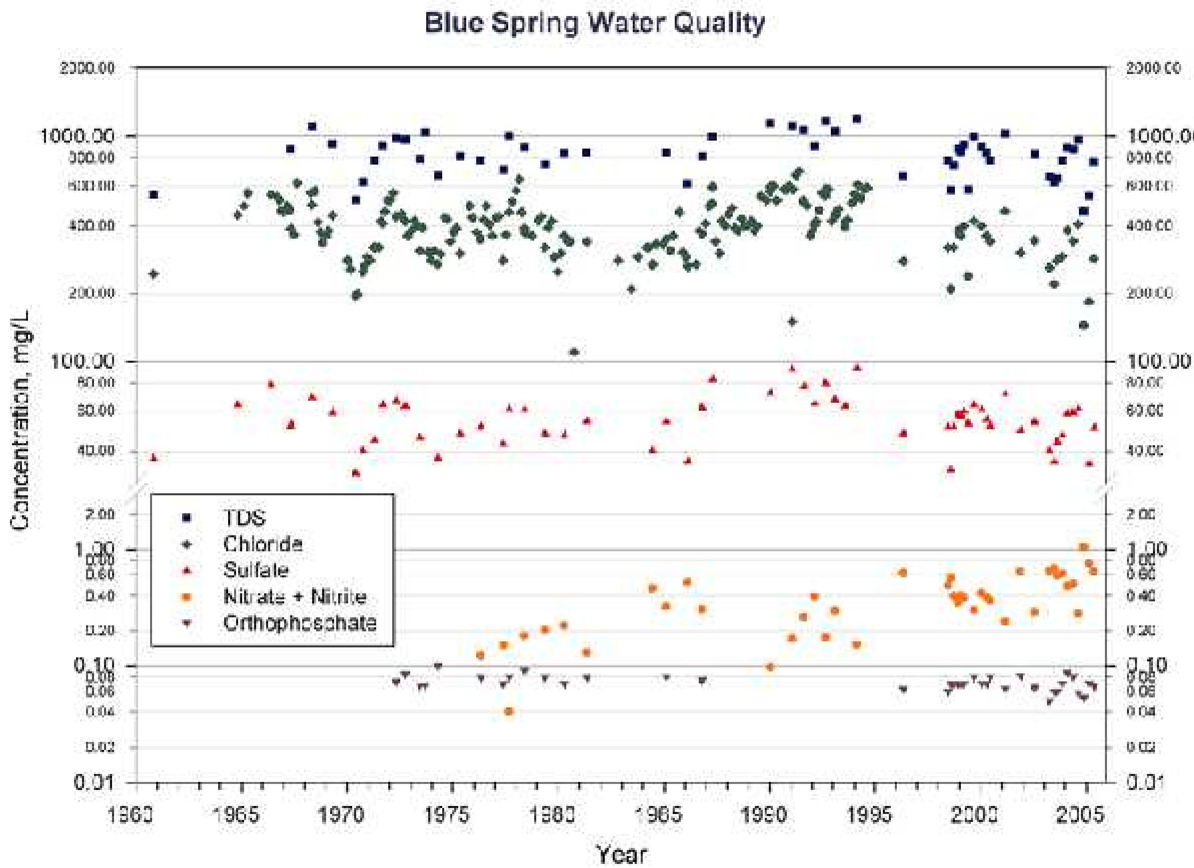


Figure 1.4 Water Quality concentrations from 1960-2005 (SJWMD, 2010)

Blue Spring - Volusia County	Min	Mean	Median	Max	Count	Period
Water temperature, °C	21.5	23.2	23	24.5	261	1960-2005
Specific conductance, field, µmhos/cm at 25 °C	729	1550	1420	2320	22	1984-2005
Specific conductance, lab, µmhos/cm at 25 °C	808	1693	1675	2610	203	1960-2005
pH, field	6.5	7.4	7.41	8.2	58	1960-2005
Discharge, cfs	87	157	158	218	643	1932-2005
Calcium, dissolved, mg/L as Ca	42	61.2	60	87	47	1960-2001
Calcium, total, mg/L as Ca	41	62.7	64.3	71.8	18	1992-2005

Magnesium, dissolved, mg/L as Mg	15	25.5	25	38.7	47	1960-2001
Chloride, total, mg/L as Cl	110	401.9	395	700	199	1960-2005
Nitrate + nitrite, total, mg/L as N	0.04	0.39	0.37	1.04	42	1976-2005
Nitrate + nitrite, dissolved, mg/L as N	0.02	0.29	0.24	0.62	3	1996-2001
Phosphorus, total, mg/L as P	0.05	0.07	0.07	0.14	35	1972-2005
Orthophosphate, total, mg/L as P	0.1	0.07	0.07	0.1	38	1972-2005
Alkalinity, total, mg/L as $CaCO_3$	105	127.3	128	158	46	1960-2005
Total dissolved solids, mg/L	462	836	839	1200	56	1960-2005
Total organic carbon, mg/L as C	0	11.6	4.5	72	16	1971-2005

Units: µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
cfs = cubic feet per second

Table 1 Water Quality at Volusia Blue Spring (SJWMD, 2010)

West Indian Manatee

One of the most famous inhabitants of Blue Spring State Park is the West Indian Manatee (*Trichechus manatus latirostris*). The constant water temperature of the spring attracts hundreds of manatees every winter seeking warm water refuge. Blue Spring is considered the only natural winter refuge for manatees on the east coast of Florida and the United States Fish and Wildlife has designated the spring as a critical manatee habitat (SJWMD, 2010).

The West Indian Manatees were declared endangered in 1973 by the U.S. Endangered Species Act and the U.S. Marine Mammal Protection Act of 1972 (www.wikipedia.com). Protection efforts succeded and in 2007 the U.S. Fish and Wildlife reclassified the West Indian manatee as threatened due to increases in population (www.wikipedia.com). Evidence of the growing population can be seen every year at Blue Spring as more manatees inhabit their winter refuge, see Figure 1.5 (German, 2008). The USGS estimates that the number of manatees that visit the spring every year have increased from than 60 in the mid 1980's to over 250 in 2007 (German, 2008).

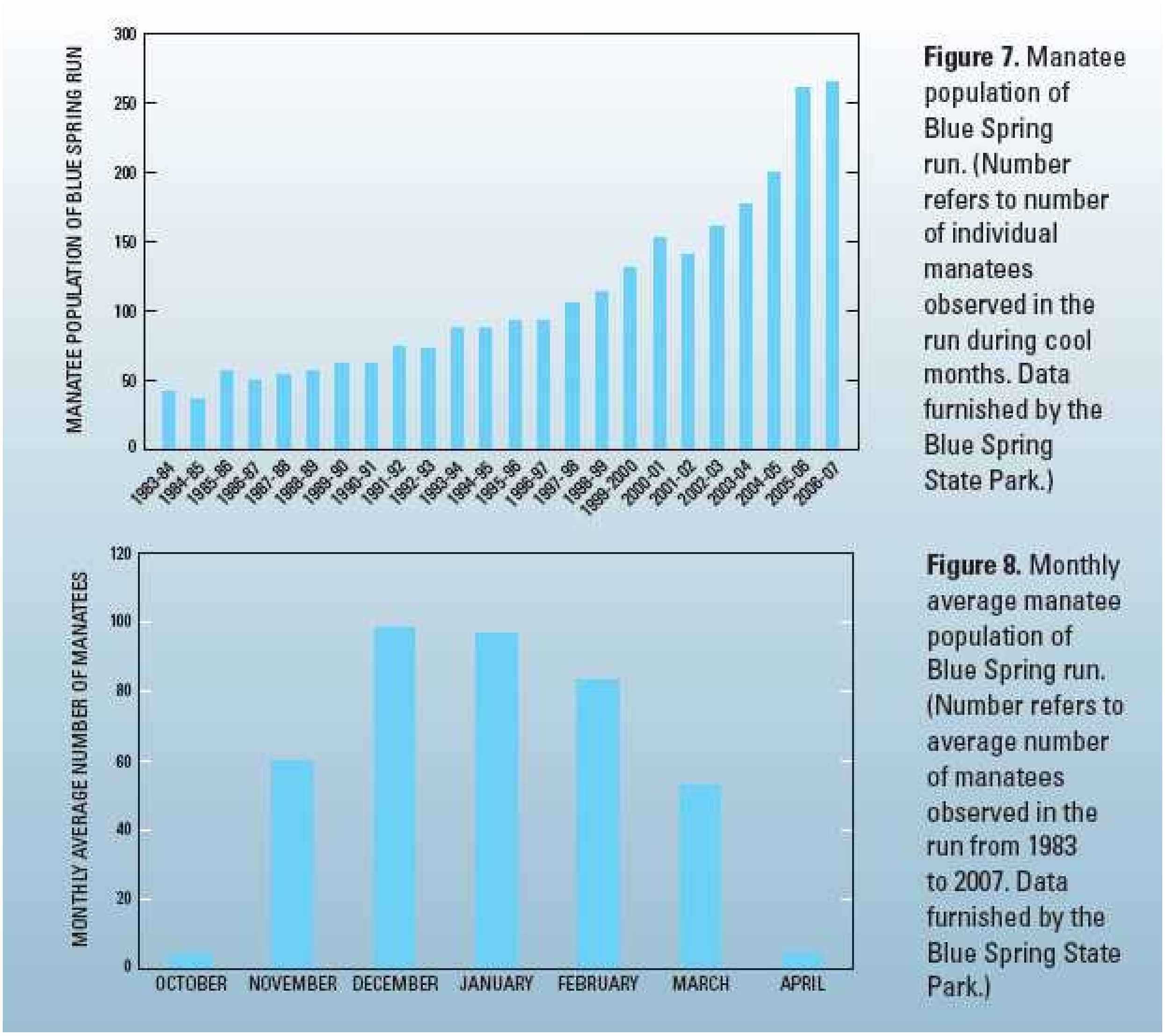


Figure 1.5 Manatee population in Blue Spring run from 1983-2007 and monthly average of manatee numbers (German, 2008)

Blue Spring Basin

Figure 2.0 Blue Spring Basin (Stokes, 2008)

The USGS defines a springshed as areas within ground and surface water basins that contribute to the discharge of the spring (German, 2008).). Based on multiple ground-water flow models, the composite area for the spring-shed of Blue Spring in Volusia County is 130 square miles (Shoemaker *et al.*, 2004). The majority of the recharge area is located east of the spring in the vicinity of Deltona, Orange City, and Deland (Shoemaker *et al.*, 2004). Two of the three models predicted a small area west of the St John's River in Lake County to contribute recharge to the spring as shown in Figure 2.4. However, further examination shows ground-water flow discharging in the St John's River with possible surplus flow continuing under the river to discharge at Blue Spring (Shoemaker *et al.*, 2004). The same study used backward tracking analysis to determine that 45-80% of the total discharge of Blue Spring reaches the spring within 100 years. This indicates that present day water quality may be influenced by water that entered the aquifer decades before (German, 2008).

As pictured in Figure 2.1, discharge from the Blue Spring vent is a result of water flowing upward through a natural breach in the confining layers of the Surficial and Floridan aquifer system (German, 2008). When the potentiometric surface of the aquifer is higher than the surrounding land elevation springs occur. The upland areas that surround Blue Spring have highly permeable soil that allows water to seep into the aquifer, see figure 2.2 and 2.3 (SJWMD, 2010). Recharge of the aquifer general occurs in these karst areas where soil drainage is excessive and the aquifer is close to or at the surface (SJWMD, 2010). Rainfall is the principal means of recharge to the aquifer and ultimately affects the discharge of the spring. On average, the Blue Spring spring shed receives 50 inches of rainfall annually (German, 2008). However, only one-third is accounted for in spring discharge and the rest is lost to evaporation and transpiration (German, 2008).

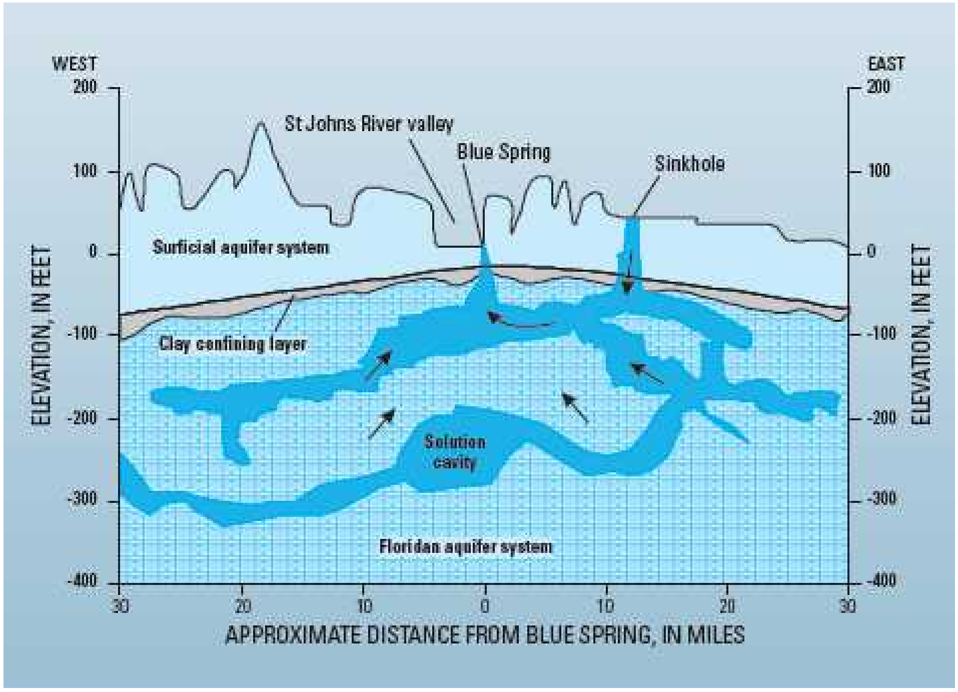
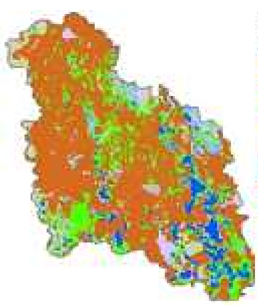


Figure 2.1 Generalized cross-section west to east of Blue Spring by USGS (German, 2008)



Legend	Area, km²	% of area
Excessive (220)	131.141	60.18%
Moderately Well (416)	33.600	15.42%
Well (106)	16.139	7.41%
Water (165)	14.370	6.59%
Very Poor (187)	7.988	3.67%
Poor (114)	6.789	3.12%
Somewhat Poor (77)	4.675	2.15%
Info Unavailable (39)	3.226	1.48%
	217.928	

Figure 2.2 Soils Drainage in the Blue Spring Watershed (SJWMD, 2001)

Legend	Area, km²	% of area
> 12 (2)	172.735	79.26%
0 - 4 (3)	25.147	11.54%
4 - 8 (5)	15.673	7.19%
8 - 12 (4)	4.373	2.01%
	217.928	

Figure 2.3 Recharge to the Floridan Aquifer in inches per year (SJWMD, 1995)

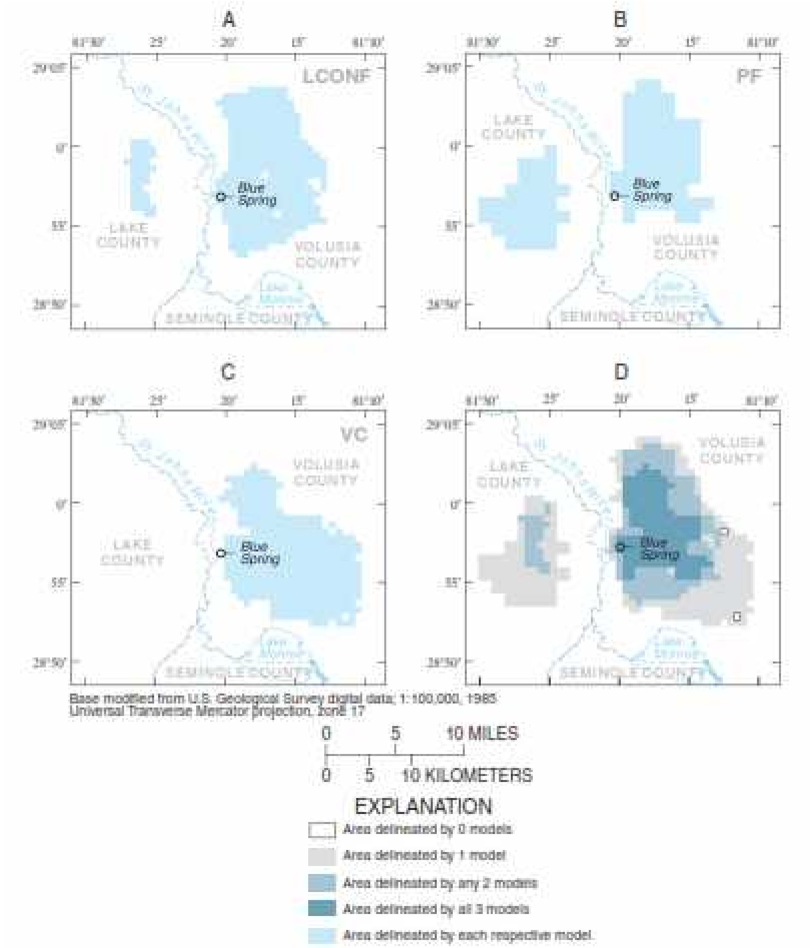


Figure 2.4 Areas contributing recharge to Blue Spring (Shoemaker et al., 2004)

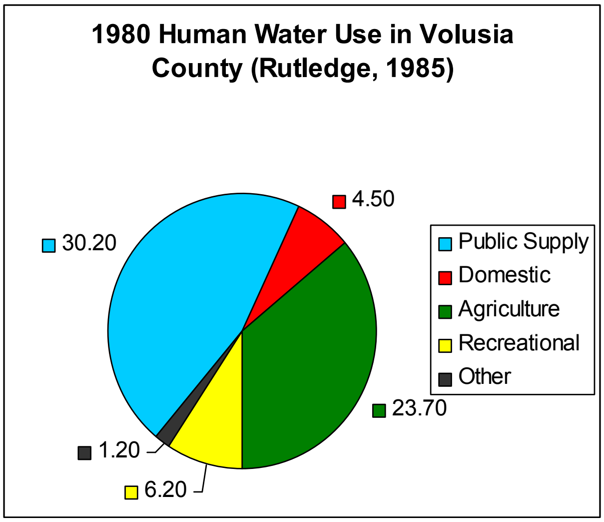
Water Use

Human water uses for Volusia County, Florida can be divided into six categories: Thermoelectric, Public supply, Agricultural irrigation, Domestic self-supply, Recreational irrigation, and Industrial. According to the USGS, the predominant human water use in Volusia County for 2005 was thermoelectric withdrawals used in power generating facilities (Marella, 2008). Of the 89.38 million gallons per day (mgd) of freshwater used, 88% was immediately returned to the water source after flow through cooling (Marella, 2008). The actual amount of consumptive water used in thermoelectric cooling is much lower and 97% of the fresh water used is surface water (Borisova and Carriker, 2009).

Public supply water withdrawals were the second largest human water use with 34.19% totaling 58.55 mgd (Marella, 2008). Agricultural irrigation used 10.35% of the total water usage with 17.72 mgd. Domestic self supply, recreational irrigation, and industrial uses totaled 1.6%, 1.24%, and 0.42% respectively (Marella, 2008). The total fresh groundwater used in the county was 76.62 mgd and the total fresh surface water used was 94.62 mgd (Marella

2008). The USGS estimates that the majority, 98.69%, of the groundwater withdrawals in Volusia County are from the Floridan Aquifer and a small percentage .31% are from the Surficial Aquifer (Marella, 2004)

Historically, the water use in Volusia County has increased 260% from 1980 to 2005. Public supply water use has almost doubled from 30.2mgd to 58.55mgd, while the domestic self-supply and agricultural uses have decreased from 4.5mgd to 2.75mgd and 23.7mgd to 17.72mgd respectively.



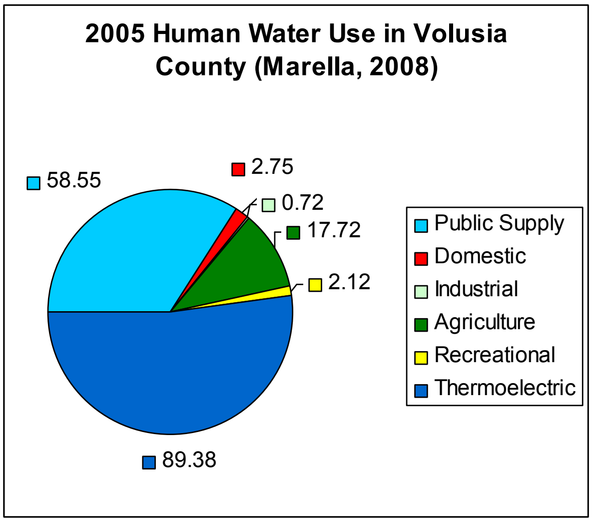


Figure 2.5 Human Water Use in Volusia County in 1980 and 2005 (Rutledge, 1985 and Marella, 2008)

Water Budget

The water cycle in Volusia County consists of an average annual rainfall of 53 inches, evapotranspiration loss of 38 inches, streamflow loss of 11 inches, spring and flowing well discharge of 2.3 inches, and groundwater flow loss of 8.7 inches, see figure 2.6 (German, 2009) . The amount of water stored in the atmosphere, surface water or ground water is constantly changing and is impacted by human use, see Figure 2.7 (German, 2009). Human uses that alter the flow or storage of surface water and ground water include irrigation in agriculture and domestic uses. Water used in irrigation that is not consumed by plants can be returned to the ground water or to the atmosphere by transpiration (German, 2009). Water used for domestic purposes is either consumed or returned as wastewater in sewage treatment facilities or septic tanks (German, 2009).

To determine an estimate of wastewater discharge and unused agricultural irrigation to the spring recharge area, the land area of the spring shed, 130 sqm, was divided by the total land area in the county, 1,103 sqm (Wikpedia, 2010). The Blue spring recharge area represents 11.59% of the total land area in the county. The previously estimated amount of discharge in the county, 94.18 mgd, multiplied by the percentage of area in the spring shed, 11.59%, is equal to 10.92 mgd of freshwater discharge to the Blue Spring recharge area.

However, this estimate is approximate and may be less than the actual amount. Considering that urban areas contribute more freshwater discharge than agricultural lands due to the higher rates of evapotranspiration in crops (Marella, 2008). The spring shed has more urban land than agriculture and therefore the discharge to the spring may be greater than 10.92 mgd.

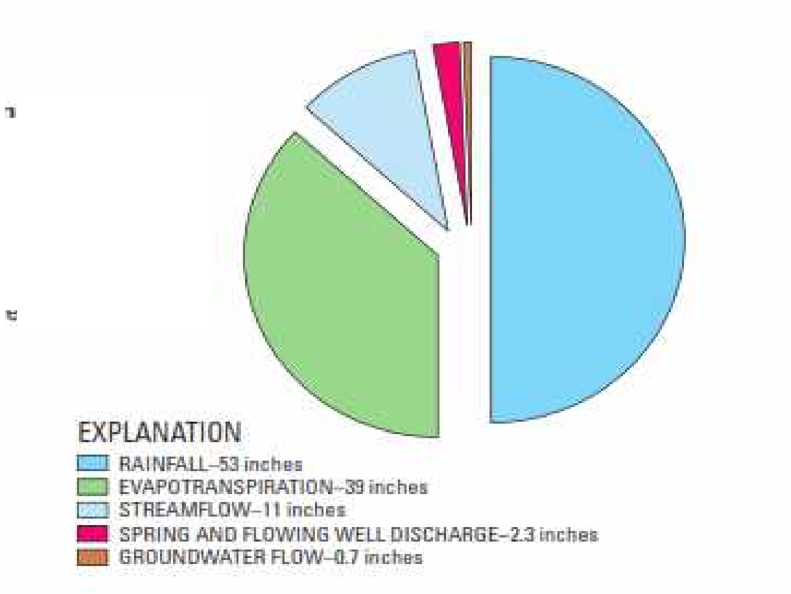


Figure 2.6 Annual Water Budget in Volusia County (German, 2009)

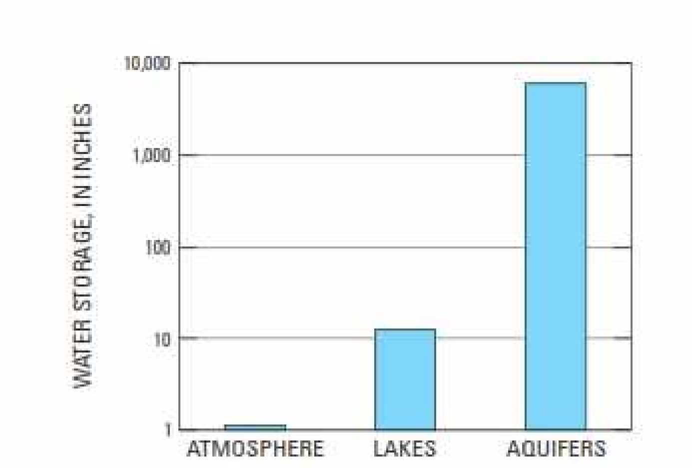


Figure 2.7 Estimated Average Water Storage in Volusia County (German, 2009)

Potentiometric Maps

Potentiometric maps show the relative water level of the Floridan aquifer by measuring wells in the spring shed area. The water levels are affected seasonally by the amount of rainfall and groundwater consumption (Kinneman and Dixon, 2009). Seasonal differences in rainfall patterns have shown to alter the potentiometric surface by 4-6 feet (Kinneman and Dixon, 2009). Draw downs or conical depressions in the potentiometric surface typically result from increased groundwater pumping. As shown in Figures 2.8 and 2.9, local groundwater withdrawals have lowered the potentiometric surface of the Floridan aquifer by as much as 5 feet from pre-developed to 1988 conditions (McGurk, 1998). Measurements made in 2009 have shown an estimated lowering of the potentiometric surface by as much as 10 feet (Kinneman and Dixon, 2009). Simulations of predicted water usage and the potentiometric surface peformed by McGurk in 1998 had shown similar results and may be a useful tool for future water planning.

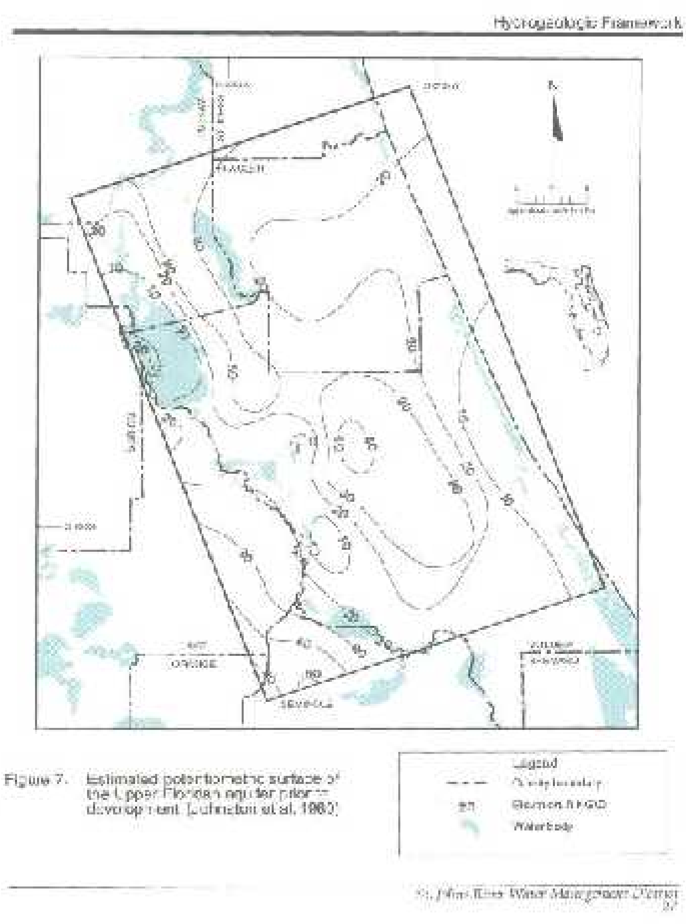


Figure 2.8 Estimated Potentiometric surface of the Upper Floridan Aquifer prior to development (McGurk, 1998)

Figure 2.10 Average Potentiometric surface of The Upper Floridan Aquifer in 1988 (McGurk, 1998)

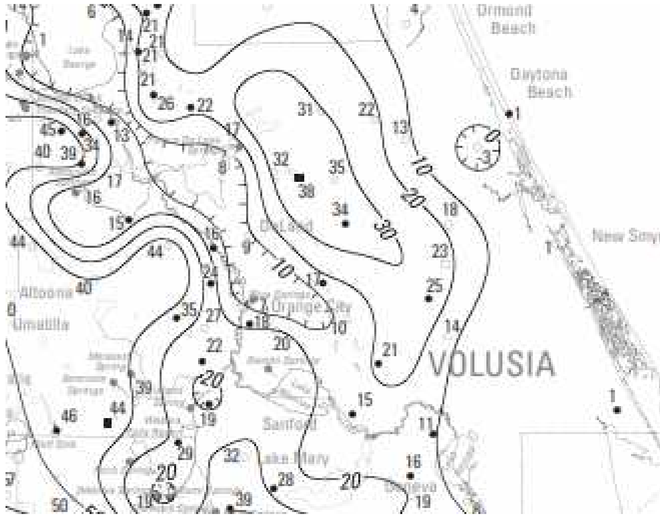


Figure 2.11 Potentiometric surface of the Upper Floridan Aquifer in Volusia County for May 2009 (Kinneman and Dixon 2009)

General Land Use

The general land use in the Blue Spring watershed in 2000 was predominately urban, 59.08%, followed by forested areas, 24.24%, as shown in Figure 2.6 (SJWMD, 2010). The current 2010 population of the spring shed is about 155,000 people with an average growth rate sine 2000 of about 25%, see Table 2 (www.bestplaces.net). Although the population has grown, land use within the spring basin has not changed significantly from 2000 to 2004, see Figure 2.7.

Figure 2.6 General Land Use in the Blue Spring Watershed (SJWMD, 2008)

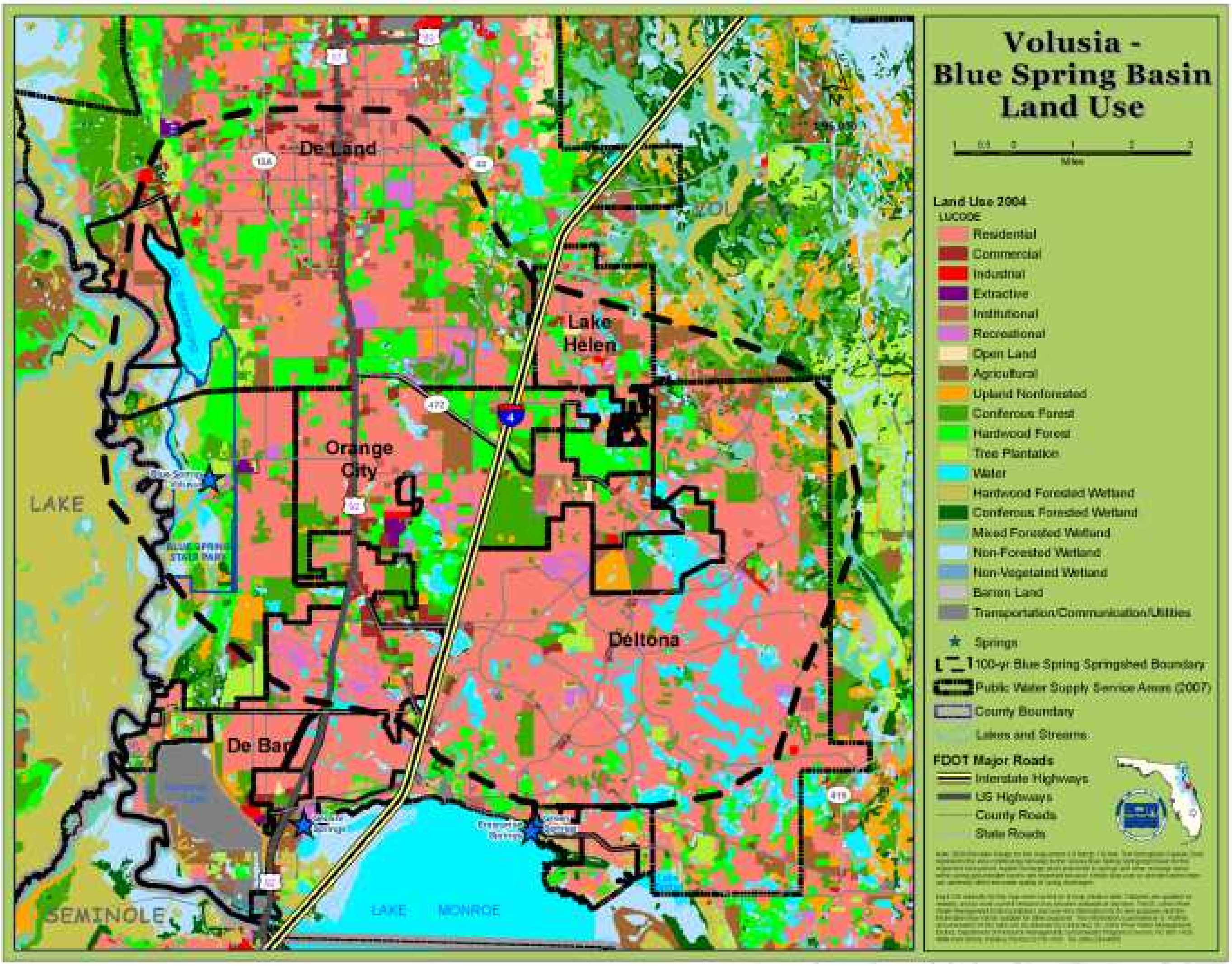


Figure 2.7 General Land Use Blue Spring Basin 2004 (USGS, 2010)

	Population 2010	% Growth Since 2000	Projected Population 2020*
Orange City	19,377	23.47%	23,924
Deltona	87,698	26.02%	110,517
Deland	26,466	26.58%	33,500
Lake Helen	2,774	1.13%	3,087
De Bary	19,231	23.56%	23,761
Total Population	155,546		194,789

Table 2 General Population of the Blue Spring Basin (www.bestplaces.net, 2010) *the population in 2020 was calculated by multiplying the current growth rate by the 2010 population

Impairments to Spring Ecosystems

Over time spring ecosystems had evolved into efficient steady state ecosystems with a variety of indigenous flora and fauna residing in crystal clear spring water. As the population of Florida grew, developments, tourism and human alterations have changed the appearance, function and quality of most of Florida's springs.Indicators of impaired spring ecosystems include reduced spring flow, increasing nitrate levels, salt water intrusion, increased abundance of filamentous algae, and higher bacterial counts. In some cases it is challenging to prove a deviation from normal conditions without baseline measurements of predevelopment conditions. The ecologist Howard T. Odum was one of the first scientists to study the ecosystems and productivity of Florida springs in the 1960's before human interactions had a major impact. Detailed data collections of primary production and efficiency, water quality, and resident flora and fauna provide a picture of pre-development conditions in several of the Florida springs (Odum, 1957) . There are also water quality measurements and photographs that date back to the 1930's that are useful in comparing current springs to their historical conditions.

Nitrogen Inputs and Loading

Elevated nitrate concentrations can be an indication of surface contamination mainly from fertilizer inputs and wastewater discharge. In general nitrate concentrations in spring discharge has increased statewide from a background concentration of 0.05mg/L to more than 1.0 mg/L ( ). The concentrations of total nitrogen, including nitrate and nitrite in Blue Spring have fluctuated since 1975 but have shown an overall increasing trend in concentration, see figure 3.0 (German, 2008).

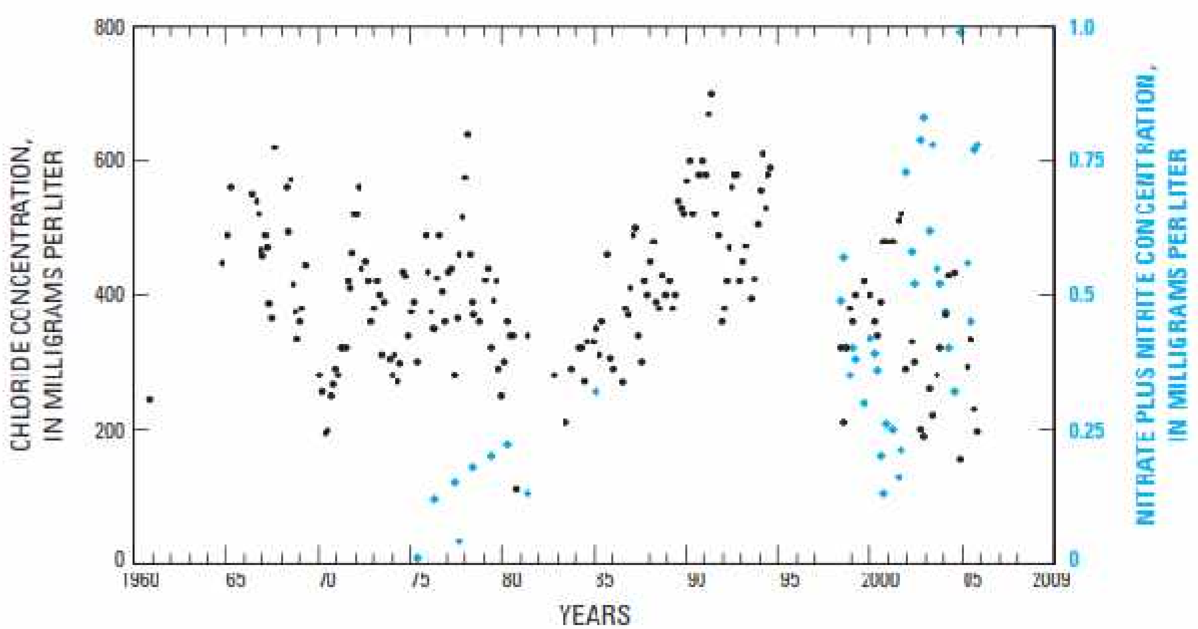


Figure 3.0 Chloride and Nitrate / Nitrite concentrations from 1975 to 2008 (German, 2008)

Nitrogen Inputs

To determine the nitrogen inputs from fertilizer in the Blue Spring recharge area, the total amount of fertilizer including agricultural and recreational fertilizers was examined. Although the agricultural land use in the basin is small the inputs from residential fertilizers in urban areas can be equal to or even exceed the contributing agricultural amounts (Roeder, 2008). The estimated total fertilizer used for agriculture in Volusia County in 2005 was about 22,000 tons and the total nitrogen in fertilizers used was 2,600 tons (www.flaes.org).

To determine the nitrogen inputs from fertilizers used in the spring recharge area, the percentage of the land in the spring shed, 11.59%, was multiplied by the total nitrogen in fertilizers used by the county, 2,600 tons. This amount equals 301.34 tons of nitrogen inputs to the spring recharge area. Over a ten year period if the amount of nitrogen input remained constant, the estimated nitrogen input from fertilizer to Blue Spring recharge area would be about 3,000 tons.

*There were many assumptions used to calculate the input, these include; an equal distribution of agricultural land across the county, equal distribution and concentrations of fertilizers in land areas and constant fertilizer use over a ten year period.

Nitrogen Loading

To determine the amount of nitrogen loading to the Blue Spring recharge area, a similar report by Roeder (2008) of the Wekiva Study Area was utilized as a comparison. Roeder (2008) found that "Overall, these two estimates indicated that about 70% of the nitrogen input to the Wekiva Study Area is not transferred to ground or surface water". The Wekiva Study Area estimates included nitrogen loading from onsite sewage treatment and disposal systems, land use areas, atmospheric deposition, waste water treatment facilities and storm water runoff (Roeder, 2008).

The previously calculated nitrogen inputs from fertilizer for the Blue Spring recharge area in 2005 was 301.34 tons. The nitrogen input, 301.34 tons, multiplied by 30% of actual transferred nitrogen, equals 90.4 tons of nitrogen loads via groundwater and surface water to the spring recharge area. Over a ten year period the approximate amount of nitrogen load from fertilizer to the groundwater and surface water would be about 900 tons.

*Again, many assumptions were made to determine the estimated loading, these include; constant fertilizer use and irrigation over a 10 year period, the resulting percentage of nitrogen loading from nitrogen inputs used in the Wekiva Study Area is comparable to Blue Spring's recharge area, land use areas and soil types are comparable, and that the calculated estimate for nitrogen inputs is adequate.

Calculated Estimates	2005	2000-2010
Discharged freshwater in Volusia County	94.18 mgd	
Discharged freshwater in the Blue Spring recharge area	10.92 mgd	
Nitrogen input in the Blue Spring recharge area	301.34 tons	3,000 tons
Nitrogen loading in the Blue Spring recharge area	90.4 tons	900 tons

Table 3.0 Calculated Estimates of Nitrogen inputs and Loading to the Blue Spring Basin

Reduced Flow Rates

Reduced spring discharge is related to the potentiometric surface of the Upper Floridan Aquifer. Rainfall patterns have been found to correlate with the discharge measurements of Blue Spring (WSI, 2009). Lowering of the potentiometric surface due to increased groundwater pumping and seasonal drought can potentially decreases the discharge observed in Blue Spring, as shown in Figure 3.1. There are many effects of reduced spring discharge to the ecosystem of Blue Spring. The quantity of spring discharge directly affects manatee refuge and habitat, macro-invertebrates and stream condition index, and water quality.

Decreased spring discharge ultimately decreases water volume and temperature stability essential for manatee habitat and refuge. As a protected species, maintaining a minimum flow and stable environment is critical. There is a positive correlation between manatee numbers average discharge although it is not statistical relevant, Figure 3.1 (WSI, 2009).

Macro-invertebrate populations as measured by the Stream Condition Index (SCI) also show a positive correlation to spring discharge, Figure 3.2 (WSI, 2009). As the discharge decreases the SCI index decreases. SCI values of Blue Spring range from 4-15 on a scale of 100, which designates Blue Spring as being impaired (0-34) (FDEP, 2009). In conjunction with discharge rates, macro-invertebrate communities are also affected in Blue Spring by low dissolved oxygen, elevated conductivity, and increased algal populations (FDEP, 2009).

Parameters of water quality such as total nitrogen are positively correlated to discharge whereas conductivity shows a negative correlation and the pH and temperature remain relatively stable, Figure 3.3 (WSI, 2009). Higher concentrations of conductivity are indicative of older water from the Upper Floridan aquifer which is generally expressed when the potentiometric surface is low. The increasing total nitrogen with increased discharge is indicative of more recent water from the aquifer. As management practices and efforts to reduce nitrogen loading in the spring basin begin to take effect, which could take decades to show, total nitrogen concentrations may become more reduced with increased discharge.

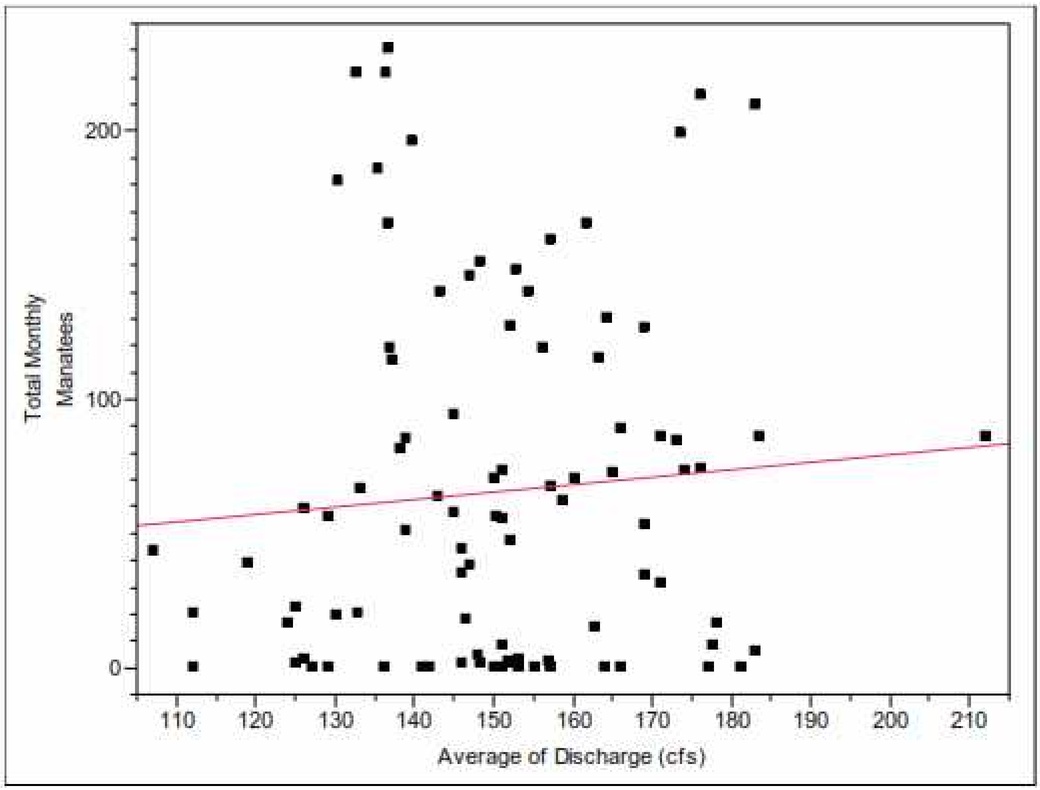


Figure 3.1 Relationship of monthly manatee numbers to average spring discharge from 1983 to 2008 (WSI, 2009)

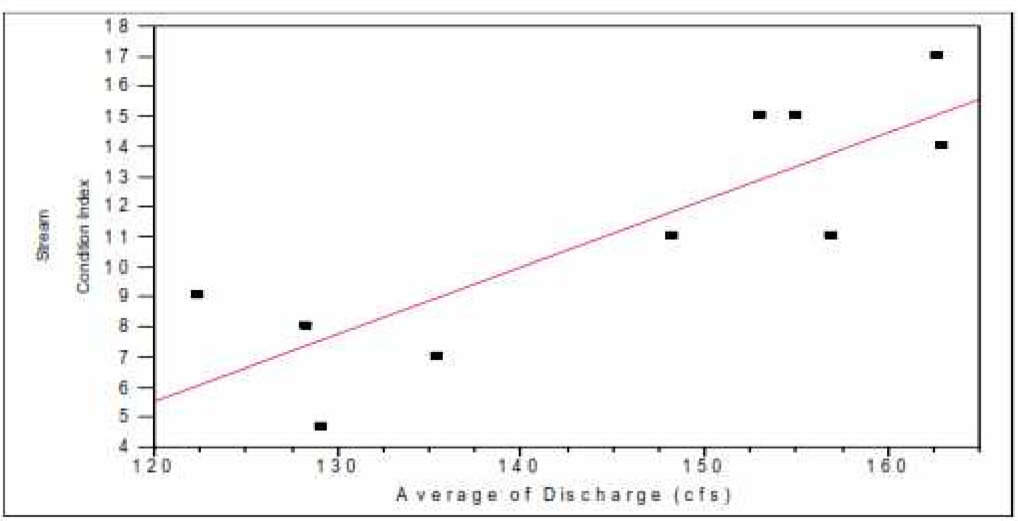


Figure 3.2 Relationship of SCI to average spring discharge from 2000 to 2008 (WSI, 2009)

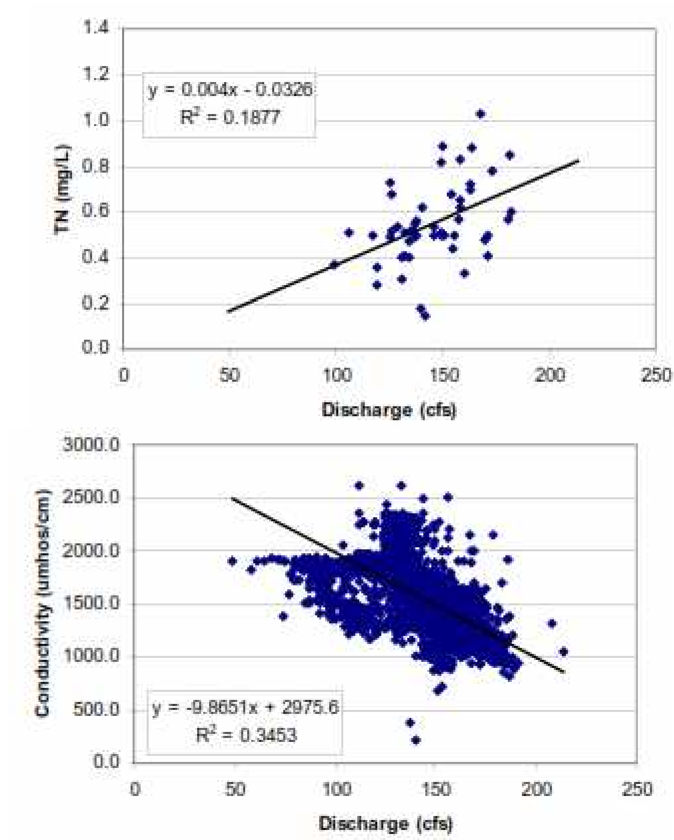


Figure 3.3 Relationships of total nitrogen and conductivity to spring discharge (WSI, 2009)

Filamentous Algae

Filamentous algae in Blue Spring may be a result of increased nutrient concentrtions, low dissolved oxygen, human and grazing impacts. Filamentous algae such as *Lyngyba* a blue-green cyanobacteria, seems to be an opportunistic species that has replaced a majority of the native submerged aquatic vegetation. Cyanobacteria can release toxic substances and that deter grazing and they are also epiphytic, smoothering vegetation and macroinvertebrate habitat Benthic algal mats often cover and shade the remaining macrophytes, disrupting their efficiency. In a 50 year retrospective study of Silver Springs, net primary productivity has decreased 59% and algal biomass has grown from almost zero to representing almost half of the total plant biomass (Munch et al, 2006). This relationship shows that increases in algal biomass and decreases in macrophyte biomass, decreases the overall productivity and efficiency of the springs community.

Algal thickness in Blue Spring run was greatest near the spring boil at the upper and middle stations and not as abundant at the lower station, as shown in Figures 3.4, 3.5, and 3.6 (FDEP, 2009). The upper and middle stations measured greater than 20mm of algal thickness and dominated the periphyton community (FDEP, 2009).

Algal Thickness Ranks
0 = 0mm, rough
1 = <0.5 mm or slimy
2 = 0.5-1 mm
3 = >1 to <6 mm
4 = 6-20 mm
5 = > 20 mm

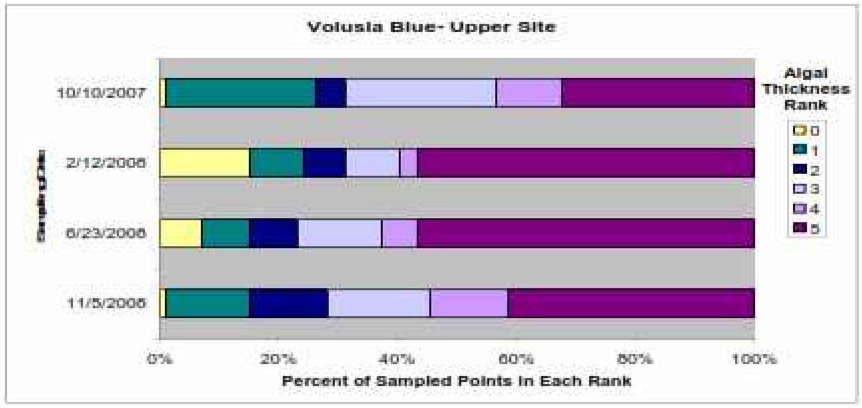


Figure 3.4 Filamentous algae thickness for Upper Blue Spring Run (FDEP, 2009)

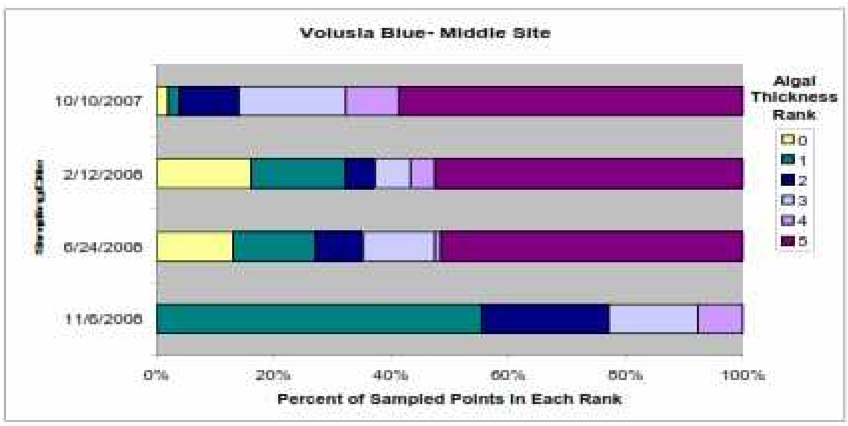


Figure 3.5 Filamentous algae thickness for Middle Blue Spring Run (FDEP, 2009)

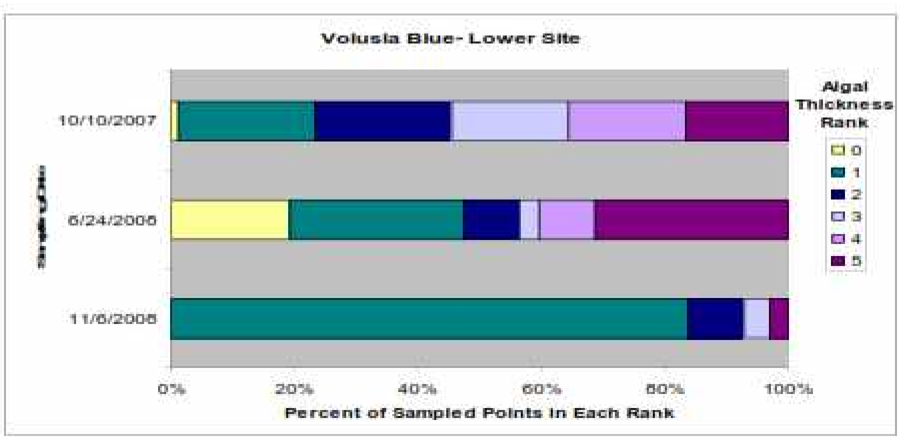


Figure 3.6 Filamentous algae thickness for Lower Blue Spring Run (FDEP, 2009)

Saltwater Intrusion

Saltwater borders Florida's coasts but also lies deeper within the Floridan Aquifer and is considered to be ancient seawater. In some places in Florida, such as Blue Spring, saltwater of a characteristic sodium-chloride concentration indicative of relic seawater can move through the aquifer and discharge at the spring (German, 2008). When the potentiometric surface of the Floridan aquifer is low and the subsequent discharge at the spring is low, chloride concentrations have been high (German, 2008). Conditions that lower the potentiometric surface such as deficit rainfall and excessive groundwater pumping allow more of the relic seawater to contaminate surface waters. The Floridan Aquifer is the sole water source for Volusia County, and elevated chloride concentrations negatively impact the availability of drinking water. High chloride concentrations also affect the organisms living in the spring. Most species are sensitive to changing salinity and can not survive in environments with high chloride levels. As a result of fluctuating chloride concentrations, species composition shifts toward to more tolerant and opportunistic species.

Bacterial Contamination

Bacterial contamination has been a recent concern at blue Spring State Park and the park was closed for almost two weeks during the hottest time of the summer (Geggis, 2010). This closure due to high bacterial counts is the first within five years and is thought to be a result of intermittent rain flushing the bacteria from the spring basin into the swimming area (Geggis, 2010). Warmer air temperatures and higher evaporation tends to lower water levels and increase the fecundity of bacterial growth. As many as 2,000 people visit the spring during a summer weekend and increased human use may contribute to elevated ecoli and total coliform bacteria.

Current Mitigation Strategies

Currently there is a combination of efforts from the federal, state and local level that are trying to preserve Blue Spring water quality and habitat. As of 2006, the St Johns River Water Management District in conjunction with the Florida Department of Environmental Protection, Florida Fish and Wildlife Conservation Commission and local groups has adopted a Minimum Flows and Levels (MFL's) program for Blue Spring (SJWMD, 2009). The MFL defines the limit of flow which further reductions would be significantly harmful to the water resources or ecology of the area (SJWMD, 2010). The MFL's protect the manatee habitat by ensuring there is adequate water volume in Blue Spring run and also support 7 other water resource values. These water resource values include; Recreation in and on the water, fish and wildlife habitats and passage, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, Sediment loads, and water quality (WSI, 2009).

The U.S. Environmental Protection Agency has mandated a Total Maximum Daily Load for Blue Spring in 2005 (EPA, 2005). The state of Florida narrative criteria state that " in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations" (EPA, 2005). The TMDL target is to lower nitrate concentration in Blue Spring to levels observed in unimpacted springs with a median concentration of 0.11 mg/L. To reach the target level, a percent reduction of 91% was calculated for allocated loads and total maximum daily loads based on the current conditions (EPA, 2005). The 2005 TMDL report by the US EPA states that nitrate-nitrite concentrations found in Blue Spring are higher than those found in 90 percent of Florida streams and that elevated levels are a result of nitrogen loading in the spring recharge basin. The Florida Department of Environmental Protection has implemented the Basin Management Action Plan for Blue Spring which includes; allocations among stakeholders, listing of specific activities to achieve reductions, project initiation and completion timelines, identification of funding opportunities, agreements, local ordinances, local water quality standards and permits, and follow-up monitoring.

The Florida Springs Initiative has also replaced the septic system at the park ranger residence to a sewer system in addition to educational brochures, videos, and sponsored working group programs.

Key Stakeholders

The key stakeholders in the Blue Spring basin include the cites of Deland, De Bary, Deltona, Lake Helen, and Orange City, St Johns Water Management District, Florida Department of Environmental Protection, US Fish and Wildlife, State of Florida Parks System, and Volusia County. All of these entities represent a stake in the protection efforts of Blue Spring and should therefore share the responsibility of implementing the necessary actions integral reduce impairment.

Proposed Mitigation Strategies

In addition to the current management strategies further actions could be taken to mitigate the impairment to Blue Spring. Other actions may include; sediment and filamentous algae removal, reintroduce and propagate native submerged aquatic vegetation, reduced fertilizer applications in residential areas, strict storm-water management protocols, limiting the number of visitors to the spring at any given time and to designate more protected areas, and promoting incentives for homeowners and business in the spring basin to adopt water saving designs and appliances.

Costs associated with sediment and nuisance algae removal can be compared to the Alexander Springs sediment removal in 2002. The cost was $60,000 and was completed within a year (FDEP, 2009). The other costs associated with education, program incentives and the renewal of submerged aquatic vegetation require further investigation and planning. Limiting visitors to the park during peak season does not require funding but will reduce the revenue received from park entrance fees.

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