SANTA FE RIVER SPRINGS BASIN
POE AND HORNSBY SPRINGS
NITRATE SOURCE INVESTIGATION

Protect Florida Springs Tag Grant PFS 1314-03

Watermelon Spring #2 in the Santa Fe River, January 2014

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INTRODUCTION

The Santa Fe River is designated as an Outstanding Florida Water (OFW); its basin covers approximately 1,400 square miles in North Florida and contains over 60 named springs. Alachua County has three first magnitude springs Hornsby, Treehouse (primarily resurgence) and Santa Fe River Rise (River Rise) and several second magnitude springs, including Poe Spring (Appendix A). Numerous first and second magnitude springs are also located in adjacent counties. The river and springs contain remarkable ecosystems and exceptional karst geology. Collectively billions of gallons of water discharge from the Floridan aquifer through these springs to the rivers each day. The rivers and springs systems within the Santa Fe Basin are unquestionably very important natural resources in Florida that must be protected.

Hornsby Spring, January 2014

Previous studies conducted by the U. S. Geological Survey (USGS) and the Florida Department of Environmental Protection (FDEP) reported that Poe and Hornsby springs have lower nitrate, lower dissolved oxygen, and higher organic carbon values than many other springs along the Santa Fe River in adjoining Columbia and Gilchrist counties (Chasar et al., 2005; FDEP, 2012a). These studies concluded that Poe and Hornsby springs are susceptible to fecal pollution from human wastewater sources at various times of the year and additional work is needed to address temporal and environmental factors influencing water quality. A qualitative dye study, conducted by Karst Environmental Services at Mill Creek and Lee sinks in Alachua County, confirmed a hydrogeologic connection between Mill Creek and Lee sinks and Hornsby Spring (Butt et al., 2006). A nitrate source evaluation, using land use mapping and groundwater travel time modeling, indicated that agricultural fertilizer was the primary source of nitrogen in the Santa Fe River Basin in Alachua County and surrounding areas (AMEC, 2012). The USGS, Karst Environmental Services, and AMEC studies concluded that travel time to these springs was relatively short (25-year groundwater travel time is shown in Appendix A), which was corroborated by flow responses at these springs in the extreme dry and wet conditions before and after tropical storm Debby in June 2012. In many instances shorter groundwater travel times may equate to a smaller contributing area and a more rapid response to rainfall.

Collaborative work with FDEP detected nitrogen isotope values indicative of denitrification that most likely originated from mineralized ammonium nitrate ($NH_4 - NO_3$) fertilizer and organic sources, such as wastewater, in the Poe and Hornsby springsheds. The samples collected at Poe and Hornsby springs indicate that denitrification has occurred to the point that a source cannot be determined from the isotope analyses. However, domestic wastewater could be a significant source based on the elevated chloride and boron concentrations (FDEP, 2012a). The presence of sucralose, an artificial sweetener and potential indicator of wastewater influences, was also detected in samples from Poe Spring (FDEP, 2012b).

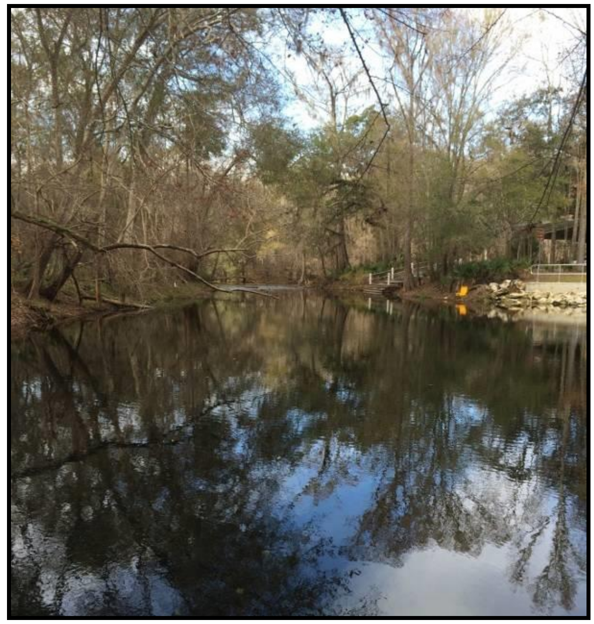
Historical water quality data for surface water at the springs is available; however, there is little information on groundwater quality within the contributing area for Poe and Hornsby springs. These two springs are vulnerable to contamination as indicated by the relatively short average residence time of groundwater in their contributing areas: Hornsby, 40 years and Poe, 25 years (Chasar et al., 2005). A detailed geochemical and nutrient analysis is needed for the contributing groundwater to the springs in order to develop a proactive spring's water quality improvement plan. Two specific areas where further research would be beneficial include a relatively dense area of septic systems on individual lots adjacent to Poe Spring (Appendix B inset) and the area surrounding the small package wastewater treatment plant and rapid infiltration basins that serve Camp Kulaqua near Hornsby Spring. This project complements the larger FDEP Middle Santa Fe Nutrient Fate and Transport study currently underway and is needed to better define sources so that nutrient load reductions can be identified and implemented.

Water quality and flow in Poe and Hornsby springs have been declining in recent years and a better understanding of water chemistry patterns and source waters for these springs is essential to the development of protection and restoration strategies. The Alachua County Environmental Protection Department (ACEPD) received a Protect Florida Springs Tag Grant from the Wildlife Foundation of Florida for Fiscal Year 2013-14 for the project titled Santa Fe River Springs Basin Poe and Hornsby Springs Nitrate Source Investigation. The funding was utilized to conduct a temporal assessment of groundwater in contributing areas to Poe and Hornsby springs (Appendix B). Initially, water samples were collected from 44 wells; and 17 sites with elevated concentrations of nitrate + nitrite as N were selected for further sampling and analysis. During January and June 2014, water quality samples were collected at a total of 20 sites, including three spring locations, for a more extensive suite of water chemistry analytes including additional nutrients, major anions/cations, and other potential source indicators. The January sampling event also included analyses of nitrate isotopes and sucralose.

The nitrogen and oxygen isotopic composition of nitrate (expressed in parts per thousand using delta notation relative to isotopic standards, $\delta^{15}N$, $\delta^{18}O$) has been used by other studies in Florida and elsewhere to determine the sources of nitrate in groundwater and surface waters. Inorganic fertilizer, animal waste, and wastewater have relatively distinct ranges of $\delta^{15}N$ and $\delta^{18}O$ values (Roadcap *et al*., 2002; Chasar *et al*., 2005). The isotopic composition of nitrate also can be used to assess the extent of denitrification, which results in the enrichment of $\delta^{15}N$ and $\delta^{18}O$ values compared with initial values derived from the original nitrate source (FDEP, 2014a).

LOCATION OF SAMPLING SITES

Poe Spring, a second magnitude spring, is the focus of recreational activities within the Poe Springs County Park. There is a 120-foot diameter circular head pool, with a maximum depth of approximately 19 feet. There are numerous vents in the exposed limestone bedrock within the head pool area and a small, restrictive cave has been explored. A 75-foot spring run flows to the Santa Fe River. Other springs within the park include Watermelon Spring (also known as Little Poe Spring), a small spring that discharges into a long run that flows west and parallel to the river. Watermelon Spring #2, which has much greater flow, is located on the bottom of the Santa Fe River, near the riverbank near Watermelon Spring. This vent produces a noticeable raised boil on the surface of the river under normal water conditions.



Poe Spring Run, January 2014

Hornsby Spring is an historic first magnitude spring located on the southeast side of the Santa Fe River, with 4,200 feet of spring run to the river. The spring lies within Camp Kulaqua, a privately-owned retreat and park northwest of the City of High Springs, and is the recreational waterfront for the park. It flows from a 35-foot deep pool, surrounded by limestone ledges, into a bottomland swamp towards the Santa Fe River. The spring is fed by a network of cave passages that have been explored and surveyed by cave divers since the 1970's. Both Poe and Hornsby springs are located in the upper reaches of the Lower Santa Fe River in Alachua County, downstream of Santa Fe River Rise (Appendix A). These two springs are some of the springs on the Lower Santa Fe River closest to the edge of the Cody Scarp (escarpment). Springs in this region are typically more influenced by surface waters than those further downstream, such as Ginnie or Gilchrist Blue springs. Butt et al. (2006) identified a connection between Mill Creek Sink and Lee Sink and Hornsby Spring. Following the high river levels of 1998, color and organic carbon concentration increased in Poe Spring indicative of river water influences (ACEPD, 2014). Springshed boundaries shown in Appendix A and B are from Upchurch et al. (2011).

The ACEPD conducted an assessment of groundwater quality in proximity to Poe and Hornsby springs, including the collection of springs' samples when groundwater sampling was conducted to provide a more complete temporal data set. ACEPD began by mapping the nearby contributing area and evaluating the topography (for evidence of karst features) and current land use (Appendix C). The land use categories are based on Florida land use codes and the urban category depicted is primarily low density residential. A contributing area with approximately a two mile radius surrounding Poe and Hornsby springs was utilized based on modeled groundwater travel times (AMEC, 2012). A detailed evaluation of the Floridan aquifer potentiometric surface was not possible due to relatively flat potentiometric surface in the area and the lack of wells surveyed to a known datum.

Parcels (properties) with existing wells were identified and well completion reports or other documentation of well construction was obtained from the Suwannee River Water Management District. Existing private wells in the contributing area were selected based on permission from homeowners to allow ACEPD to sample their wells to assess water quality. Homeowners were asked about any observed water quality abnormalities or surface water intrusion into the well (as noted by observable color) and if their well had required disinfection at any time in the past. ACEPD staff conducted field reconnaissance and preliminary nitrate + nitrite as N sampling at 44 possible well locations during October and November 2013. Seventeen of the wells, with nitrate + nitrite as N concentrations above 0.65 mg/L, were selected for additional sampling. Two sampling events were conducted for the 17 selected wells (Table 1) and three springs including Hornsby, Poe, and Watermelon Spring #2 (WTRMLN2). The relatively high rainfall during the winter and spring and accompanying high water levels in the Santa Fe River precluded sampling nearby smaller springs, such as Darby or Watermelon Spring #3, that either were not flowing or a discrete sample of spring water could not be collected. Winter and spring 2014 were the wettest conditions during winter and spring observed since 1998 (SRWMD, 2014).

Table 1. 2010-2011 Land Use Data and Well Construction Details for Sample Locations

Station ID	Springshed	Land Use (% of contributing area)[1]			Well Construction Details (feet)		
		Natural/ Recreational	Agricultural	Residential[2]	Land Surface Elevation[3]	Casing Depth[4]	Total Depth[4]
AAC1215	Poe	100.0	0.0	0.0	54	62	96
AAJ7000	Poe	81.5	0.0	18.5	61	50	70
AAJ7002	Poe	7.2	70.6	22.2	68	70	83
AAJ7005	Poe	20.0	0.8	79.2	55	58	75
AAJ7006	Poe	31.3	0.0	68.7	64	72	94
AAJ7007	Poe	0.0	92.1	7.9	66	60	NA
AAK7001	Poe	2.0	61.4	36.6	NA	67	80
AAK7000	Poe	43.7	10.2	46.1	NA	38	131
AAK7002	Poe	52.9	4.2	42.9	53	84	102
AAK7003	Poe	1.7	0.0	98.3	78	72	100
AAK7004	Poe	29.8	0.0	70.2	52	64	82
AAK7005	Poe	75.0	0.0	25.0	53	NA	NA
AAJ7001	Hornsby	0.0	61.3	38.7	61	NA	NA
AAJ7003	Hornsby	40.2	0.0	59.8	58	60	90
AAJ7004	Hornsby	0.0	35.8	64.2	57	88	100
AAK7008	Hornsby	100.0	0.0	0.0	54	113	165
AAK7009	Hornsby	94.4	0.0	5.6	57	NA	NA

NA = Not Available

1. Source: FDEP, 2012c. The contributing area for each location was delineated using a 300’ radius following micro-land use procedures set forth by FDEP Watershed Monitoring Program; all three spring locations were located within 100% natural/recreational areas (Appendix C).
2. The residential areas associated with AAJ7004 were classified as medium density; all other stations were located within low density residential areas.
3. Land surface elevations determined from Alachua County Property Appraiser 2001 LiDAR data.
4. Obtained from the driller’s well completion report or the property owner.

PROCEDURES

Sampling was coordinated with the Suwannee River Water Management District (SRWMD) Water Resources Monitoring Program to minimize sampling costs and duplication of effort. Analyses for nutrients, major ions, and general chemical indicators were performed by TestAmerica. Nitrogen isotope samples were collected and analyzed for the January 2014 sampling event. Isotopic analyses were conducted by the Northern Arizona University Colorado Plateau Stable Isotope Laboratory in Flagstaff, Arizona. The FDEP laboratory in Tallahassee analyzed groundwater and springs samples collected during the January 2014 sampling event for sucralose. Laboratory quality assurance/quality control procedures were followed to ensure accuracy of results.

ACEPD staff collecting sample from private well, January 2014

Groundwater samples were collected from private wells prior to any treatment system. The wells were purged until stability of field parameters (temperature, pH, dissolved oxygen, specific conductance and turbidity) was reached and then water quality samples were collected. Groundwater level measurements (depth to water) were made where well conditions permitted. Grab samples were collected 1 -2 feet below the water surface at each of the three spring locations. Samples were collected approximately 100 feet downstream of the main boil at Poe and Hornsby springs, and collected from the vent at Watermelon Spring #2. Where conditions permitted, direct flow measurements were made in the spring runs at the time of sample collection (Table 2). All sample collection followed FDEP standard operating procedures in place at the time (FDEP, 2008; FDEP, 2014b). A description of the analytes is included before the appendices.

Samples were analyzed for the following parameters:

- field parameters (flow or water level, specific conductance, pH, temperature, turbidity, dissolved oxygen),
- major anions/cations and indicators (sulfate, chloride, fluoride, bromide, alkalinity, hardness, calcium, magnesium, total dissolved solids, sodium, potassium, iron, and boron),
- nutrients (nitrate + nitrite as nitrogen (N), ammonia as nitrogen (N), total Kjeldahl nitrogen, total nitrogen, total phosphorus, and total organic carbon),
- nitrogen and oxygen isotopes (δ^{15}N and δ^{18}O), and
- sucralose.

RESULTS

ACEPD staff recording flow data in Poe Spring Run, January 2014

Preliminary field sampling for field parameters and nitrate + nitrite as N was conducted for a total of 44 wells during October and November 2013. The nitrate + nitrite as N values ranged from <0.01 milligrams per liter (mg/L) to 7.6 mg/L (Appendix D-1), with an average value of 1.28 mg/L and a median value of 0.67 mg/L. Twenty-four of the wells were located in the Poe springshed and 20 were located in the Hornsby-Treehouse springshed. Nitrate + nitrite as N values for wells sampled in the Poe springshed showed a greater range of concentrations, <0.01 to 7.6 mg/L, when compared to the results for wells in the Hornsby-Treehouse springshed, <0.01 to 3.7 mg/L. In general, wells located near the river in both the Poe and Hornsby-Treehouse springsheds showed lower nitrate + nitrite as N concentrations (Appendix D-2 and D-3). The high spatial variability of nitrate + nitrite as N among wells on adjoining or nearby properties confirmed that land use in proximity to the well itself may impact nitrate + nitrite as N concentrations and can vary widely in a given area.

Seventeen candidate wells with some of the highest nitrate + nitrite as N values (ranging from 0.65 to 7.6 mg/L) were selected for the additional sampling events. Six sites were excluded from further sampling events due to issues with accessibility or sample collection. Twelve of the selected wells are located in the Poe springshed and five are located in the Hornsby-Treehouse springshed. Due to the absence of detectable nitrate + nitrite as N or the presence of very low concentrations, likely due to river water intrusion and/or denitrification, the four wells located near the Santa Fe River upstream of Poe Spring, where there is a high septic system density, could not be utilized to assess nitrogen sources. Sampling under dry conditions (low groundwater level and low river flow and stage) might provide additional information on nitrate sources in these wells. Spring flow (discharge) and stage data, available for Poe and Hornsby springs (Table 2), was used to document hydrologic conditions during sampling events. Water quality data including nutrients, major ions, nitrogen and oxygen isotopes, and sucralose analyses were used to evaluate nutrient sources.

Table 2. Spring Flow (Discharge) and Stage Data

Station ID	Date	Flow (cfs)*	Stage (ft, NGVD1929)
Poe Spring	10/17/2013	49.74*	26.04
Poe Spring	11/20/2013	43.50	25.99
Poe Spring	1/15/2014	40.62*	26.14
Poe Spring	6/3/2014	57.74*	26.51
Hornsby Spring	10/17/2013	89.31*	33.91
Hornsby Spring	11/20/2013	61.90	33.68
Hornsby Spring	1/16/2014	35.74*	33.52*
Hornsby Spring	6/4/2014	145.38*	34.38

*Flow data recorded by ACEPD staff; all other flow and stage measurements were obtained from SRWMD (http://www.mysuwanneeriver.org/portal/springs.htm)

Field data collected at each sampling location included dissolved oxygen, pH, specific conductance, turbidity, and temperature (Appendix E-1). In general, the average dissolved oxygen values at the spring locations (0.2 to 0.5 mg/L) were considerably lower than the samples collected from the groundwater wells (1.1 to 7.3 mg/L) with the exception of AAK7009 (0.2 mg/L), which is open to the conduit that feeds Hornsby Spring (Table 3). The pH values were relatively consistent among the samples collected, with values ranging from 6.9 to 7.8 SU. Specific conductance values ranged from 261 to 622 µmhos/cm. Turbidity values were generally low, ranging from 0.1 to 4.5 NTU, with most results below 1 NTU; however, higher turbidity was noted at AAK7000 (4.5 NTU). The pump in this well had been recently replaced and the homeowner reported the well had been pumping more sediment. The water temperature for all samples was recorded between 21.3 and 23.4 °C.

Table 3. Summary of Groundwater Sampling Results

Station ID	Springshed	Mean* DO (mg/L)	Mean* $NO_3 + NO_2$ as N (mg/L)	Mean* TOC (mg/L)	Jan 2014 $\delta^{15}N$ (0/00)	Jan 2014 $\delta^{18}O$ (0/00)	Jan 2014 Sucralose (µg/L)
AAC1215	Poe	3.4	0.75	0.5 U	6.01	6.29	0.01 U
AAJ7000	Poe	3.3	6.37	0.5 U	10.61	6.72	0.01 U
AAJ7002	Poe	2.2	3.33	0.5 U	7.78	8.40	0.058
AAJ7005	Poe	6.6	3.50	0.5 U	5.68	5.71	0.01 U
AAJ7006	Poe	3.3	0.99	0.9	5.90	3.66	0.066
AAJ7007	Poe	5.1	3.93	0.5 U	4.78	3.28	0.082
AAK7000	Poe	2.5	1.60	0.5 U	7.36	10.31	0.038 I
AAK7001	Poe	7.0	7.53	0.5 U	2.18	3.64	0.01 U
AAK7002	Poe	3.4	1.27	0.5 U	2.81	5.22	0.01 U
AAK7003	Poe	7.3	1.33	0.5 U	1.49	5.81	0.01 U
AAK7004	Poe	1.1	1.11	0.5 U	8.61	8.70	0.023 I
AAK7005	Poe	6.3	0.80	0.5 U	5.00	0.08	0.01 U
Poe	Poe	0.2	0.18	2.7	21.44	15.78	0.2
WTRMLN2	Poe	0.2	0.32	3.5	19.40	13.75	0.2
AAJ7001	Hornsby	3.0	2.53	0.5 U	6.58	5.35	0.01 U
AAJ7003	Hornsby	6.4	3.27	0.5 U	7.92	1.17	0.01 U
AAJ7004	Hornsby	6.3	4.20	0.5 U	5.03	1.89	0.041 I
AAK7008	Hornsby	1.5	0.89	1.6	26.47	10.72	0.13
AAK7009	Hornsby	0.2	0.60	1.9	15.54	11.36	0.14
Hornsby	Hornsby	0.3	0.56	2.3	17.78	12.98	0.16

*Arithmetic mean (or average) of all data collected in October/November 2013, January 2014, and June 2014.
U = The compound was analyzed for but not detected; the value reported is the method detection limit.
I = The reported value is between the method detection limit and the practical quantitation limit.

Samples collected in January and June 2014, and samples from four wells and Poe and Hornsby springs in October 2013, were analyzed for nitrate + nitrite as N, total nitrogen, Total Kjeldahl Nitrogen, ammonia as N, total phosphorus, and total organic carbon (Appendix E-2). Average nitrate + nitrite as N values ranged from 0.18 mg/L at Poe Spring to 7.6 mg/L at AAK7001 (Table 3 and Figure 1). In general, wells located near the river in both the Poe and Hornsby-Treehouse springsheds showed lower nitrate + nitrite as N concentrations, possibly due to river water intrusion and/or denitrification (Appendix F). Total nitrogen values were approximately equal to nitrate + nitrite as N values and results for Total Kjeldahl Nitrogen and ammonia as N were negligible for most samples. Total phosphorus was detected at low levels in less than half of the groundwater samples collected; the highest values were found at AAK7000 and AAK7008 in June 2014 (0.14 and 0.13 mg/L, respectively). Total organic carbon (TOC) was detected at the three springs and only three well locations (AAJ7006, AAK7008 and AAK7009).

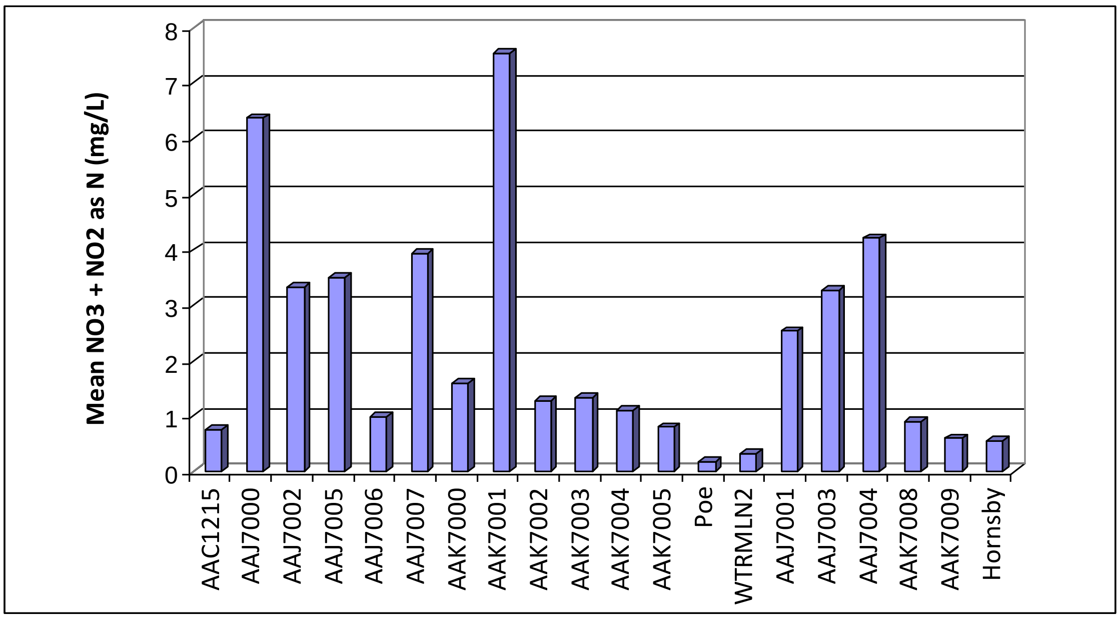


Figure 1. Summary of Groundwater Nitrate Results, October 2013 – June 2014

The isotopic composition of nitrate ($\delta^{15}N$, $\delta^{18}O$) was used to determine the sources of nitrate and assess the extent of denitrification for samples collected in January 2014. Inorganic fertilizer, animal waste and wastewater have relatively distinct ranges of $\delta^{15}N$ and $\delta^{18}O$ values (FDEP, 2014a). Nitrate isotope analysis was conducted on samples collected in January 2014. Three wells (AAK7001, AAK7002, and AAK7003) had $\delta^{15}N$ values consistent with inorganic fertilizers (Figure 2). Most of the samples had $\delta^{15}N$ values that were consistent with organic sources such as animal wastes and/or wastewater. However, many of these samples also had elevated $\delta^{18}O$ values, which suggest that denitrification has occurred. The five samples with the highest $\delta^{15}N$ and $\delta^{18}O$ values, shown in the upper right hand side of Figure 2, are the three springs and two wells near Hornsby Spring (AAK7008 and AAK7009), all of which had low dissolved oxygen and the presence of organic carbon necessary for denitrification to occur (Table 3). As a result, isotopic composition of nitrate alone is not sufficient to determine the source of nitrate.

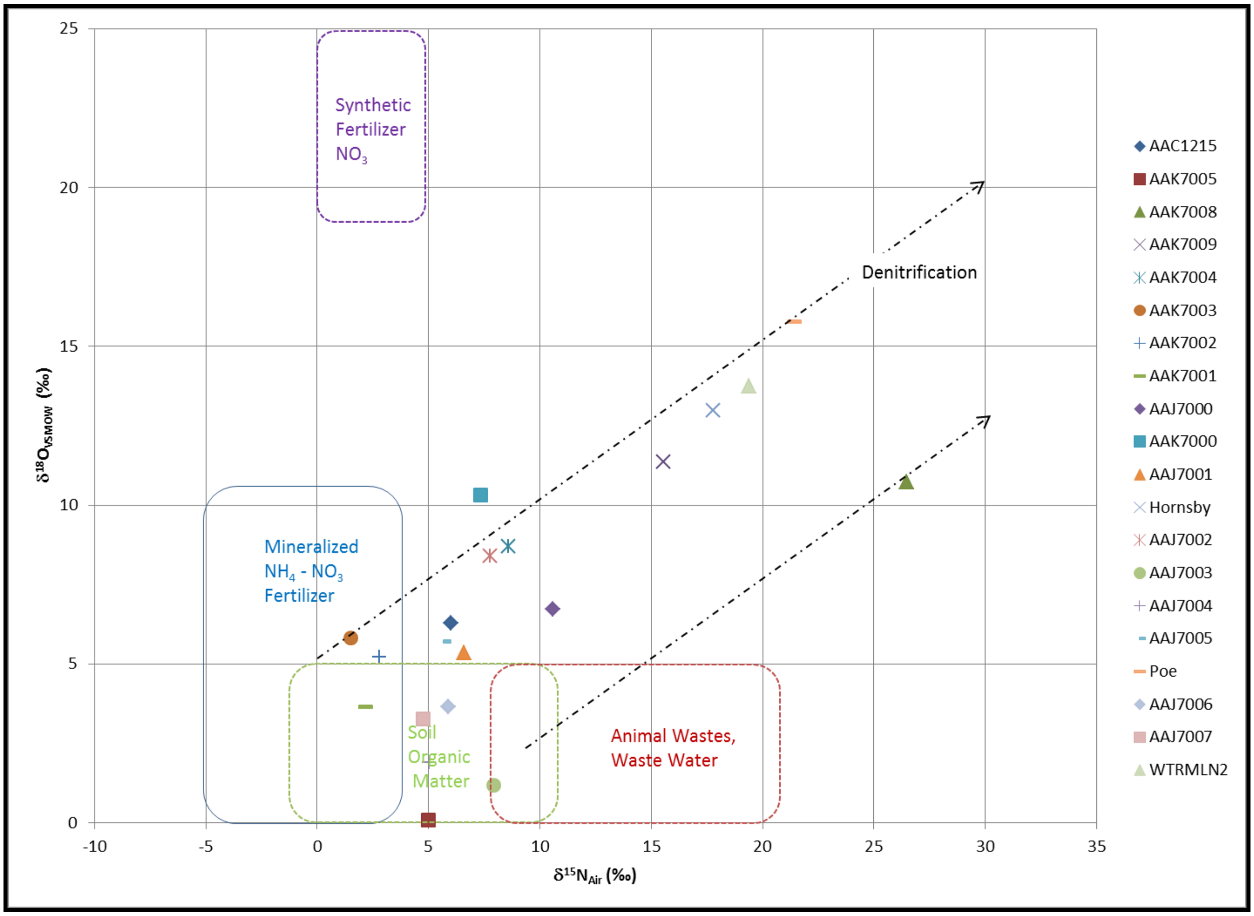


Figure 2. Nitrogen and Oxygen Isotope Results, January 2014 (modified from Roadcap et al., 2002)

Sucralose, an artificial sweetener and indicator of domestic wastewater influences, was detected in samples collected from the three springs and two wells near Hornsby Spring (AAK7008 and AAK7009) in January 2014 (Table 3). Previous samples collected from Poe Spring, Hornsby Spring and AAK7008 have had detectable sucralose, which would suggest that the springs and nearby wells are likely impacted by a wastewater source. Sucralose was also detected in three other wells in the Poe springshed (AAJ7002, AAJ7006 and AAJ7007) in January 2014. Well AAJ7002 had a nitrate + nitrite as N concentration of 2.2 mg/L in January and 4.2 mg/L in June 2014. The land use surrounding the well is primarily agriculture and residential. The increase in nitrate could be the result of fertilizer application during the early growing season. The elevated $\delta^{15}N$ and $\delta^{18}O$ value indicates the source could be inorganic fertilizer that has undergone denitrification (Figure 2). Well AAJ7006 is located in a primarily low density residential area and had an average nitrate + nitrite as N concentration of 0.99 mg/L. Well AAJ7007 is located in a primarily agricultural area and had an average nitrate + nitrite as N concentration of 3.93 mg/L. The isotope values for wells AAJ7006 and AAJ7007 indicate a mixture of inorganic and organic sources. The presence of sucralose indicates that there is likely some wastewater influence. Additional sampling for sucralose should be conducted to further support the identification of the source since sucralose concentrations have been shown to be highly variable. Given the mixture of agricultural and residential land use surrounding the wells, it is most likely a combination of inorganic fertilizers, wastewater from septic systems, and possibly animal wastes from live stock (Figure 2).

Samples collected in January and June 2014, and samples from four wells and Poe and Hornsby springs in October 2013, were analyzed for major cations and anions, selected metals, and other indicators including total dissolved solids, alkalinity, and hardness (Appendix G). The comparison of major cations and anions, and selected metals using Piper and Stiff diagrams does not show any significant differences in water type or aquifer source material (Appendix H). The water type is a high calcium and bicarbonate/carbonate typical of the Floridan aquifer system, which is comprised primarily of limestone (calcium carbonate). All of the three springs sampled had elevated sulfate and slightly elevated chloride concentrations. Five wells were identified as having slightly elevated chloride (AAJ7000, AAJ7007, AAK7005, AAK7008, and AAK7009) and two wells also had elevated sulfate concentrations (AAK7008 and AAK7009).

Wells AAJ7000, AAJ7007, and AAK7005 are located in the Poe springshed. The slightly elevated chloride concentrations may be a result of impacts from domestic wastewater, fertilizer, or possibly water treatment systems. Two of these wells (AAJ7000 and AAK7005) are located within areas with current land uses primarily in the natural/recreational category, 81.5% and 75%, respectively. Historical land use or current land use activities on the properties may increase chloride concentrations due to anthropogenic changes and the presence of septic systems on the properties. The land use in proximity to well AAJ7007 is predominantly agricultural (92.1%). Although Poe Spring had elevated chloride and sulfate concentrations, a detailed analysis of groundwater wells near the river and upstream of the spring was not conducted due to the influence of river water and the low concentrations of nitrate observed in October 2013, likely due to denitrification.

The three samples with the highest chloride and sulfate concentrations are from Hornsby Spring and the two nearby wells (AAK7008 and AAK7009), another indicator of potential wastewater influences on the surrounding groundwater and spring. Nonparametric statistics (Spearman's rho) were utilized to determine if there was a correlation between nitrate + nitrite as N and potassium, which would indicate a fertilizer source. The correlation was not statistically significant and did not provide further evidence of a fertilizer source in the water samples. Elevated magnesium was also observed at these locations, and combined with elevated sulfate, may indicate a different aquifer composition. Dolostone (carbonate rock containing magnesium in the mineral dolomite) or a dolomitic limestone may be present in the limestones of the Upper Floridan aquifer system. Elevated magnesium, sulfate, fluoride, and chloride could be indicative of a deeper water source within the Floridan aquifer system or water that is moving through the Hawthorn Group sediments where these materials discontinuously overly the limestones of the Floridan aquifer system.

SUMMARY

The Santa Fe River is designated as an Outstanding Florida Water (OFW); its basin covers approximately 1,400 square miles in north Florida and contains over 60 named springs. Alachua County alone has three first magnitude springs and numerous first and second magnitude springs are located in adjacent counties. The river and springs contain remarkable ecosystems and exceptional karst geology. Collectively, billions of gallons of water discharge from the Floridan aquifer through these springs to the rivers each day. The rivers and springs system within the Santa Fe Basin are unquestionably very important natural resources in Florida that must be protected.

Sample collection at Watermelon Spring #2 in the Santa Fe River, January 2014

This project provides current (2013-2014) water quality data for groundwater and springs that can be used by policy makers, planners, and regulatory agencies. Land use near the springs was evaluated to provide information on potential areas of concern, such as clusters of on-site sewage treatment and disposal systems (septic systems) on small lots or other wastewater treatment and disposal issues. Groundwater samples were analyzed for nutrients, nitrate isotopes, major ions, sucralose, and other indicators to assess potential sources. ACEPD staff used statistical analysis and Stiff and Piper diagrams, to compare springs and groundwater chemistry. The project report findings will be presented to the Santa Fe Springs Protection Forums, ACEPD, and other interested groups. This final report summarizing the results will be available to the public on the ACEPD and Santa Fe River Springs Protection Forum websites, and a link to the final copy of the report will be sent to key stakeholders and regulatory scientists.

Groundwater and spring water samples were analyzed for nutrients (nitrogen and phosphorus), major inorganic ions, such as calcium and magnesium, nitrogen and oxygen isotopes, the artificial sweetener sucralose, and other chemical indicators. These analytes were selected to help identify potential sources of organic and inorganic nitrogen. Initially, 44 wells were sampled for nitrate + nitrite as N, and 17 wells with some of the highest nitrate + nitrite as N values, ranging from 0.65 to 7.6 mg N/L, were selected for the more comprehensive analyses. Twenty locations in the Poe and Hornsby-Treehouse springsheds were evaluated to assess potential sources of nitrate in groundwater and springs in January and June 2014, including the 17 wells and three springs.

Samples collected from three springs, Poe, Watermelon #2, and Hornsby, showed indications of potential wastewater influences including the presence of sucralose, and elevated chloride and sulfate concentrations. The elevated isotopes also indicate a mineralized fertilizer source that has undergone denitrification. Two wells near Hornsby Spring (AAK7008 and AAK7009) showed similar trends, indicating the small package wastewater treatment plant and rapid infiltration basins that serve Camp Kulaqua near Hornsby Spring may be influencing groundwater wells and the spring. These two wells and

Hornsby Spring also had increased levels of magnesium. Sulfate and magnesium can also be indicative of changes in lithology, or may indicate anthropogenic changes. Increased magnesium content may be indicative of dolostone or dolomitic limestone in the aquifer and sulfate may indicate the presence of gypsum ($CaSO_4$), although gypsum is usually found at a greater depth. Three wells in the Poe springshed showed slightly elevated chlorides, potentially indicative of wastewater influences or other non-point source contamination. Land use did not directly correlate with elevated nitrate and other indicators; however the land use evaluation was limited to a 300 foot radius surrounding the well. The presence of organic carbon and low concentrations of dissolved oxygen may be favorable conditions for denitrification occurring in the subsurface. Due to the absence of detectable nitrate + nitrite as N or very low concentrations, likely due to river water intrusion and/or denitrification, the four wells located near the Santa Fe River upstream of Poe Spring, where there is a high septic system density, could not be utilized to assess nitrogen sources (nitrate + nitrite as N concentrations were too low to be analyzed for nitrate isotopes).

There was a considerable amount of spatial variability of nitrate + nitrite as N concentrations in water samples from wells in proximity to springs. This spatial variability coupled with denitrification (based on nitrate isotope data) made it difficult to definitively assign nitrogen sources to the elevated nitrate + nitrite as N concentrations observed in groundwater samples. The proximity of Poe and Hornsby springs to the Santa Fe River along with high flow conditions increase the potential for interactions between river water and groundwater, particularly with dissolved organic carbon mixing with groundwater in the springs and nearby wells during high flow conditions. Sampling under drier (low flow) hydrologic conditions (lower groundwater levels and lower river flow than during the present study) might provide additional useful information on nitrate sources.

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- Protect Florida Springs Tag Grant Program & Wildlife Foundation of Florida
- Florida Department of Environmental Protection
- Camp Kulaqua (Hornsby Spring)
- Alachua County Public Works Parks Office

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GLOSSARY

Carbonate Rock - A class of sedimentary rocks composed primarily of carbonate minerals. The two major types are limestone, which is composed of calcite or aragonite (different crystal forms of CaCO3) and dolostone, which is composed of the mineral dolomite (CaMg(CO3)2).

Cody Scarp - An outfacing escarpment or steep slope corresponding to the marine shoreline of the late Pliocene (from about five to two million years ago). The Cody Scarp is the most persistent topographic break in Florida, separating the Northern Highlands physiographic province from the lowland provinces of the Western Valley and Alachua Lake Cross Valley in Alachua County. Locally, the scarp is most pronounced along the western flank, becoming more gradual toward the east and southeast. The scarp domain in western and central Alachua County is a zone of high sinkhole activity due to continued erosional retreat and the development of karst features by flowing water from streams originating in the Northern Highlands.

Discharge (or Flow) - 1) Release of water at a given point into a waterbody. 2) The rate and volume of flow of water such as in a stream, generally expressed as cubic feet per second.

Dolostone (Dolomite Rock) - A sedimentary carbonate rock that contains a high percentage of the mineral dolomite. The mineral dolomite, the primary component of the rock, is a calcium magnesium carbonate (CaMg- (CO3)2).

Floridan Aquifer System - Thick carbonate sequence which includes all or part of the Paleocene to early Miocene Series and functions regionally as a water-yielding hydraulic unit. Where overlain by either the intermediate aquifer system or the intermediate confining unit, the Floridan contains water under confined conditions. Where overlain directly by the surficial aquifer system, the Floridan may or may not contain water under confined conditions depending on the extent of low permeability material in the surficial aquifer system. Where the carbonate rocks crop out, the Floridan generally contains water under unconfined conditions near the top of the aquifer system, but because of vertical variations in permeability, deeper zones may contain water under confined conditions. The Floridan aquifer system is present throughout the state and is the deepest part of the active groundwater flow system for mainland Florida.

Groundwater - Water that occurs in the subsurface and fills or saturates the porous openings, fractures, and fissures of underground soils and rock units.

Gypsum - A soft white or gray mineral consisting of hydrated calcium sulfate. Gypsum is often found in the deeper or more highly mineralized portions of the Floridan aquifer system.

Hawthorn Group - A series of geologic formations comprised of complex, highly variable strata consisting of interbedded and intermixed siliciclastic (sands and clay), carbonate, and phosphatic sediments of Miocene age.

Isotopes - Isotopes are atoms of the same element that have the same numbers of protons and electrons but different numbers of neutrons. Naturally occurring isotopes that exist in water can be used to investigate groundwater and surface water systems. Nitrogen and oxygen isotopes are frequently used for this purpose. For this work, $\delta^{15}N$ and $\delta^{18}O$ isotopes of nitrate were used to evaluate sources of nitrogen (nitrate) enrichment in springs and groundwater.

Isotope data are expressed in delta (δ) notation as the ratio of the heavy to the light isotope, normalized to a standard (equation below).

$$\delta_{sample} = 1000[(R_{sample}/R_{standard})-1]$$

Where R_{sample} and $R_{standard}$ are the ratio of the heavy to the light isotope in the sample and in the standard, respectively. Delta nitrogen-15 of nitrate ($\delta^{15}N$) is reported relative to nitrogen in air, and delta oxygen-18 of nitrate ($\delta^{18}O$) is reported relative to Vienna Standard Mean Ocean Water.

Major Ions - Groundwater contains mineral ions. These ions slowly dissolve from soil particles, sediments, and rocks as the water travels through those materials. These ions may be referred to as dissolved solids and are either positively charged ions (cations) or negatively charged ions (anions).

Minimum Detection Limit (MDL) - An estimate of the minimum amount of a substance that an analyte process can reliably detect. An MDL is analyte-specific, matrix-specific, and laboratory dependent.

Karst - A type of terrain characterized by sinkholes, caves, disappearing streams, springs, rolling topography and underground drainage systems. Such terrain is created by groundwater dissolving limestone.

Land Use - For this study, land use was estimated from digitized water management district GIS maps and aerial photography. The relative amount of natural, recreational, silvicultural (tree plantations), agricultural, residential, commercial, and industrial land uses were estimated and noted as a percentage of land area.

Limestone - A sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate (CaCO3).

Lithology (lithologic) - The physical character of rocks or unconsolidated sediments, generally determined visually with or without the aid of a low-power magnifier.

Practical Quantitation Limit (PQL) - The lowest level of measurement that can be reliably achieved during routine laboratory operating conditions within specified limits of precision and accuracy.

Sucralose - chlorinated sugar compound used as an artificial sweetener. Common brand names of sucralose-based sweeteners are Splenda, Sukrana, SucraPlus, Candys, Cukren, and Nevella. Wastewater treatment has been shown to have little effect on sucralose, which may persist in the environment. It has been used in conjunction with other constituents to trace domestic wastewater influences in groundwater.

Spearman's rho - is a nonparametric measure of statistical dependence (strength of association) between two variables.

Spring – A point where groundwater emerges onto the Earth's surface

Spring magnitude – A category based on the volume of flow from a spring per unit time.
The classification system used in Florida is based on Meinzer (1927).
Magnitude Metric Units English Units
1 ≥ 2.832 cms ≥ 100 cfs (≥ 64.6 mgd)
2 ≥ 0.283 to 2.832 cms ≥ 10 to100 cfs (≥ 6.46 to 64.6 mgd)
3 ≥ 0.028 to 0.283 cms ≥ 1 to 10 cfs (≥ 0.646 to 6.46 mgd)
4 ≥ 0.0063 to 0.028 cms ≥ 100 gpm to 1 cfs (≥ 100 to 448gpm)
5 ≥ 0.631 to 6.308 lps ≥ 10 to 100 gpm
6 ≥ 0.063 to 0.631 lps ≥ 1 to 10 gpm
7 ≥ 0.473 to 3.785 lpm ≥ 1 pint/min to 1 gpm
8 < 0.473 lpm < 1 pint/min
cms = cubic meters per second lps = liters per second
cfs = cubic feet per second pint/min = pints per minute
mgd = million gallons per day lpm = liters per minute
gpm = gallons per minute

Stiff and Piper diagrams - two graphical methods that can be used to compare major-ion chemical composition of groundwater and show differences where they exist. Stiff diagrams allow visual comparison of the concentrations of major ions (cations and anions). Different chemical composition can be easily discerned by comparing the graphs. A Piper diagram is a water analysis diagram that graphically depicts the major cations and anions in the water as percentages and allows categorization by the dominant ions, such as calcium, magnesium, sodium, and potassium. In the Upper Floridan aquifer system within the study area, calcium and magnesium are the dominant positive ions or cations and carbonate (CO_3) and bicarbonate (HCO_3) are the major negative ions or anions.

Travel time (groundwater) - The time required for groundwater to travel between two locations.

Wastewater - septic system or sewage treatment plant effluent from treatment of human or domestic sewage.

DESCRIPTIONS OF ANALYTES

Water quality of groundwater was determined by collecting and analyzing water samples from wells and springs. A series of field measurements were taken on site prior to sample collection. They include dissolved oxygen, pH, specific conductance, water temperature and flow rate or discharge. Other observations and data recorded in the field include local geology, weather conditions and adjacent land use practices. When combined, field and analytical data give a snapshot of water quality at that point in time. Comparing similar data, taken over time, can yield information about how water quality changes over time and what may be causing these changes.

Alkalinity - In the natural environment carbonate alkalinity tends to make up most of the total alkalinity due to the common occurrence and dissolution of carbonate rocks and presence of carbon dioxide in the atmosphere. Alkalinity is the measure of the ability of a solution to neutralize acids to the equivalence point of carbonate (CO_3) or bicarbonate (HCO_3).

Boron (B) - a nonmetallic element occurring naturally only in combination, as in borax or boric acid. Boron can be an indicator of wastewater since it is a common component of laundry soap. Boron can be an effective tracer of sewage sources because natural groundwater and surface water concentrations are relatively low.

Calcium (Ca) - Calcium occurs naturally in Florida groundwater primarily from interaction with limestone rock. Calcium is often discussed in relation to total hardness as a measure of calcium carbonate and is one of the most abundant minerals in the human body.

Chloride (Cl^-) - Chloride is the most abundant constituent in seawater. Groundwater that is tidally influenced may have high chloride concentrations. Chloride is added to the atmosphere via marine aerosols from the ocean. Other sources are weathering of rock, agriculture fertilization, wastewater and water softeners. The state of Florida has a secondary drinking water standard for chloride at 250 mg/L.

Dissolved Oxygen (DO) – Atmospheric oxygen readily dissolves in water. Typically unconfined aquifers have higher DO levels then confined aquifers. In the unconfined portion of the Floridan aquifer DO levels can approach saturation while in the confined portions the DO levels can be virtually zero.

Fluoride (F^-) - Fluoride occurs naturally in some water supplies. Fluoride is often added to drinking waters at appropriate values to reduce dental cavities. State regulations set concentrations of Fluoride as not to exceed 4.0 mg/L in drinking water.

Iron (Fe) - Iron occurs naturally in groundwater. Iron exists in a number of forms in water. Water with high iron levels can form reddish brown deposits. Concentrations of iron as low as 300 µg/L can leave reddish brown stains on plumbing fixtures, tableware and laundry that can be very hard to remove. When these deposits break loose from water piping, rusty water will flow through the faucet. Excess iron may cause the growth of iron bacteria that leave a reddish brown or yellow slime that can clog plumbing. The state of Florida has set a secondary drinking water standard for iron at 300 µg/L. There are generally no adverse health effects associated with the concentrations set by the secondary drinking water standard but at considerably higher concentrations health implications may exist as well as aesthetic degradation.

Magnesium (Mg) - Sources of Magnesium occur naturally in Florida. Dissolved Magnesium is added as groundwater percolates through dolomite rock and limestone.

Nitrate + Nitrite (NO_3^- + NO_2^-) as N - Nitrate and nitrite are both found in groundwater in Florida. Nitrate contamination recently has become a problem in Florida's springs. Nitrate found in groundwater originates from fertilizers, septic tanks and animal waste that enter the aquifer in recharge areas. Nitrate, being a nutrient, encourages algal and aquatic plant growth in surface water, which may lead to eutrophication of the springs and the associated water bodies. Nitrite, which is much less of a problem, can originate from sewage and other organic waste products. FDEP regulates nitrogen, in the form of nitrates and nitrites, in drinking water in Florida. The maximum contaminant level in drinking water for nitrate-N is 10 mg/L, for nitrite-N is 1 mg/L and the combined total for nitrate + nitrite as N is 10 mg/L.

pH - pH measures the acidity or alkalinity of water. It is defined as the negative log of the hydrogen ions (H_3O^+) in a solution. A low pH indicates a high concentration of hydrogen ions, while a high pH indicates a low concentration. Values range between 0 and 14 standard units (SU). A low pH (below7) represents acidic conditions, and a high pH (above 7) represents alkaline conditions. A pH of 7 indicates the water is near neutral conditions. As raindrops form they incorporate dissolved carbon dioxide, forming weak carbonic acid. The resulting rain has a low pH. In Florida, as rainwater passes through soil layers it incorporates organic acids and the acidity increases. When acidic water enters a limestone aquifer, the acids react with calcium carbonate in the limestone and dissolution occurs. Generally, most Floridan aquifer system groundwater falls within a pH range of 7 to 8. During heavy rain events, groundwater can drop in pH as tannic acids from nearby surface waters are flushed into the aquifer system; surface waters and water in the surficial (shallow) aquifer frequently have a pH less than 7. This dissolution of calcium carbonate in the limestone results in the formation of karst features such as sinkholes and cave systems.

Potassium (K^+) - Potassium occurs in trace amounts in Florida's groundwater and is derived primarily from seawater. Therefore, it occurs in higher concentration along the coast. The weathering of mica, feldspar and clay minerals can contribute potassium to groundwater. In addition, because potassium is an essential nutrient, it is a component of fertilizers.

Sodium (Na^+) - In Florida, sodium occurring in groundwater has several sources. Marine aerosols, mixing of seawater with fresh water and the weathering of sodium-bearing minerals like feldspars and clays are the primary sources. The maximum contaminant level in drinking water is 160 mg/L (160,000 µg/L).

Sulfate (SO_4^{2-}) - Sulfate is commonly found in aquifer waters in Florida and has several sources. The two most common sources are from seawater and the dissolution of gypsum and anhydrite (naturally occurring rock types within Florida's aquifer systems). Sulfate is often used as a soil amendment to acidify soils, and thus is associated with agricultural activities. Finally, disposal and industrial waste activities release sulfate to groundwater. Sulfate-rich spring water can potentially be toxic to plants. In higher concentrations it affects the taste of drinking water. The secondary drinking water standard is set at 250 mg/L.

Specific Conductance - Specific conductance is a measure of the ability of a substance, in this case groundwater, to conduct electricity. The conductance is a function of the amount and type of ions in the water.

Total Ammonia (NH_3 + NH_4^+) - Ammonia (NH_3) occurs in groundwater primarily as the ammonium ion (NH_4^+) because of the prevalent pH and reduction-oxidation potential. Microbial activity within the soil can convert nitrogen to ammonium. Other sources include human and animal wastes and the decomposition of organic materials.

Total Dissolved Solids (TDS) - Total dissolved solids is a measure of the dissolved chemical constituents, primarily ions, in groundwater. Concentrations in Florida's groundwater vary widely. Since most of Florida's groundwater issues from carbonate aquifers, the total dissolved solid concentrations are fairly high. Higher concentrations are found in areas that are tidally influenced. The secondary drinking water standard is set at 500 mg/L.

Total Kjeldahl Nitrogen (TKN) - This is a measure of the sum of the ammonia nitrogen and organic nitrogen in the groundwater sample. The ammonia nitrogen, mainly occurring as ammonium (NH_4^+), occurs in trace amounts in groundwater. Organic nitrogen describes a nitrogen compound that had its origin in living material either from waste products or decomposing plant materials.

Total Nitrogen (TN) - The amount of nitrate, nitrite, ammonia, and organic nitrogen, when summed, gives the total nitrogen content of water.

Total Organic Carbon (TOC) - Natural and non-naturally occurring organic carbon are present in varying concentrations in groundwater in Florida. The primary source of naturally occurring organic carbon is humic substances (decaying plant material). Synthetic organic carbon represents a minor component.

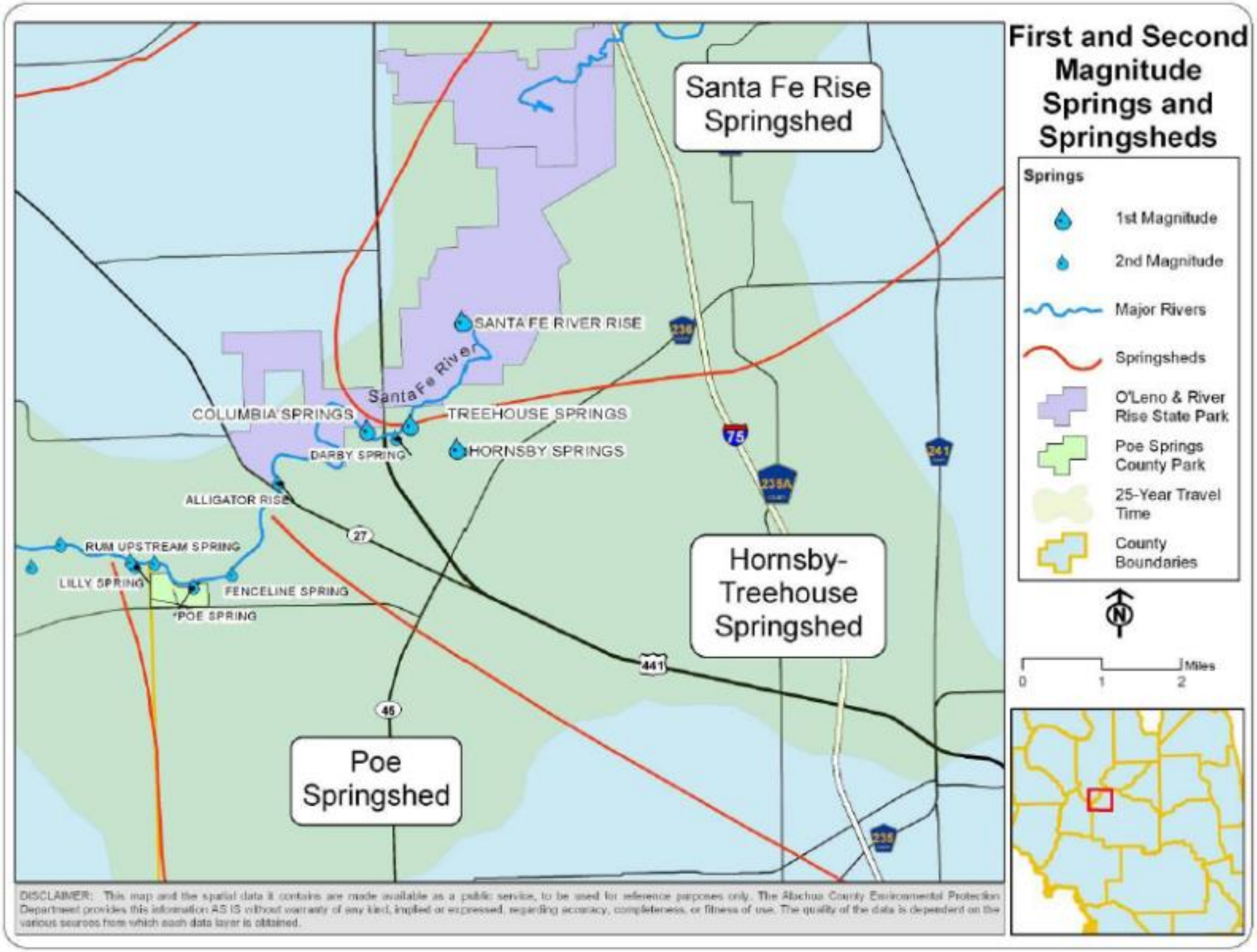
Total Phosphorus - Phosphorus is an essential nutrient and occurs in groundwater in Florida. Unfortunately, an excess can cause excessive plant growth and the eutrophication of surface waters. The Hawthorn Group, a geological unit in Florida, is the most important source of phosphorus in water. Other sources include organic and inorganic fertilizers, animal waste, human waste effluent and industrial waste.

Turbidity - Turbidity is a measure of the colloidal suspension of tiny particles and precipitates in groundwater. High turbidity water impedes the penetration of light and can be harmful to aquatic life. Most of Florida's groundwater is low in turbidity. Turbidity is measured in Nephlometric Turbidity Units (NTUs).

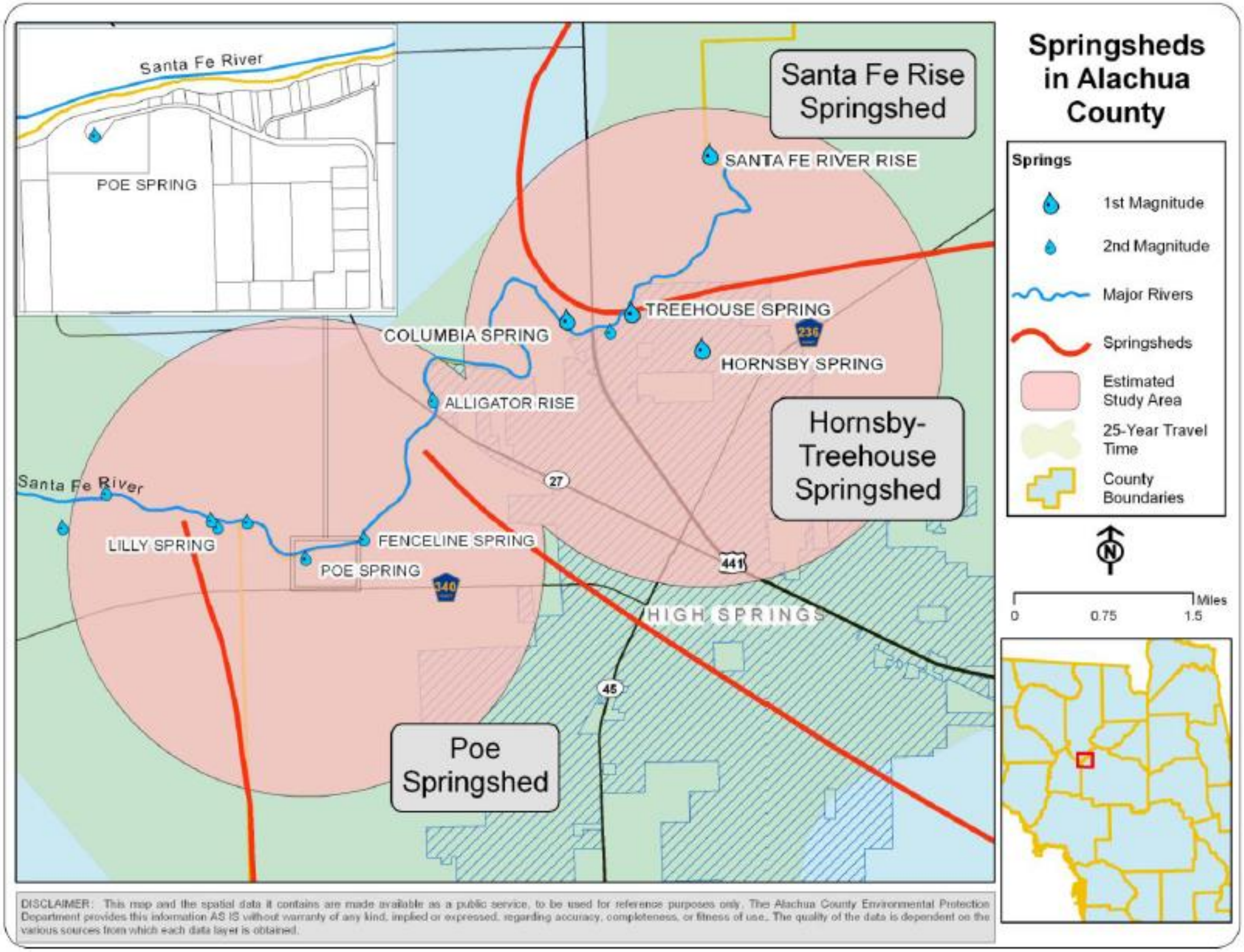
Trace Metals - Metal analyses for this report include: calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), fluoride (F), and phosphorous (P). Trace metals, when present in groundwater, are found in very low concentrations and are measured in parts per billion (ppb), or micrograms per liter (µg/L). In Florida, calcium and magnesium occur in higher concentrations and in this report although they are metals they are considered major ions (cations). The naturally low abundance of trace metals in Florida's groundwater can be attributed to several factors including: low natural abundance in aquifer rocks, low solubility of metal bearing minerals, high adsorption potential of metal ions on clays and organic particulates and precipitation in the form of sulfides and oxides. Many biochemical processes require small amounts of some trace metals; however, high concentrations can be toxic. Industrialization and increased demand for products containing trace metals have overwhelmed the natural biogeochemical cycle, and anthropogenic sources of trace metals now far outweigh natural sources.

Water Temperature - Geologic material is characteristically a good insulator. Rocks and sediments tend to buffer changes in the temperature of groundwater. Thus, groundwater temperature does not vary much and tends to reflect the average annual air temperature. In Florida, this temperature can range from 68°F to 75°F (20° C to 24° C), plus or minus several tenths of a degree. Temperature plays a role in chemical and biological activity within the aquifer and can help in determining residence time of the water in the aquifer.

APPENDIX A: First and Second Magnitude Springs and Springsheds Map



APPENDIX B: Study Area Map for Poe and Hornsby-Treehouse Springsheds



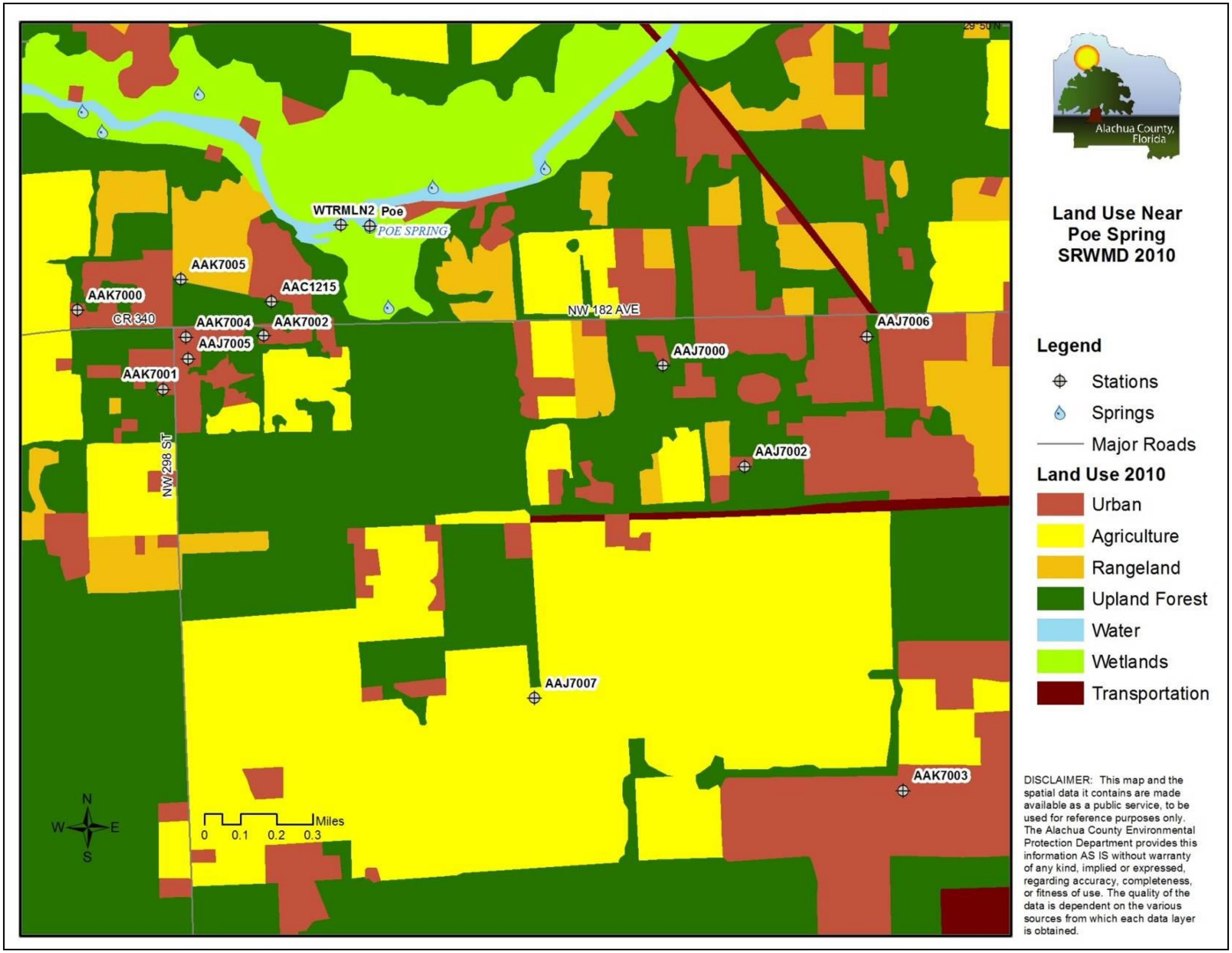
APPENDIX C-1: Land Use Surrounding Sampling Locations

Station ID	Springshed	Natural/Recreational									Residential		Agricultural	
		Major Springs	Streams and Waterways	Wetland Hardwood Forests	Wetland Forested Mixed	Recreational	Upland Hardwood Forests	Upland Mixed Forests	Herbaceous	Other Open Lands (Rural)	Residential Low Density	Residential Medium Density	Cropland and Pastureland	Tree Plantations
AAC1215	Poe	0.0	0.0	0.0	0.0	43.7	56.3	0.00	0.0	0.0	0.0	0.0	0.0	0.0
AAJ7000	Poe	0.0	0.0	0.0	0.0	0.0	81.5	0.00	0.0	0.0	18.5	0.0	0.0	0.0
AAJ7002	Poe	0.0	0.0	0.0	0.0	0.0	0.0	0.00	7.2	0.0	22.2	0.0	0.0	70.6
AAJ7005	Poe	0.0	0.0	0.0	0.0	0.0	0.0	20.1	0.0	0.0	79.2	0.0	0.0	0.8
AAJ7006	Poe	0.0	0.0	0.0	0.0	0.0	31.3	0.00	0.0	0.0	68.7	0.0	0.0	0.0
AAJ7007	Poe	0.0	0.0	0.0	0.0	0.0	0.0	7.9	0.0	0.0	0.0	0.0	92.1	0.0
AAK7000	Poe	0.0	0.0	0.0	0.0	0.0	26.3	<0.1	0.0	17.3	46.2	0.0	10.2	0.0
AAK7001	Poe	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	36.6	0.0	0.0	61.4
AAK7002	Poe	0.0	0.0	0.0	0.0	0.0	15.4	37.5	0.0	0.0	42.9	0.0	4.2	0.0
AAK7003	Poe	0.0	0.0	0.0	0.0	0.0	1.7	0.00	0.0	0.0	98.3	0.0	0.0	0.0
AAK7004	Poe	0.0	0.0	0.0	0.0	0.0	16.7	13.1	0.0	0.0	70.2	0.0	0.0	0.0
AAK7005	Poe	0.0	0.0	0.0	0.0	0.0	31.5	0.00	43.5	0.0	25.0	0.0	0.0	0.0
Poe	Poe	22.7	13.6	0.0	63.7	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
WTRMLN2	Poe	4.8	28.3	24.7	42.2	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
AAJ7001	Hornsby-Treehouse	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	38.7	0.0	61.3	0.0
AAJ7003	Hornsby-Treehouse	0.0	0.0	0.0	0.0	0.0	0.0	40.2	0.0	0.0	59.8	0.0	0.0	0.0
AAJ7004	Hornsby-Treehouse	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	64.2	6.3	29.5
AAK7008	Hornsby-Treehouse	0.0	0.0	0.0	0.0	83.1	0.0	16.9	0.0	0.0	0.0	0.0	0.0	0.0
AAK7009	Hornsby-Treehouse	0.0	0.0	0.0	0.0	0.0	0.0	94.4	0.0	0.0	5.6	0.0	0.0	0.0
Hornsby	Hornsby-Treehouse	7.7	0.0	33.0	0.0	59.3	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0

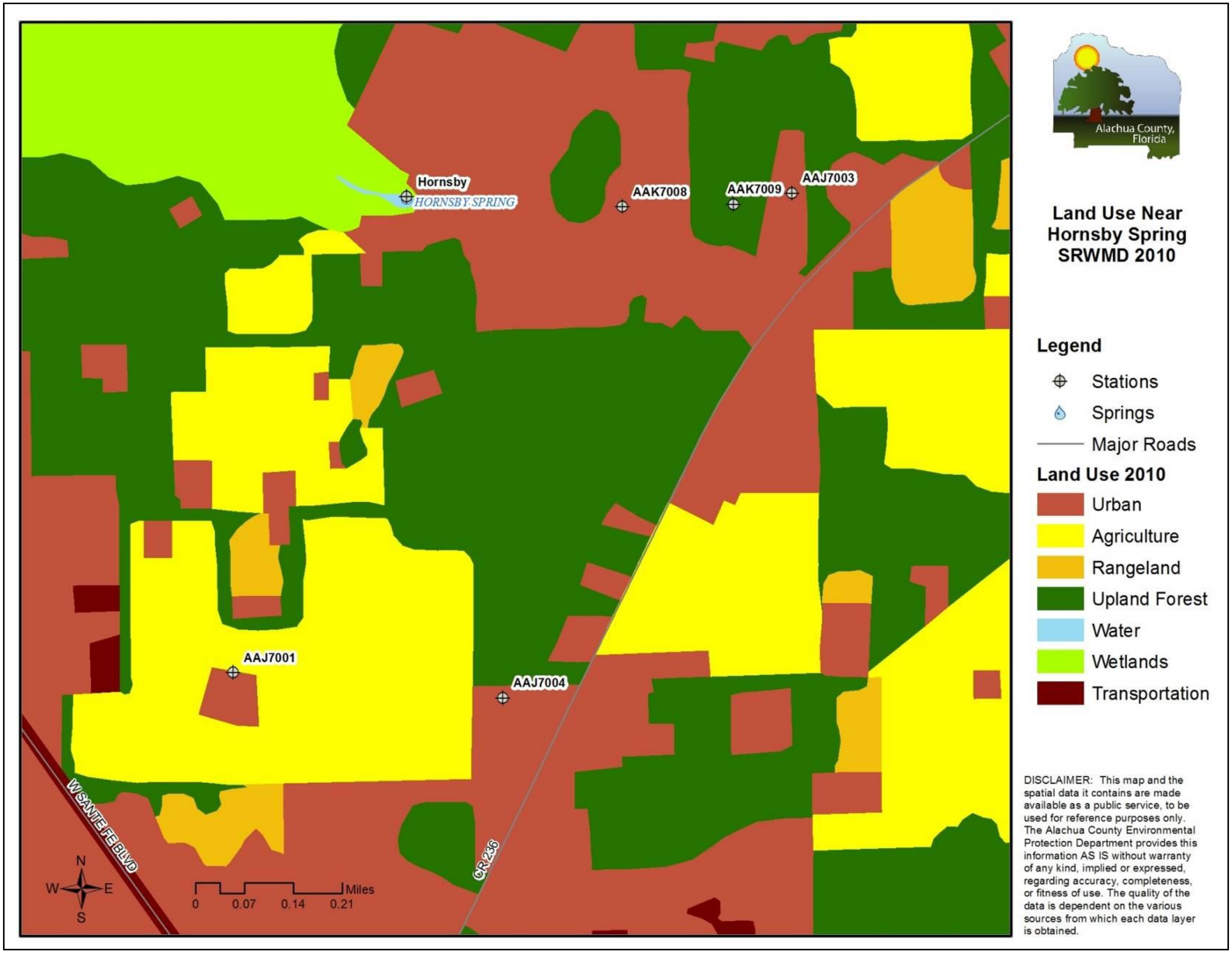
Source: Suwannee River Water Management District Land Use and Cover 2010 – 2011.

Land use values are percent of the contributing area, delineated using a 300’ radius following micro-land use procedures set forth by FDEP Watershed Monitoring Program.

APPENDIX C-2: Land Use Map Near Poe Spring



APPENDIX C-3: Land Use Map Near Hornsby Spring



APPENDIX D-1: Nitrate and Field Parameter Results, October – November 2013

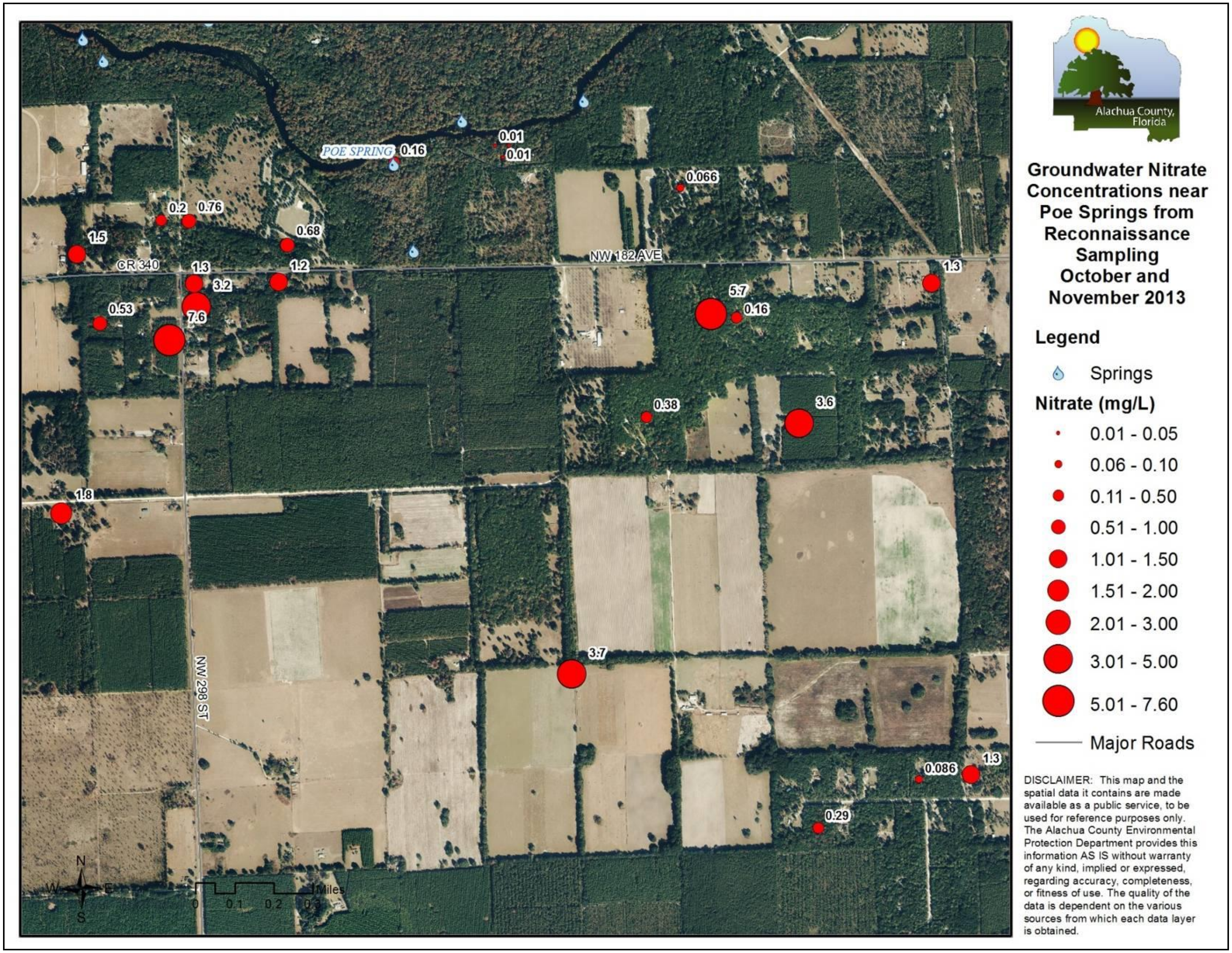
Sample ID	Springshed	Sample Date	$NO_3 + NO_2$ (mg/L)	Purge Volume (Gallons)	DO (mg/L)	DO Saturation (%)	pH (SU)	Sp Cond (µmhos/cm)	Turb (NTU)	Temp (°C)
AAK7001	Poe	10/24/13 15:10	7.6	110	7.2	85.1	7.8	261	NM	22.4
AAJ7000	Poe	11/7/13 11:29	5.7	84	3.3	37.1	7.1	528	0.1	21.7
AAJ7007	Poe	11/5/13 11:51	3.7	76	5.3	62.0	6.9	566	0.2	23.2
AAJ7002	Poe	10/22/13 12:01	3.6	132	2.6	30.8	7.1	505	0.1	22.7
AAJ7005	Poe	10/24/13 14:47	3.2	83.2	6.6	76.4	7.6	276	NM	22.6
GW1	Poe	10/24/13 15:40	1.8	88	2.1	24.6	7.4	415	NM	22.6
AAK7000	Poe	10/24/13 13:34	1.5	180	2.2	25.4	7.3	428	NM	22.4
AAJ7006	Poe	10/22/13 11:05	1.3	156	4.2	48.7	7.3	399	0.2	22.4
AAK7003	Poe	11/5/13 12:46	1.3	112	7.5	86.2	7.2	386	0.2	22.4
AAK7004	Poe	10/24/13 14:14	1.3	106.4	1.0	11.2	7.4	388	NM	22.5
AAK7002	Poe	11/5/13 10:36	1.2	108	3.9	44.9	7.5	295	0.7	21.8
AAK7005	Poe	10/17/13 14:09	0.76	209	6.8	77.2	7.3	399	0.3	21.9
AAC1215	Poe	10/17/13 13:29	0.68	112.2	2.9	33.9	7.4	333	0.8	22.2
GW2	Poe	11/7/13 10:33	0.53	150	4.1	47.4	7.4	413	0.9	23.1
GW3	Poe	10/22/13 12:54	0.38	132	2.0	22.4	7.3	423	0.9	22.0
GW4	Poe	11/5/13 13:46	0.29	91	7.0	80.0	7.3	362	0.1	21.7
GW5	Poe	10/24/13 12:54	0.2	140	5.8	66.5	7.5	291	NM	22.3
GW6	Poe	11/7/13 13:00	0.16	99	0.3	4.0	7.3	425	0.7	22.7
Poe	Poe	10/17/13 15:10	0.16	NA	0.2	1.8	7.3	420	0.4	22.4
GW7	Poe	11/5/13 13:11	0.086	120	0.0	0.3	7.3	428	3.6	22.5
GW8	Poe	10/24/13 16:09	0.066	120	6.3	72.4	8.1	152	NM	22.5
GW9	Poe	10/24/13 11:11	0.043 I	99	1.3	15.1	7.1	581	NM	20.8
GW10	Poe	10/24/13 10:33	0.025 I	156	0.1	1.5	6.8	2089*	NM	21.2
GW11	Poe	10/24/13 11:35	0.01 U	83	0.1	1.6	7.4	421	NM	22.0
GW12	Poe	10/22/13 14:36	0.01 U	144	0.1	1.9	7.4	430	6.9	22.5
AAJ7004	Hornsby-Treehouse	11/5/13 15:09	3.7	132	6.2	72.5	7.4	352	0.1	23.0
GW13	Hornsby-Treehouse	11/5/13 16:39	3.6	85	6.5	74.7	7.3	376	1.3	22.6
AAJ7003	Hornsby-Treehouse	10/29/13 15:30	3.3	120	6.4	74.8	7.5	289	NM	23.1
GW14	Hornsby-Treehouse	11/5/13 15:56	2.7	110	6.8	77.5	7.4	315	0.3	22.3

Sample ID	Springshed	Sample Date	$NO_3 + NO_2$ (mg/L)	Purge Volume (Gallons)	DO (mg/L)	DO Saturation (%)	pH (SU)	Sp Cond (µmhos/cm)	Turb (NTU)	Temp (°C)
AAJ7001	Hornsby-Treehouse	11/7/13 17:25	2.2	229	4.1	47.0	7.1	440	0.1	22.9
AAK7008	Hornsby-Treehouse	10/17/13 11:15	0.93	NM	0.7	8.2	7.3	549	0.4	23.3
GW15	Hornsby-Treehouse	10/31/13 11:26	0.81	120	4.4	51.3	7.3	453	0.3	23.3
GW16	Hornsby-Treehouse	10/29/13 16:34	0.71	100	4.5	51.5	7.7	236	NM	22.2
GW17	Hornsby-Treehouse	10/29/13 14:40	0.7	100	6.1	71.2	7.4	320	NM	22.9
AAK7009	Hornsby-Treehouse	10/17/13 10:33	0.65	NM	0.1	1.1	7.3	452	0.2	22.8
Hornsby	Hornsby-Treehouse	10/17/13 12:23	0.63	NA	0.4	4.0	7.4	452	0.2	22.4
GW18	Hornsby-Treehouse	10/31/13 10:44	0.62	140	6.0	68.7	7.4	359	0.1	22.2
GW19	Hornsby-Treehouse	11/7/13 16:00	0.48	120	2.1	23.9	7.4	334	0.3	22.8
GW20	Hornsby-Treehouse	11/7/13 13:54	0.37	108	3.4	39.1	7.9	178	0.5	22.9
GW21	Hornsby-Treehouse	10/29/13 16:00	0.14	156	7.3	83.4	8.0	156	NM	22.0
AAC1211	Hornsby-Treehouse	10/29/13 10:39	0.089	120	1.1	12.3	7.3	418	0.2	21.7
AAC1214	Hornsby-Treehouse	10/29/13 12:39	0.039 I	102	0.1	0.8	7.3	431	NM	22.0
AAC1212	Hornsby-Treehouse	10/29/13 13:12	0.02 I	85	0.1	1.3	7.0	1712*	NM	23.2
AAC1213	Hornsby-Treehouse	10/29/13 11:38	0.01 U	108	0.0	0.2	7.2	507	NM	22.6
AAC2182	Hornsby-Treehouse	10/29/13 11:21	0.01 U	132	0.0	0.3	7.2	510	0.6	22.3
GW22	Hornsby-Treehouse	11/7/13 16:37	0.01 U	105	0.9	11.1	7.4	370	1.0	22.4

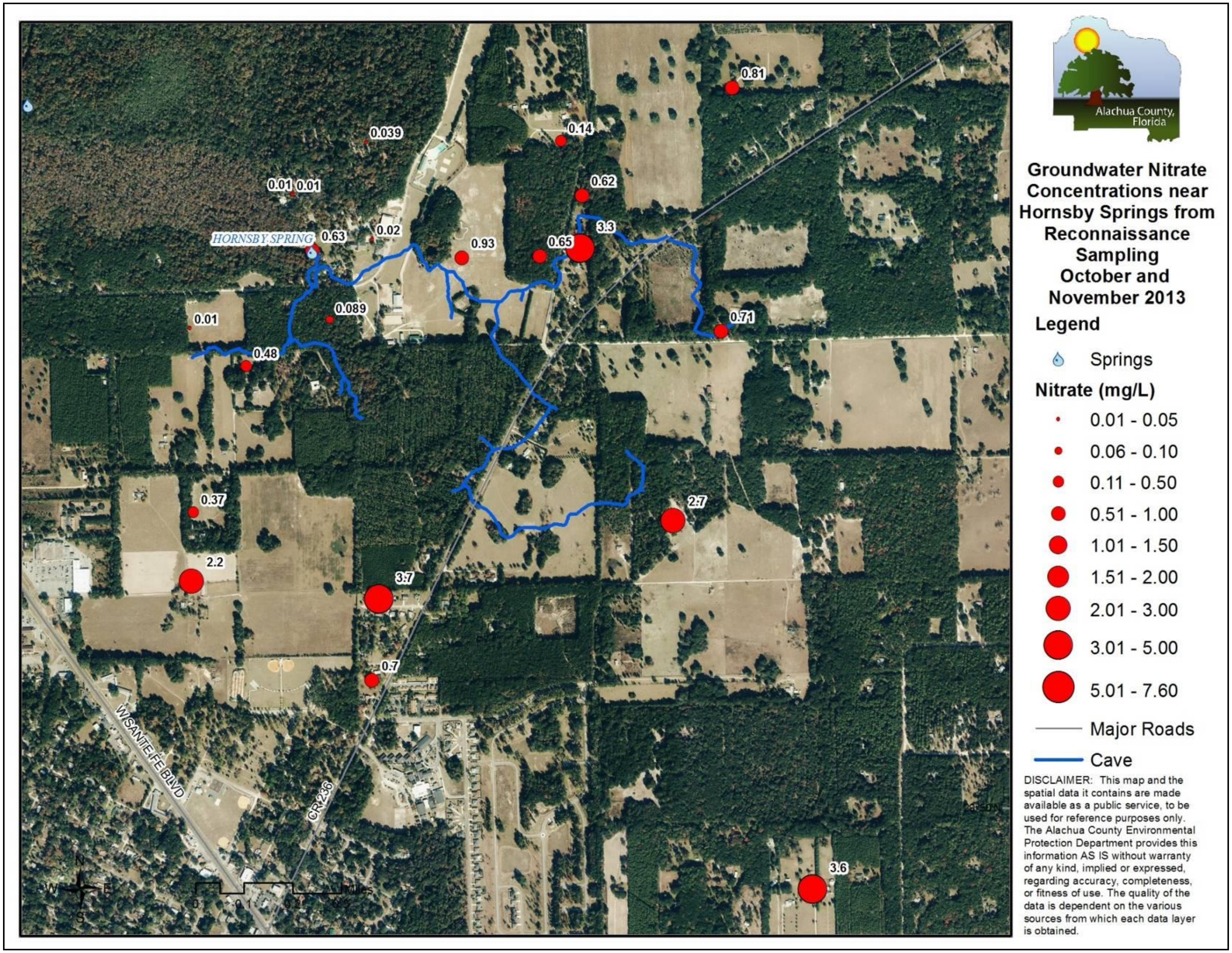
NM = Not Measured; NA = Not Applicable

*Water quality may be impacted by water treatment and/or well disinfection.

APPENDIX D-2: Groundwater Nitrate Results Map, Near Poe Spring, October and November 2013



APPENDIX D-3: Groundwater Nitrate Results Map, Near Hornsby Spring, October and November 2013



APPENDIX E-1: Field Parameter Results, October 2013 – June 2014

Station ID	Sample Date	Depth to Water (feet)	Purge Volume (Gallons)	DO (mg/L)	DO Saturation (%)	pH (SU)	Sp Cond (µmhos/cm)	Turb (NTU)	Temp (°C)	Temp, Air (°C)
AAC1215	10/17/13 13:29	28.52	112	2.9	33.9	7.4	333	0.8	22.2	NM
AAC1215	1/15/14 12:44	29.58	NM	2.2	25.0	7.3	354	0.2	21.8	14.0
AAC1215	6/3/14 10:06	28.53	NM	5.0	56.8	7.3	355	0.2	22.2	24.0
AAJ7000	11/7/13 11:29	NM	84	3.3	37.1	7.1	528	0.1	21.7	NM
AAJ7000	1/14/14 11:10	35.94	96	3.3	37.1	7.1	536	1.0	21.6	NM
AAJ7000	6/2/14 14:07	34.99	88	3.3	37.0	7.0	552	<0.1	21.8	30.0
AAJ7002	10/22/13 12:01	NM	132	2.6	30.8	7.1	505	0.1	22.7	NM
AAJ7002	1/14/14 15:56	45.9	130	1.6	18.8	7.2	455	0.2	22.6	NM
AAJ7002	6/2/14 14:54	44.97	72	2.3	26.7	7.1	497	0.1	22.7	28.0
AAJ7005	10/24/13 14:47	NM	83	6.6	76.4	7.6	276	NM	22.6	NM
AAJ7005	1/15/14 13:33	32.33	92	6.2	71.0	7.6	275	0.2	22.0	16.0
AAJ7005	6/2/14 11:57	31.11	130	7.0	80.9	7.6	274	0.3	22.6	31.0
AAJ7006	10/22/13 11:05	38.74	156	4.2	48.7	7.3	399	0.2	22.4	NM
AAJ7006	1/15/14 11:35	38.93	195	1.7	19.0	7.4	422	1.7	22.0	NM
AAJ7006	6/2/14 15:37	37.87	110	4.1	47.6	7.2	408	0.8	22.5	33.0
AAJ7007	11/5/13 11:51	NM	76	5.3	62.0	6.9	566	0.2	23.2	NM
AAJ7007	1/15/14 12:31	NM	88	4.8	55.3	7.0	564	0.2	22.9	16.0
AAJ7007	6/3/14 15:54	NM	84	5.2	60.8	6.9	579	0.1	23.2	31.0
AAK7000	10/24/13 13:34	NM	180	2.2	25.4	7.3	428	NM	22.4	NM
AAK7000	1/13/14 13:40	NM	300	2.7	30.7	7.2	428	0.7	22.5	22.0
AAK7000	6/2/14 10:03	NM	168	2.6	29.6	7.2	432	4.5	22.2	23.0
AAK7001	10/24/13 15:10	NM	110	7.2	85.1	7.8	261	NM	22.4	NM
AAK7001	1/13/14 15:35	29.88	216	7.0	80.2	7.7	261	0.3	22.0	NM
AAK7001	6/2/14 11:22	28.48	132	6.7	77.5	7.7	622	0.5	22.4	29.0
AAK7002	11/5/13 10:36	NM	108	3.9	44.9	7.5	295	0.7	21.8	NM
AAK7002	1/13/14 16:36	27.97	153	2.8	31.5	7.5	309	2.1	21.7	NM
AAK7002	6/2/14 13:32	26.77	152	3.4	38.9	7.5	280	1.7	22.0	28.0
AAK7003	11/5/13 12:46	NM	112	7.5	86.2	7.2	386	0.2	22.4	NM
AAK7003	1/15/14 10:43	NM	348	6.7	76.6	7.2	385	0.1	22.2	13.0

Station ID	Sample Date	Depth to Water (feet)	Purge Volume (Gallons)	DO (mg/L)	DO Saturation (%)	pH (SU)	Sp Cond (µmhos/cm)	Turb (NTU)	Temp (°C)	Temp, Air (°C)
AAK7003	6/3/14 15:01	NM	NM	7.8	89.9	7.1	386	0.1	22.5	30.0
AAK7004	10/24/13 14:14	NM	106.4	1.0	11.2	7.4	388	NM	22.5	NM
AAK7004	1/13/14 14:40	NM	208	1.3	14.7	7.3	387	0.1	22.5	22.5
AAK7004	6/2/14 10:42	NM	176	1.2	13.8	7.3	384	0.1	22.6	26.0
AAK7005	10/17/13 14:09	30.68	209	6.8	77.2	7.3	399	0.3	21.9	28.0
AAK7005	1/15/14 11:48	31.03	192	5.9	66.9	7.2	396	0.4	21.3	14.0
AAK7005	6/3/14 10:44	29.8	132	6.3	72.0	7.2	398	0.4	21.9	25.5
Poe	10/17/13 15:10	NA	NA	0.2	1.8	7.3	420	0.4	22.4	NM
Poe	1/15/14 14:35	NA	NA	0.4	4.9	7.2	416	0.5	22.1	15.0
Poe	6/3/14 11:45	NA	NA	0.2	1.9	7.3	415	0.3	22.5	25.5
WTRMLN2	1/15/14 15:40	NM	NM	0.2	2.6	7.2	416	0.5	21.9	15.5
WTRMLN2	6/3/14 13:00	NM	NM	0.1	1.6	7.2	412	NM	22.3	NM
AAJ7001	11/7/13 17:25	NM	229.5	4.1	47.0	7.1	440	0.1	22.9	NM
AAJ7001	1/21/14 11:30	36.7	NM	1.2	14.4	7.2	443	0.1	22.6	19.5
AAJ7001	6/4/14 10:57	NM	NM	3.6	41.9	7.0	498	0.2	22.8	27.0
AAJ7003	10/29/13 15:30	NM	120	6.4	74.8	7.5	289	NM	23.1	NM
AAJ7003	1/14/14 13:29	NM	198	6.3	73.6	7.5	287	0.3	23.0	17.0
AAJ7003	6/4/14 11:39	NM	150	6.6	76.6	7.3	293	0.2	23.1	26.5
AAJ7004	11/5/13 15:09	NM	132	6.2	72.5	7.4	352	0.1	23.0	NM
AAJ7004	1/21/14 10:42	25.61	216	6.4	75.1	7.4	351	0.1	23.0	18.5
AAJ7004	6/4/14 10:07	NM	120	6.3	73.9	7.3	352	0.1	23.1	25.0
AAK7008	10/17/13 11:15	NM	NM	0.7	8.2	7.3	549	0.4	23.3	28.0
AAK7008	1/16/14 14:20	NM	NM	3.7	44.3	7.5	526	0.6	22.1	9.0
AAK7008	6/4/14 13:34	NM	NM	0.2	2.1	7.2	544	0.1	23.4	30.0
AAK7009	10/17/13 10:33	25.06	NM	0.1	1.1	7.3	452	0.2	22.8	25.0
AAK7009	1/16/14 14:58	25.47	NM	0.4	4.5	7.4	465	0.3	22.6	9.0
AAK7009	6/4/14 14:24	24.48	NM	0.2	2.3	7.2	461	0.2	22.7	27.5
Hornsby	10/17/13 12:23	NA	NA	0.4	4.0	7.4	452	0.2	22.4	9.0
Hornsby	1/16/14 16:00	NA	NA	0.4	4.0	7.4	452	0.2	22.4	9.0
Hornsby	6/4/14 15:45	NA	NA	0.2	1.9	7.3	437	0.2	22.4	30.0

NM = Not Measured; NA = Not Applicable

APPENDIX E-2: Laboratory Results, Nutrients and Sucralose, October 2013 – June 2014

Station ID	Sample Date	$NO_3 + NO_2$ (mg/L)	TN (mg/L)	TKN (mg/L)	NH_3 (mg/L)	TP (mg/L)	TOC (mg/L)	$\delta^{15}N$ (0/00)	$\delta^{18}O$ (0/00)	Sucralose (µg/L)	Br (mg/L)
AAC1215	10/17/13 13:29	0.68	0.68	0.15 U	0.16	0.041 U	0.35 U	NM	NM	NM	NM
AAC1215	1/15/14 12:44	0.82	0.82	0.15 U	0.035 I	0.041 U	0.5 U	6.01	6.29	0.01 U	0.25 U
AAC1215	6/3/14 10:06	0.76	0.76	0.15 U	0.059	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAJ7000	11/7/13 11:29	5.7	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7000	1/14/14 11:10	6.1	6.1	0.15 U	0.051	0.041 U	0.5 U	10.61	6.72	0.01 U	0.25 U
AAJ7000	6/2/14 14:07	7.3	7.3	0.15 U	0.052	0.046 I	0.5 U	NM	NM	NM	0.25 U
AAJ7002	10/22/13 12:01	3.6	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7002	1/14/14 15:56	2.2	2.2	0.15 U	0.056	0.048 I	0.5 U	7.78	8.40	0.058	0.25 U
AAJ7002	6/2/14 14:54	4.2	4.2	0.15 U	0.098	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAJ7005	10/24/13 14:47	3.2	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7005	1/15/14 13:33	3.6	3.6	0.15 U	0.028 I	0.041 U	0.5 U	5.68	5.71	0.01 U	0.25 U
AAJ7005	6/2/14 11:57	3.7	3.7	0.15 U	0.059	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAJ7006	10/22/13 11:05	1.3	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7006	1/15/14 11:35	0.57	0.57	0.15 U	0.028 I	0.07 I	1.3	5.90	3.66	0.066	0.25 U
AAJ7006	6/2/14 15:37	1.1	1.1	0.15 U	0.059	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAJ7007	11/5/13 11:51	3.7	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7007	1/15/14 12:31	4.7	4.7	0.15 U	0.039 I	0.041 I	0.5 U	4.78	3.28	0.082	0.25 U
AAJ7007	6/3/14 15:54	3.4	3.4	0.15 U	0.08	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAK7000	10/24/13 13:34	1.5	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAK7000	1/13/14 13:40	1.5	1.5	0.15 U	0.026 U	0.044 I	0.5 U	7.36	10.31	0.038 I	0.25 U
AAK7000	6/2/14 10:03	1.8	1.8	0.15 U	0.099	0.14	0.5 U	NM	NM	NM	0.25 U
AAK7001	10/24/13 15:10	7.6	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAK7001	1/13/14 15:35	7.4	7.6	0.17 I	0.026 U	0.047 I	0.5 U	2.18	3.64	0.01 U	0.25 U
AAK7001	6/2/14 11:22	7.6	0.38	0.15 U	0.06	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAK7002	11/5/13 10:36	1.2	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAK7002	1/13/14 16:36	1.2	1.2	0.15 U	0.026 U	0.053 I	0.5 U	2.81	5.22	0.01 U	0.25 U
AAK7002	6/2/14 13:32	1.4	1.4	0.15 U	0.052	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAK7003	11/5/13 12:46	1.3	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAK7003	1/15/14 10:43	1.3	1.3	0.15 U	0.029 I	0.041 U	0.5 U	1.49	5.81	0.01 U	0.25 U
AAK7003	6/3/14 15:01	1.4	1.4	0.15 U	0.027 I	0.048 I	0.5 U	NM	NM	NM	0.25 U

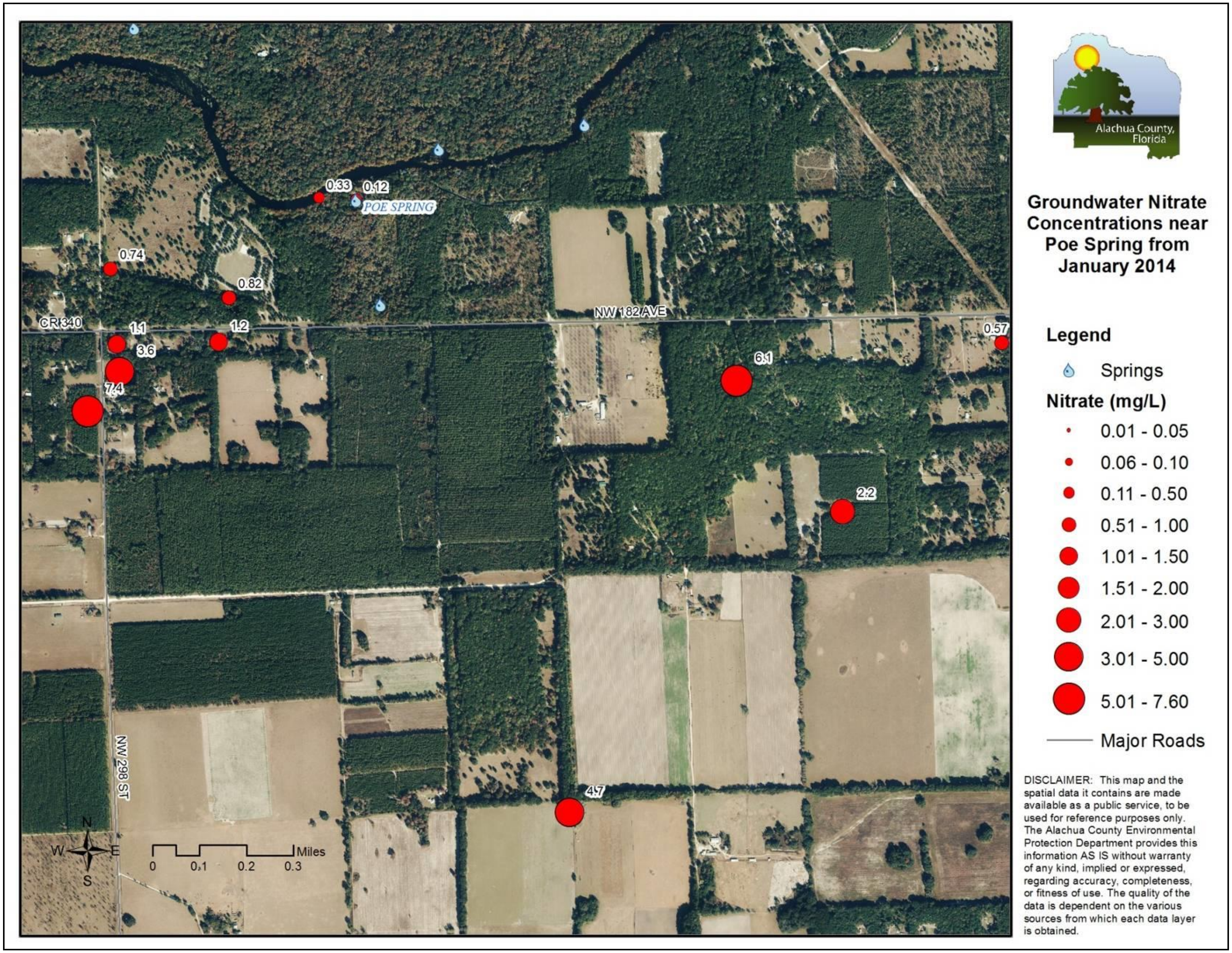
Station ID	Sample Date	$NO_3 + NO_2$ (mg/L)	TN (mg/L)	TKN (mg/L)	NH_3 (mg/L)	TP (mg/L)	TOC (mg/L)	$\delta^{15}N$ (0/00)	$\delta^{18}O$ (0/00)	Sucralose (µg/L)	Br (mg/L)
AAK7004	10/24/13 14:14	1.3	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAK7004	1/13/14 14:40	1.1	1.3	0.2	0.026 U	0.05 I	0.5 U	8.61	8.70	0.023 I	0.25 U
AAK7004	6/2/14 10:42	0.92	0.92	0.15 U	0.054	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAK7005	10/17/13 14:09	0.76	0.76	0.15 U	0.1	0.041 U	0.35 U	NM	NM	NM	NM
AAK7005	1/15/14 11:48	0.74	0.74	0.15 U	0.048 I	0.041 U	0.5 U	5.00	0.08	0.01 U	0.25 U
AAK7005	6/3/14 10:44	0.9	0.9	0.15 U	0.051	0.041 U	0.5 U	NM	NM	NM	0.25 U
Poe	10/17/13 15:10	0.16	0.34	0.18 I	0.026 U	0.041 U	2.7	NM	NM	NM	NM
Poe	1/15/14 14:35	0.12	0.25 U	0.15 U	0.045 I	0.084 I	3.4	21.44	15.78	0.2	0.25 U
Poe	6/3/14 11:45	0.25	0.25	0.15 U	0.026 U	0.076 I	1.9	NM	NM	NM	0.25 U
WTRMLN2	1/15/14 15:40	0.33	0.33	0.15 U	0.066	0.083 I	3.5	19.40	13.75	0.2	0.25 U
WTRMLN2	6/3/14 13:00	0.3	0.3	0.15 U	0.041 I	0.041 U	3.4	NM	NM	NM	0.25 U
AAJ7001	11/7/13 17:25	2.2	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7001	1/21/14 11:30	3.1	3.1	0.15 U	0.04 I	0.041 U	0.5 U	6.58	5.35	0.01 U	0.25 U
AAJ7001	6/4/14 10:57	2.3	2.3	0.15 U	0.091	0.048 I	0.5 U	NM	NM	NM	0.25 U
AAJ7003	10/29/13 15:30	3.3	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7003	1/14/14 13:29	3.1	3.1	0.15 U	0.045 I	0.041 U	0.5 U	7.92	1.17	0.01 U	0.25 U
AAJ7003	6/4/14 11:39	3.4	3.4	0.15 U	0.078	0.041 U	0.5 U	NM	NM	NM	0.25 U
AAJ7004	11/5/13 15:09	3.7	NM	NM	NM	NM	NM	NM	NM	NM	NM
AAJ7004	1/21/14 10:42	4.6	4.6	0.15 U	0.039 I	0.041 U	0.5 U	5.03	1.89	0.041 I	0.25 U
AAJ7004	6/4/14 10:07	4.3	4.3	0.15 U	0.52	0.057 I	0.5 U	NM	NM	NM	0.25 U
AAK7008	10/17/13 11:15	0.93	1.3	0.37	0.3	0.041 U	2.1	NM	NM	NM	NM
AAK7008	1/16/14 14:20	0.55	0.55	0.15 U	0.062	0.063 I	1.6	26.47	10.72	0.13	0.25 U
AAK7008	6/4/14 13:34	1.2	1.2	0.15 U	0.13	0.13	1.1	NM	NM	NM	0.25 U
AAK7009	10/17/13 10:33	0.65	0.89	0.24	0.34	0.041 U	2.1	NM	NM	NM	NM
AAK7009	1/16/14 14:58	0.47	0.47	0.15 U	0.045 I	0.055 I	2	15.54	11.36	0.14	0.25 U
AAK7009	6/4/14 14:24	0.67	0.67	0.15 U	0.034 I	0.082 I	1.7	NM	NM	NM	0.25 U
Hornsby	10/17/13 12:23	0.63	0.63	0.15 U	0.29	0.041 U	2.3	NM	NM	NM	NM
Hornsby	1/16/14 16:00	0.45	0.45	0.15 U	0.052	0.091 I	2.2	17.78	12.98	0.16	0.25 U
Hornsby	6/4/14 15:45	0.59	0.59	0.15 U	0.026 U	0.083 I	2.3	NM	NM	NM	0.25 U

NM = Not Measured

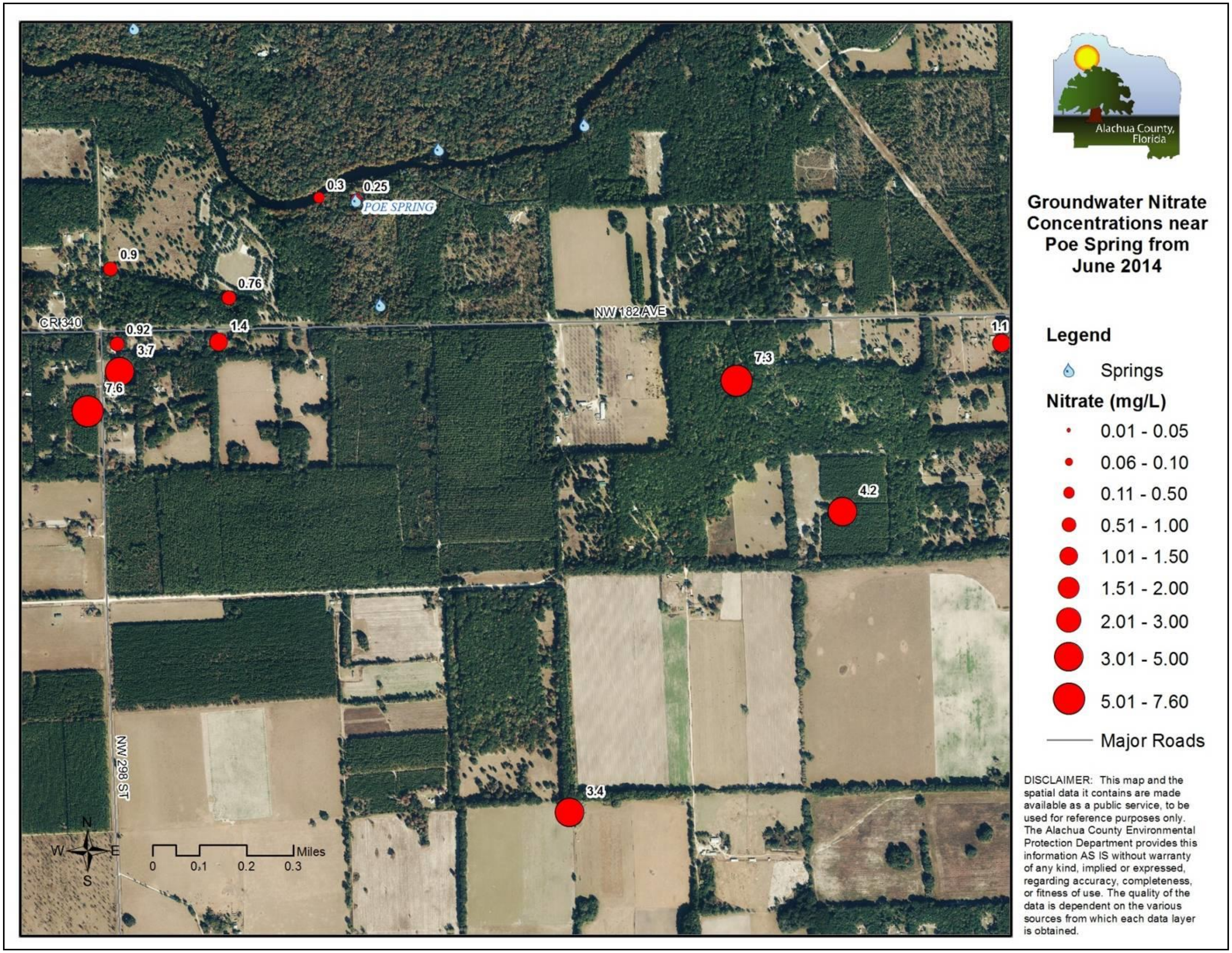
U = The compound was analyzed for but not detected, the value reported is the method detection limit.

I = The reported value is between the method detection limit and the practical quantitation limit.

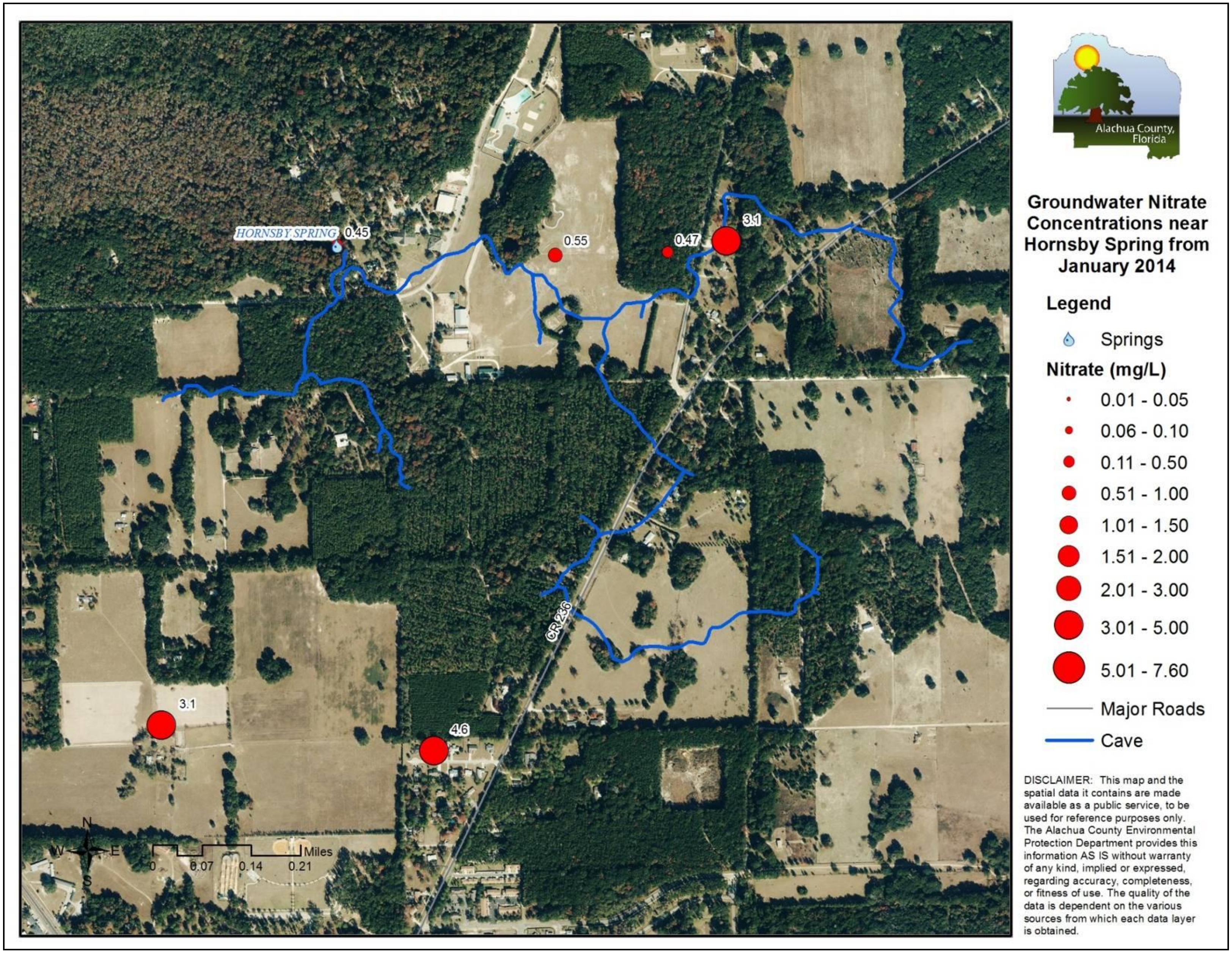
APPENDIX F-1: Groundwater Nitrate Results Map, Near Poe Spring, January 2014



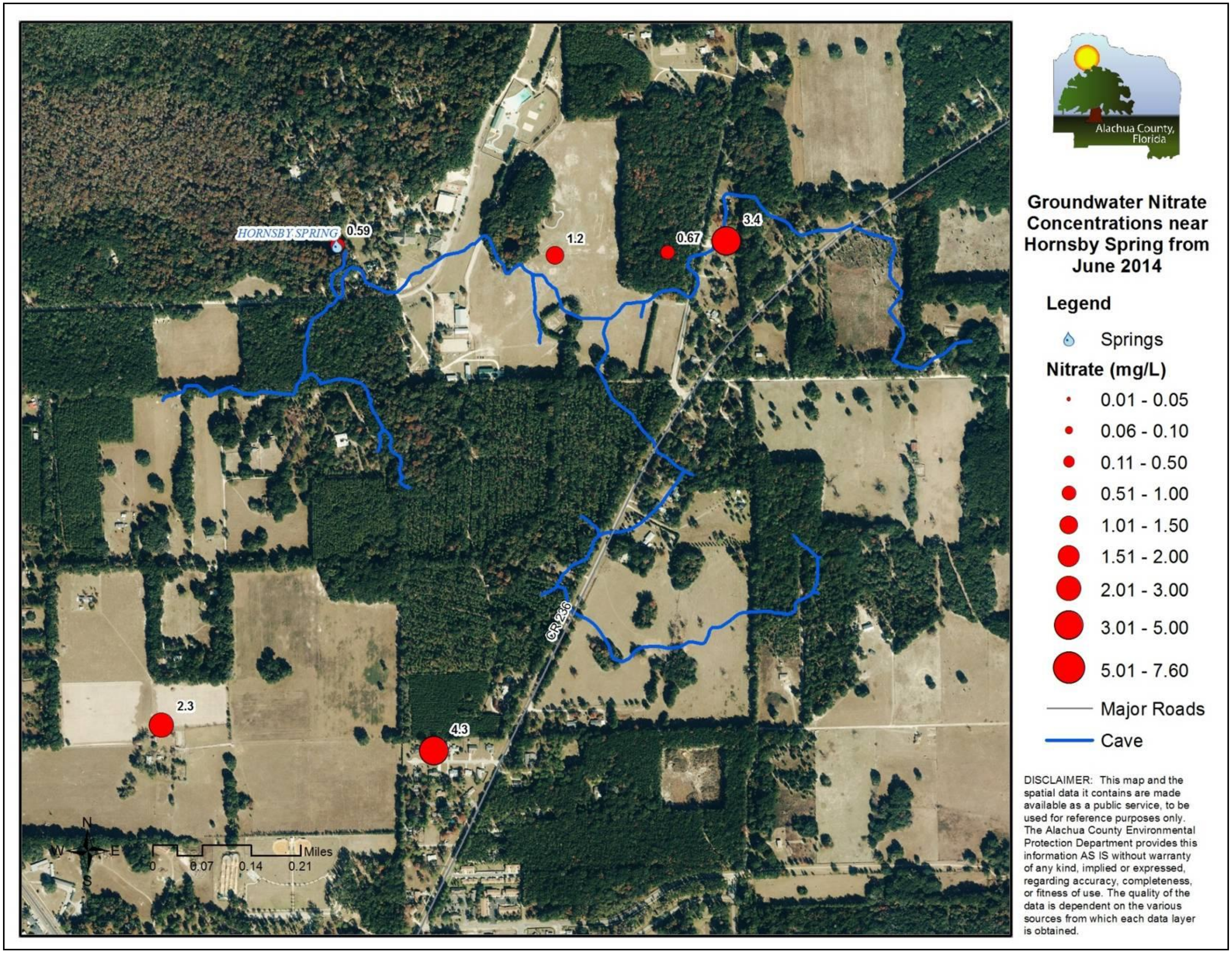
APPENDIX F-2: Groundwater Nitrate Results Map, Near Poe Spring, June 2014



APPENDIX F-3: Groundwater Nitrate Results Map, Near Hornsby Spring, January 2014



APPENDIX F-4: Groundwater Nitrate Results Map, Near Hornsby Spring, June 2014



APPENDIX G: Laboratory Results, Major Ions and Other Indicators, October 2013 – June 2014

Station ID	Sample Date	Cl (mg/L)	SO_4^- (mg/L)	Mg (mg/L)	Ca (mg/L)	Fe (µg/L)	Na (mg/L)	K (mg/L)	F (mg/L)	B (µg/L)	TDS (mg/L)	Alk, HCO_3^- as $CaCO_3$ (mg/L)	Total Alk (mg/L)	Hardness (mg/L)
AAC1215	10/17/13 13:29	7.2	7.4	3.1	63	50 U	3.9	0.32 I	0.055 I	11 I	180	160	160	170
AAC1215	1/15/14 12:44	8.4	7.7	3.9	65	50 U	4.4	0.39 I	0.046 I	14 I	170	130	140	180
AAC1215	6/3/14 10:06	7.8	7	3.3	65	24 U	4.1	0.32 I	0.062 I	40 U	180	150	150	180
AAJ7000	1/14/14 11:10	21	11	3.8	100	50 U	8.4	0.38 I	0.025 U	15 I	270	200	200	270
AAJ7000	6/2/14 14:07	21	12	3.5	98	24 U	8.4	0.42 I	0.033 I	40 U	350	220	220	260
AAJ7002	1/14/14 15:56	9.6	18	4.8	83	50 U	6.8	1.2	0.062 I	18 I	220	180	190	230
AAJ7002	6/2/14 14:54	12	17	4.4	89	24 U	6.3	1.6	0.086 I	40 U	250	190	190	240
AAJ7005	1/15/14 13:33	6.8	1.7	0.84	52	50 U	3.2	0.50 I	0.025 U	10 U	130	98	98	130
AAJ7005	6/2/14 11:57	6.4	2	0.79	49	51	3.1	0.44 I	0.025 U	40 U	150	110	110	130
AAJ7006	1/15/14 11:35	12	27	6.3	74	160 I	6.9	0.75 I	0.1	17 I	220	140	140	210
AAJ7006	6/2/14 15:37	10	14	3.7	75	120	5.0	0.76 I	0.093 I	40 U	220	180	180	200
AAJ7007	1/15/14 12:31	18	6.2	2.1	110	76 I	8.6	0.55 I	0.025 U	11 I	270	230	240	280
AAJ7007	6/3/14 15:54	18	6.2	2.0	110	24 U	9.4	0.45 I	0.032 I	40 U	340	260	270	290
AAK7000	1/13/14 13:40	9.8	12	6.0	75	50 U	5.9	1.2	0.044 I	17 I	200	170	170	210
AAK7000	6/2/14 10:03	12	13	5.5	74	180	6.0	1.2	0.079 I	40 U	290	180	180	210
AAK7001	1/13/14 15:35	5.9	4.2	0.67	47	50 U	2.9	0.62 I	0.025 U	15 I	170	73	73	120
AAK7001	6/2/14 11:22	6.9	4.9	0.60	45	24 U	2.9	0.55 I	0.025 U	40 U	170	81	81	110
AAK7002	1/13/14 16:36	6.6	7.4	3.4	56	210	4.3	0.41 I	0.041 I	13 I	150	110	110	150
AAK7002	6/2/14 13:32	7.1	6.7	2.4	48	220	3.7	0.34 I	0.054 I	40 U	130	110	110	130
AAK7003	1/15/14 10:43	6.4	1.3	1.1	78	50 U	1.9	0.19 U	0.025 U	12 I	190	160	160	200
AAK7003	6/3/14 15:01	5.9	1.6	1.0	78	24 U	2.2	0.69 I	0.026 I	40 U	210	190	190	200
AAK7004	1/13/14 14:40	9.5	9.1	5.6	69	50 U	6.7	0.85 I	0.079 I	18 I	190	150	150	200
AAK7004	6/2/14 10:42	11	11	5.3	66	24 U	6.6	0.68 I	0.11	40 U	190	170	170	190
AAK7005	10/17/13 14:09	13	1.5	1.2	78	50 U	5.1	0.19 U	0.025 U	10 U	200	190	190	200
AAK7005	1/15/14 11:48	15	1.3	1.2	78	150 I	5.2	0.19 U	0.025 U	10 U	190	160	160	200
AAK7005	6/3/14 10:44	13	1.5	1.1	75	24 U	5.5	0.40 U	0.025 U	40 U	210	190	200	190
Poe	10/17/13 15:10	14	NM	7.1	70	50 U	8.4	0.91 I	0.13	20 I	220	170	170	200

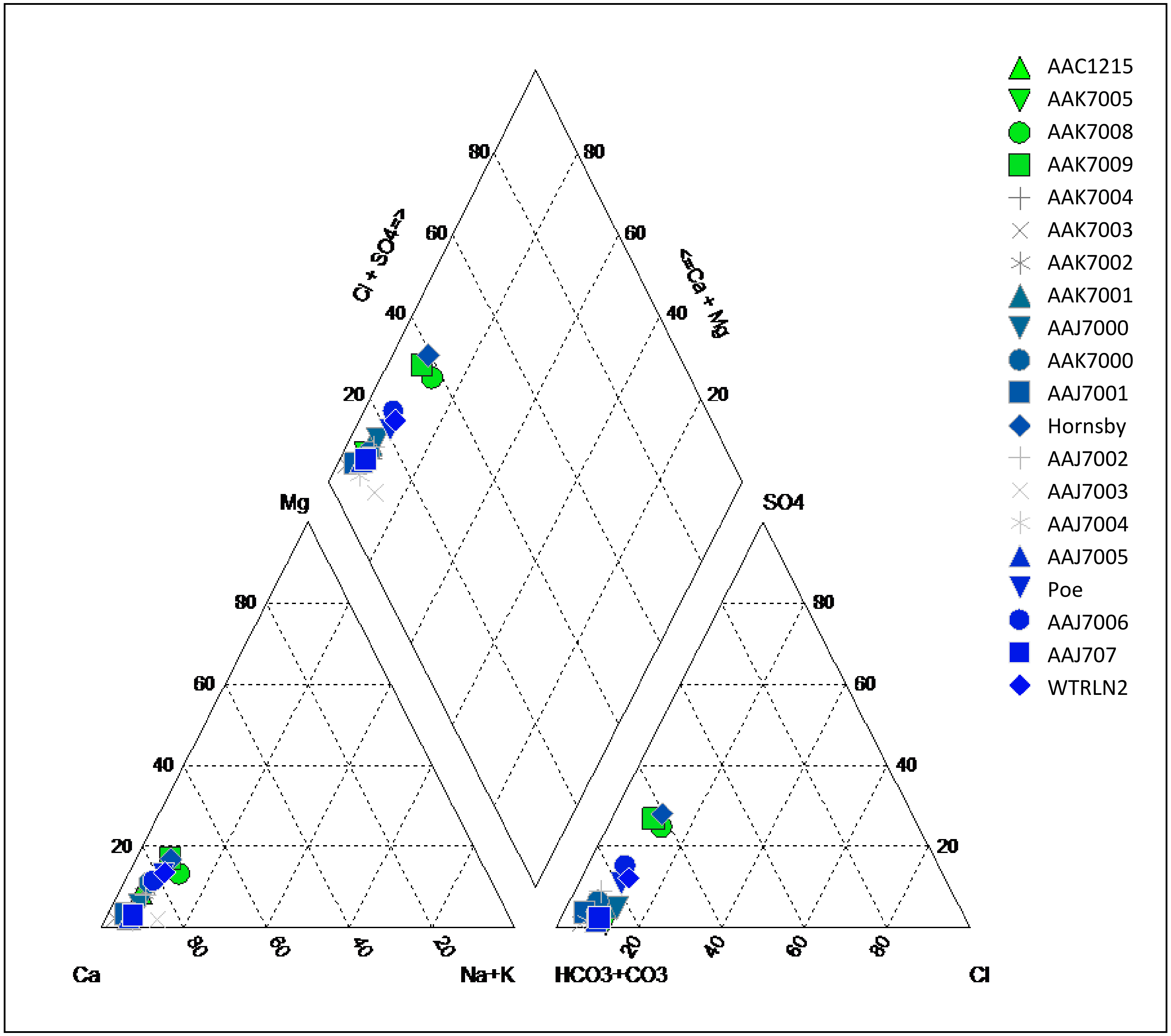
Station ID	Sample Date	Cl (mg/L)	SO_4^- (mg/L)	Mg (mg/L)	Ca (mg/L)	Fe (µg/L)	Na (mg/L)	K (mg/L)	F (mg/L)	B (µg/L)	TDS (mg/L)	Alk, HCO_3^- as $CaCO_3$ (mg/L)	Total Alk (mg/L)	Hardness (mg/L)
Poe	1/15/14 14:35	15	25	7.1	69	70 I	8.0	0.92 I	0.13	20 I	220	160	160	200
Poe	6/3/14 11:45	13	19	6.5	70	41 I	7.9	0.92 I	0.13	40 U	240	160	160	200
WTRMLN2	1/15/14 15:40	16	23	7.2	68	62 I	8.1	0.96 I	0.12	19 I	240	150	150	150
WTRMLN2	6/3/14 13:00	13	23	6.7	67	88	7.8	0.91 I	0.13	40 U	230	170	170	200
AAJ7001	1/21/14 11:30	7.7	7.1	1.8	87	50 U	4.2	1.1	0.025 U	20 I	230	190	190	230
AAJ7001	6/4/14 10:57	7.8	9.5	2.0	100	24 U	5.1	1.6	0.037 I	40 U	290	240	240	270
AAJ7003	1/14/14 13:29	6.7	2.5	0.64	49	50 U	8.2	0.19 U	0.025 U	33 I	130	110	110	130
AAJ7003	6/4/14 11:39	8.3	3.4	0.71	55	24 U	8.9	0.20 I	0.031 I	40 U	150	130	130	140
AAJ7004	1/21/14 10:42	7.5	2.7	0.79	67	50 U	5.4	0.32 I	0.025 U	27 I	190	150	150	170
AAJ7004	6/4/14 10:07	7.7	3.8	0.86	70	24 U	6.5	0.41 I	0.035 I	40 U	200	140	140	180
AAK7008	10/17/13 11:15	25	73	8.9	86	110 I	16	1.7	0.14	18 I	290	170	170	250
AAK7008	1/16/14 14:20	24	61	9.0	84	190 I	15	1.7	0.13	22 I	260	160	160	250
AAK7008	6/4/14 13:34	26	64	8.4	89	160	19	2.1	0.14	40 U	330	180	180	260
AAK7009	10/17/13 10:33	13	53	9.6	71	110 I	7.7	0.98 I	0.19	15 I	250	160	160	220
AAK7009	1/16/14 14:58	15	53	10	73	54 I	8.8	1.1	0.16	20 I	230	130	130	230
AAK7009	6/4/14 14:24	13	59	10	76	110	9.0	1.2	0.19	40 U	310	170	170	230
Hornsby	10/17/13 12:23	13	48	9.4	72	50 U	7.9	1.0	0.18	17 I	220	170	170	220
Hornsby	1/16/14 16:00	15	49	10	73	50 U	8.9	1.1	0.16	20 I	220	110	110	220
Hornsby	6/4/14 15:45	13	47	8.9	71	24 U	8.9	1.1	0.17	40 U	270	140	140	210

NM = Not Measured

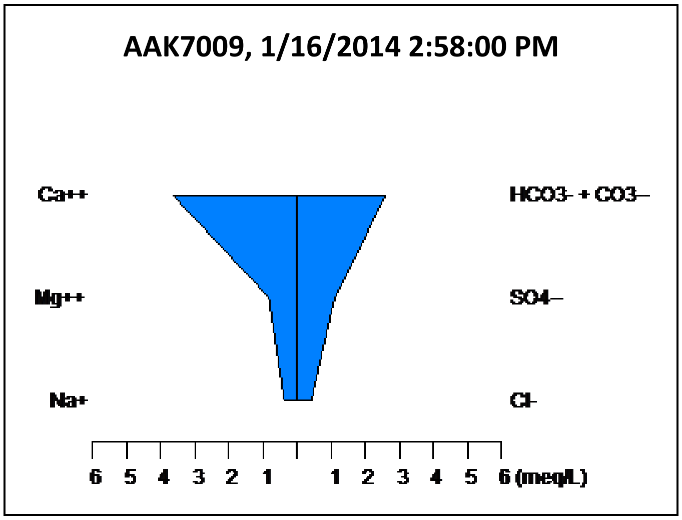
U = The compound was analyzed for but not detected, the value reported is the method detection limit.

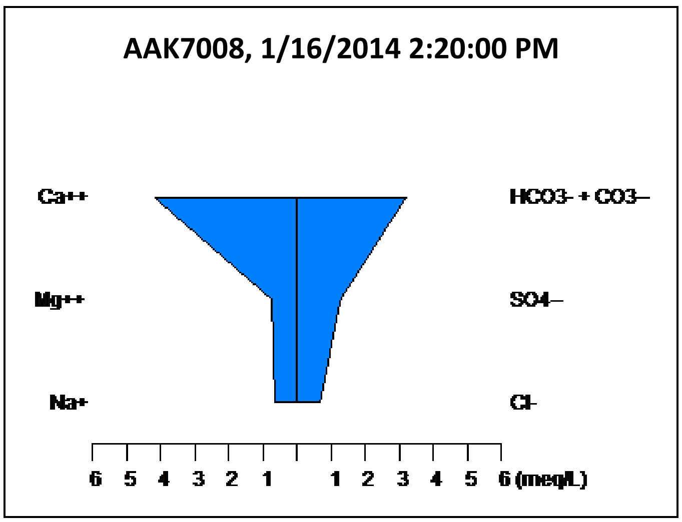
I = The reported value is between the method detection limit and the practical quantitation limit.

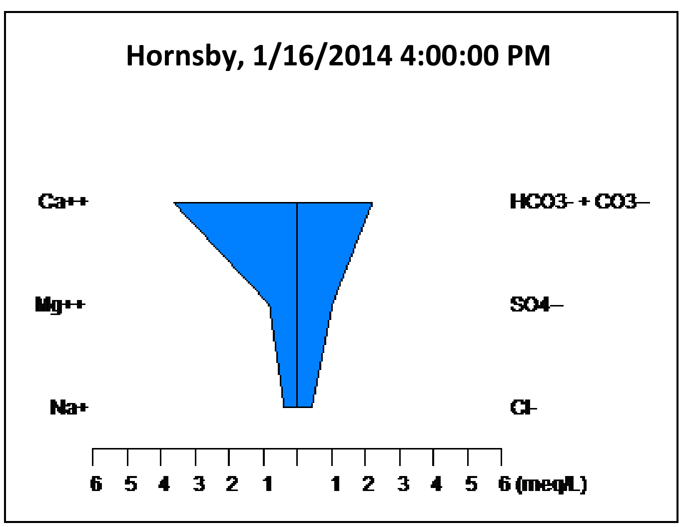
APPENDIX H-1: Piper Diagram, January 2014

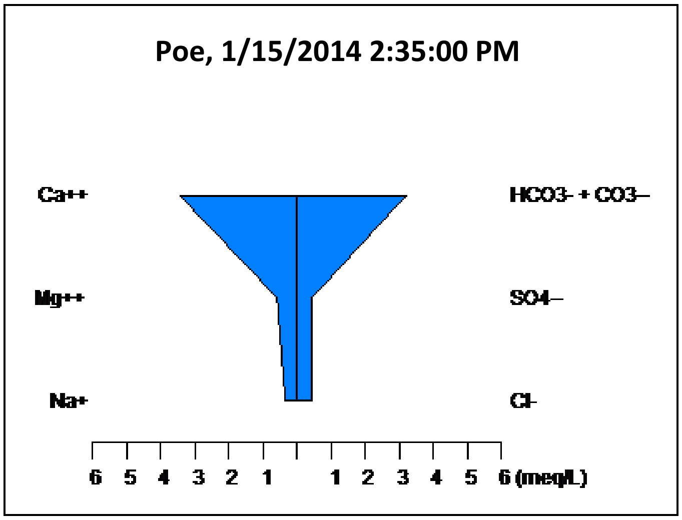


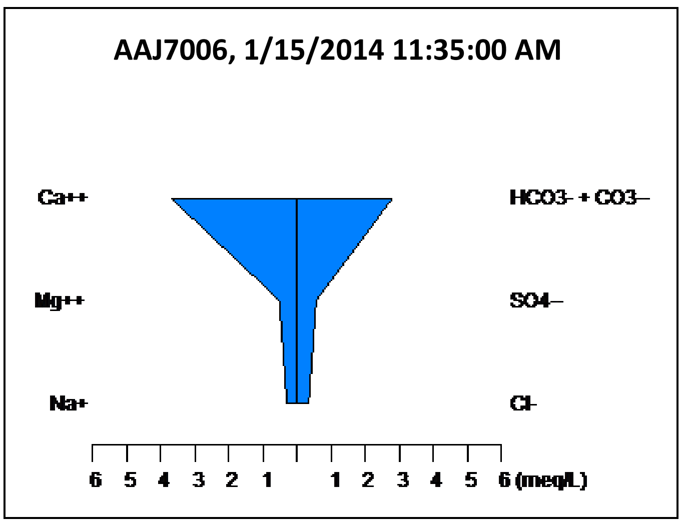
APPENDIX H-2: Stiff Diagrams, January 2014

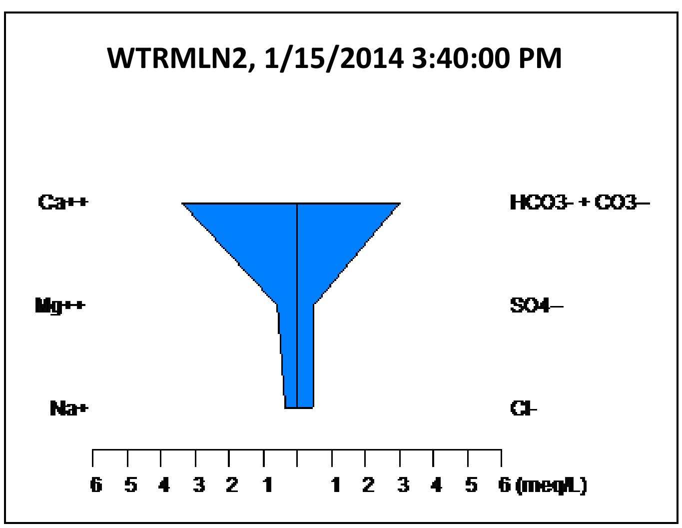




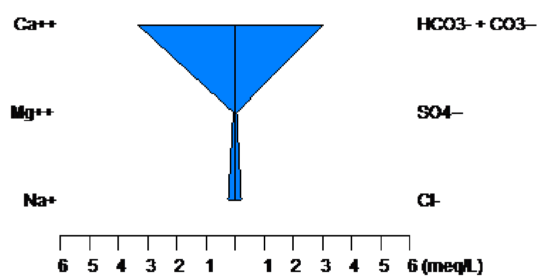



Poe, 1/15/2014 2:35:00 PM
Ca++
Mg++
Na+
HCO3- + CO3--
SO4--
Cl-
6 5 4 3 2 1 1 2 3 4 5 6 (meq/L)


AAJ7006, 1/15/2014 11:35:00 AM
Ca++
Mg++
Na+
HCO3- + CO3--
SO4--
Cl-
6 5 4 3 2 1 1 2 3 4 5 6 (meq/L)


WTRMLN2, 1/15/2014 3:40:00 PM
Ca++
Mg++
Na+
HCO3- + CO3--
SO4--
Cl-
6 5 4 3 2 1 1 2 3 4 5 6 (meq/L)

AAJ7004, 1/21/2014 10:42:00 AM



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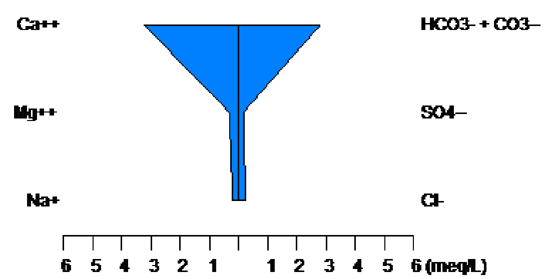
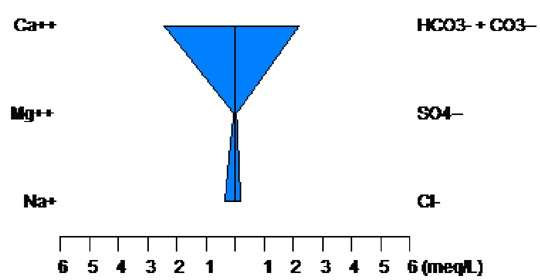


AAJ7003, 1/14/2014 1:29:00 PM



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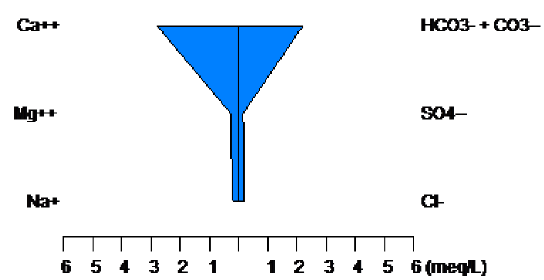

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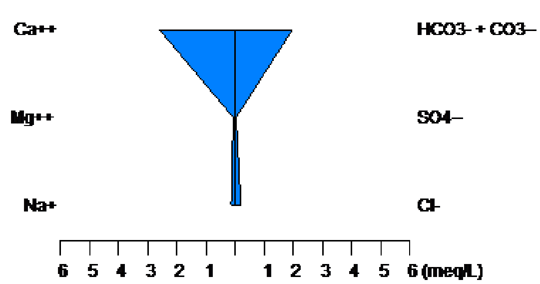
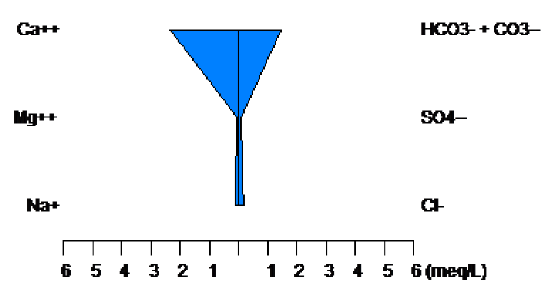


AAK7001, 1/13/2014 3:35:00 PM



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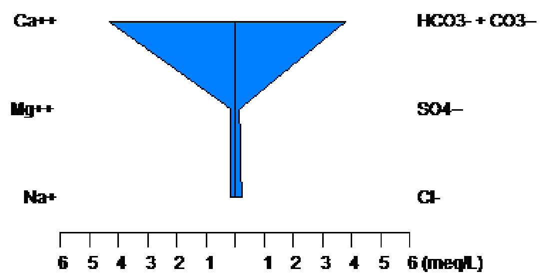

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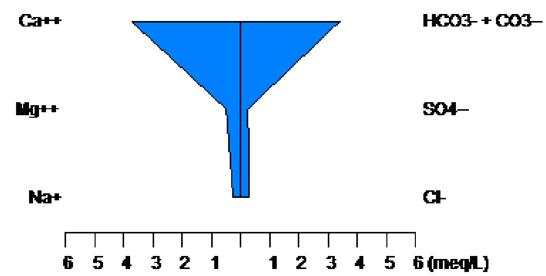

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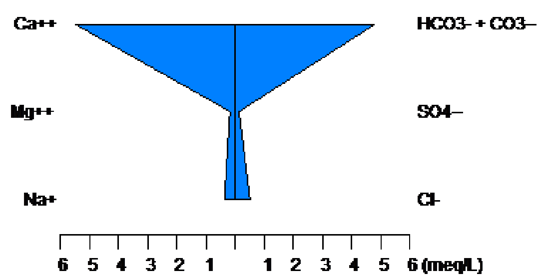

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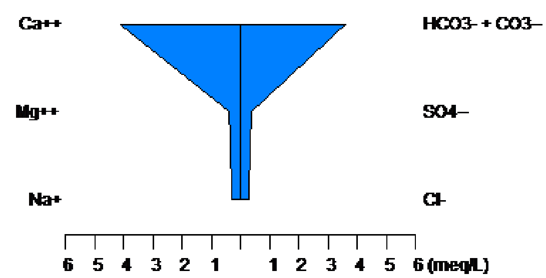

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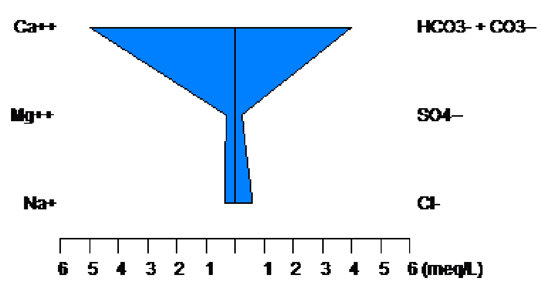
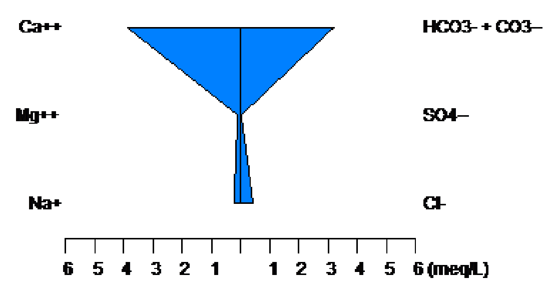


AAK7005, 1/15/2014 11:48:00 AM



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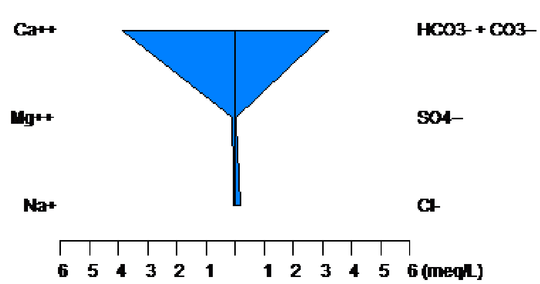

AAK7004, 1/13/2014 2:40:00 PM