INVESTIGATION OF LAND USE AND NITRATE MIGRATION POTENTIAL IN LITHIA AND BUCKHORN SPRINGS FOCUS AREA

Prepared for

TAMPA BAY WATER

SDI Project No. TBF-690

October 2005

by

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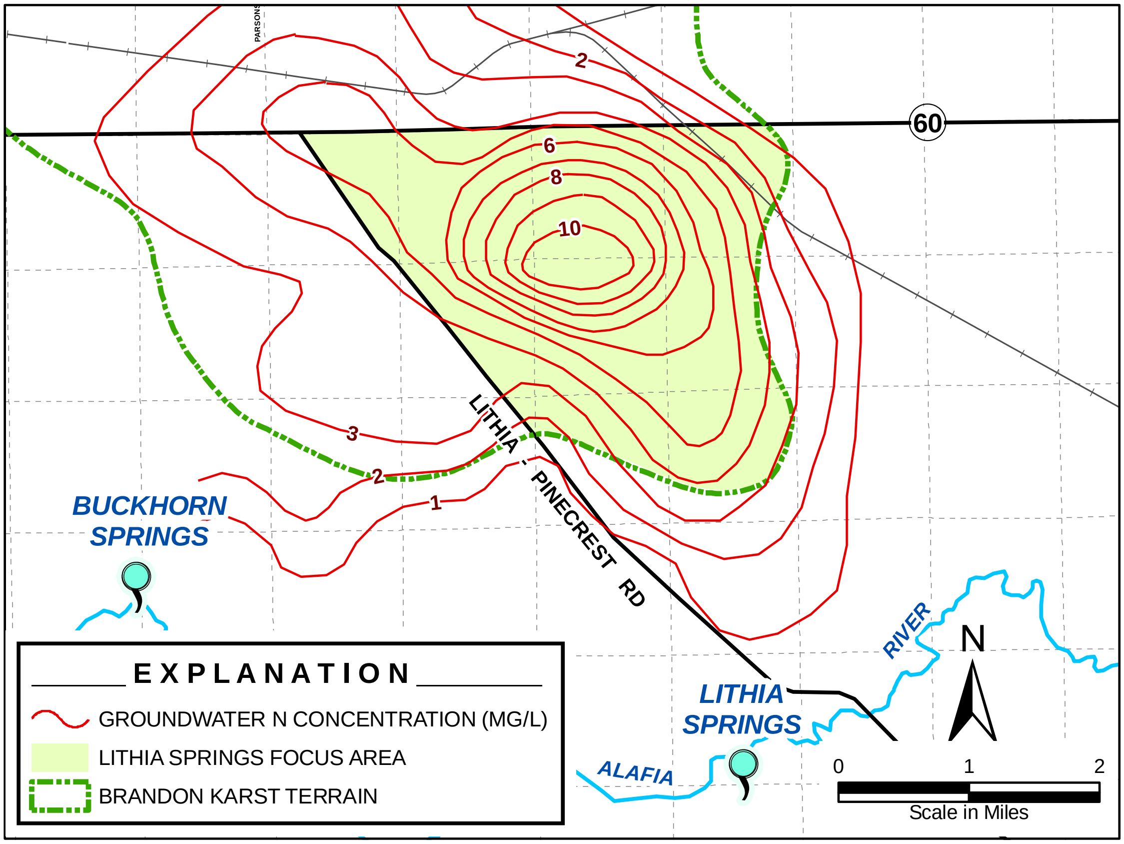
1.0 INTRODUCTION AND BACKGROUND

The Alafia River as a source of drinking water is an important component of the Tampa Bay Water Enhanced Surface Water Supply System. On average, Lithia Springs contributes approximately 11 to 12 percent of the flow in the Alafia River at Bell Shoals, upstream of Tampa Bay Water's intake structure (SDI, 2004). Jones and Upchurch (1993) documented the problem of high nitrogen levels in the discharge from Lithia and Buckhorn Springs, identifying the southern portion of the Brandon Karst Terrain (BKT) as the source area for the springs. Nitrogen applied to the land from local point- and non-point sources is able to quickly migrate downward into the upper Floridan Aquifer System (UFAS) in the BKT due to lack of confinement between the surficial aquifer and the UFAS.

Jones and Upchurch (1993) concluded that past loading from fertilizers applied to citrus crops was the primary cause of nitrogen in Lithia and Buckhorn Springs. In addition, they predicted that "septic tanks now present in the area will most likely adversely affect future concentrations of nitrogen in the springs." Their study included analyses of samples obtained between September 1991 and June 1992 from approximately 25 private domestic wells within the BKT. Nitrate concentrations (expressed as nitrate-N) ranged from less than 1.0 mg/L to more than 10.0 mg/L, with the highest concentrations found in wells south of SR60 and northeast of Lithia Pinecrest Road (Figure 1). For comparison, background groundwater nitrate concentrations in Florida are generally less than 1 mg/L (Tihansky and Sacks, 1997). Historical nitrate concentrations measured in Lithia Springs by the USGS in 1923 and 1946 were 0.2 mg/L on both occasions.



(source of nitrate concentration lines: Jones and Upchurch, 1993)

Figure 1. Lithia and Buckhorn Springs Focus Area, with Lines of Equal Nitrate Concentration in Study Area Groundwater in 1992

In light of the land use changes that have occurred in the Brandon area over the past several years, Tampa Bay Water contracted with SDI Environmental Services, Inc. (SDI) in late 2004 to conduct a review and analysis of more recent nutrient concentration data from Lithia and Buckhorn Springs, groundwater in the BKT, and the Alafia River. The 2004 SDI report included a trend analysis of nitrite plus nitrate concentrations in Lithia Springs Major, from January 1965 through April 2004 (Figure 2). A strong increasing trend in nitrite plus nitrate concentration was identified in the first 26 years (1965 through 1991). After 1991, no significant trend was detected at the 10% level of significance. The concentrations appear to have leveled off at an average value of about 3.0 mg/L. This study is a follow-up to the 2004 SDI report.

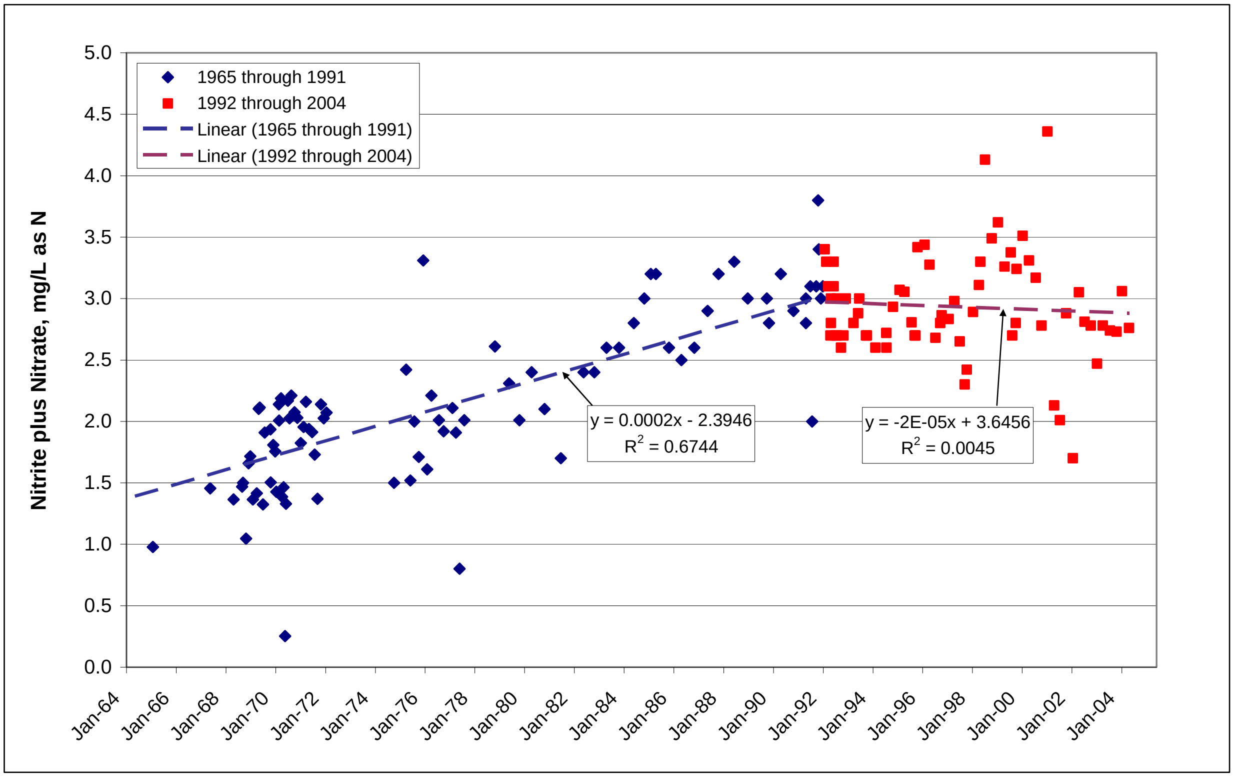


Figure 2. Nitrite plus Nitrate Concentration Trends in Lithia Springs

2.0 PURPOSE

The geographic focus of this study is the area within the Brandon Karst Terrain observed to have the highest concentrations of nitrate in the groundwater in 1992. This Focus Area, shown on Figure 1, generally lies south of SR60 and northeast of Lithia Pinecrest Road. It is also the part of the BKT that is geographically closest to Lithia Springs. This purpose of this study is to provide an updated discussion of the land uses and nitrate migration potential within the Lithia and Buckhorn Springs Focus Area. This is intended to update and expand on the relevant discussions presented in the 1993 Jones and Upchurch report.

A secondary objective for this study was to use GIS to prepare and analyze more recent and more detailed mapping information, and to evaluate currently available data sources and tools that could be used to develop estimates of the amount of nitrate leaching into the groundwater system from the various land uses and land practices for selected periods of time. These data sources and tools might then be applied to additional watershed areas if desired.

3.0 NITRATE LOADING POTENTIAL OF FOCUS AREA LAND USES

The subject of elevated nitrate levels in Florida's groundwater has been studied extensively in recent years by researchers at the University of Florida, the U.S. Geological Survey, and the Southwest Florida Water Management District (SWFWMD). In an effort to compile the results of this research, the SWFWMD has prepared a comprehensive bibliography of nitrate-related documents covering topics such as sources of nitrate loadings, impacts to water resources, hydrogeological influences on nitrate migration, and nitrate best management practices (Yingling, 2002).

This section summarizes the nitrate loading potential associated with various land uses and point sources existing inside the Focus Area. The spatial and temporal distribution of these sources will be discussed in Section 4.

3.1 CITRUS

According to the 1993 Jones and Upchurch report, inorganic fertilizer applied to citrus crops was a primary cause of nitrogen in the groundwater in the BKT. Since the publication of that report, numerous studies have documented the occurrence of elevated nitrate concentrations in groundwater in citrus groves and citrus growing regions throughout Central and South Florida (Crandall, 2000; Graham and Wheaton, 1999; McNeal and others, 1994 and 1995; Schumann, 2003; Tihansky and Sacks, 1997; Tucker and others, 1995; Wheaton and Graham, 2000). Other investigators have documented the impact of nitrate loading from citrus groves on surface waters in West-Central Florida (Champion and DeWitt, 2000; Stanley and others, 2003).

<u>Historical use of nitrogen on citrus groves</u> - For decades, citrus growers in Florida have applied nitrogen to the soil as a way to increase yields. While early citrus growers relied primarily on organic sources of nitrogen such as barnyard manures and bird guano (Tucker and others, 1995), growers began relying more on inorganic nitrogen fertilizer as it became cost effective. By the 1940's, commercially produced inorganic nitrogen was inexpensive and usually applied at high rates, with extreme cases of up to 400-500 pounds

of nitrogen per acre of citrus per year (Stricker and Muraro, 1981). This practice resulted in a general increase in the amount of nitrogen per acre leached through the soil to the groundwater under citrus groves.

In the mid to late 1970's, fertilizer prices increased dramatically, and by that time research had demonstrated that nitrogen applied at rates in excess of about 200 pounds per acre per year for non-irrigated groves and 250 pounds per acre per year for irrigated groves could rarely be justified (Stricker and Muraro, 1981). In 1994, the Florida legislature authorized the Florida Department of Agriculture and Consumer Services to develop nitrogen fertilizer best management practices (N-BMPs) designed to meet groundwater standards. A nitrogen interim measure was adopted in 1995 and replaced in 2002 by the current N-BMP rule for Florida ridge citrus. Although the current N-BMP's are not mandatory, if the grower implements the N-BMP's the landowner or lessee will not be subject to penalties if nitrate groundwater standards are violated. Information on the N-BMP's is available from several sources including Schumann (2003).

Nitrogen leaching potential from ridge citrus – Groundwater systems underlying citrus grown on "ridge" soils are particularly vulnerable to contamination by inorganic nitrogen fertilizers (Schumann, 2003). Ridge soils are defined as well drained, containing little organic matter, and lacking a spodic horizon or clay layer. These types of soils are prevalent in karst areas, including the Brandon Karst Terrain. Because fertilizer is lost to leaching following heavy rainfall events, fertilizer application rates for citrus and vegetable crops on these soils often exceed the rates recommended by the University of Florida Institute for Food and Agricultural Sciences (Stanley and others 2003). Furthermore, loss of nitrogen by denitrification is minimal in these soils due to their well aerated condition (Tucker and others, 1995).

Tucker and others (1995) estimated that if a mature grove receives a typical rate of 200 pounds of nitrogen fertilizer per acre per year, only about 75 pounds of nitrogen per acre are removed from the grove through harvesting a typical crop of 600 boxes of oranges per acre. In groves on ridge soils, much of the remaining 125 pounds of nitrogen is leached through the soil and into groundwater. In controlled leaching studies, approximately 40% of the nitrogen applied to the soil is not recovered (Tucker and others, 1995) and is assumed lost to volatilization, denitrification, and/or other unknown removal mechanisms. Based on these published rates for nitrogen removal, a net loading rate to groundwater of approximately 40-50 pounds of nitrogen per acre per year is a reasonable estimate for citrus grown on ridge soils and fertilized at an average rate of 190-200 pounds of nitrogen per acre per year. At a more likely 1940's through 1960's nitrogen application rate of 300 pounds per acre per year, the net loading rate to groundwater would have been more than 100 pounds per acre per year.

3.2 OTHER CROPS

Row crops grown on ridge soils may have nitrate loading potentials that are similar to citrus. Ridge soils are low in organic content and therefore vegetable crops grown on these soils also require extensive fertilization. The previous discussion regarding the leaching potential of nitrogen fertilizers applied to citrus on ridge soils is assumed to similarly apply to row crops grown on the same soils. However, the 1993 Jones and Upchurch report did not focus on this land use type because row crops were not prevalent in the BKT during the time frame covered by that study. In Florida, these types of crops are typically grown on soils with seasonally high water tables.

3.3 SEPTIC TANKS

Jones and Upchurch (1993) concluded that "septic tanks now present in the area will most likely adversely affect future concentrations of nitrogen in the springs". Their analysis estimated that the average septic tank in the BKT contributes approximately 40 pounds of nitrate per year, loaded directly to the groundwater. This estimate was based on literature values for nitrogen concentrations in septic tank effluent (35 to 45 mg/L), and an average 30% removal through mineralization, nitrification/denitrification, adsorption, biological uptake, fixation, or volatilization before the effluent reaches groundwater. The relative significance of this loading source depends on the densities of septic tanks and the resulting contribution of septic tank effluent compared with other sources of groundwater recharge.

3.4 SMALL WASTEWATER TREATMENT PLANTS

The Focus Area contains several small domestic wastewater treatment plants (DWWTPs), each with permitted capacities of less than 0.1 million gallons per day (mgd). None of the facilities provide more than secondary treatment. Although total nitrogen concentrations in secondarily treated effluent can vary greatly among different systems and operating conditions, typical values range from 20-26 mg/L (Veissman and Hammer, 1993).

The DWWTPs within the Focus Area utilize percolation ponds for effluent disposal. It is not clear how much, if any, nitrogen removal occurs in these ponds and in the underlying soil column. However, percolation rates of the treated effluent are likely to be rapid due to the highly permeable soils and karst geology of the Focus Area. Gilbert and Oman (1993), measured no significant nitrogen removal in soil columns under existing municipal wastewater percolation ponds with high infiltration rates. If no reduction in nitrogen is attributed to the ponds, each residence connected to one of these small DWWTPs will contribute up to 75%-80% of the amount of nitrogen from the average septic tank, or about 30 pounds of nitrate per year loaded directly to the groundwater.

The relative importance of this type of loading source depends largely on the operating characteristics of the individual plants, the number of residences connected to the DWWTPs, and on the likelihood that the plants will be abandoned in the near future as the County extends its central sewer service area to the developments currently served by the small DWWTPs. The latter two of these factors are discussed in Section 4.

3.5 GOLF COURSES

The 1993 Jones and Upchurch report cited a 1992 Sarasota Bay National Estuary Program document that estimated 28 tons/yr of nitrogen are applied to a representative golf course with 15 acres of tees and greens and 200 acres of fairways. This application rate translates into an average of 260 pounds of nitrogen per acre of golf course per year. Although this is a significant amount, recent research has shown that healthy turfgrass is relatively efficient at absorbing nitrogen, even from coarse-grained soils. In one controlled leaching experiment on sports fields with three different soils textures, Petrovic (2004) estimated that only about 9% of the applied nitrogen was leached past the root zone from turf planted on sandy soil. This translates into an average of about 23 pounds of nitrogen per acre per year leached past the root zone.

3.6 RESIDENTIAL AND COMMERCIAL LANDSCAPING

Fertilizer application rates and frequencies associated with residential and commercial landscaping vary widely. In Florida, the majority of fertilizer applied to landscaping is applied to turfgrass. The University of Florida Institute for Food and Agricultural Sciences (IFAS) recommends a universal application rate of 1 pound of actual nitrogen per 1,000 square feet of turf grass. Recommended frequencies of application vary by grass species and desired lawn quality; from twice a year for a fair quality bahia grass lawn, up to eight times a year for a high quality St Augustine grass lawn (Smith, 1985). For the typical 5,000 square-foot lawns found on quarter-acre (+/-) subdivision lots, the recommended application rates and frequencies translate into gross loading rates of about 10 to 40 pounds of nitrogen per residential lot per year.   Determining the actual fertilizer application rates for residential and commercial landscaping within the Focus Area was not possible. However, it is hypothesized that the average rate of application is on the low end of the recommended range because a certain (albeit unknown) percentage of home and business owners do not apply any fertilize to their landscaping.

In a recent study of nitrogen leaching from different landscape types, Erickson and others (2002) found that properly maintained St. Augustine grass on sandy soil is relatively efficient at using applied nitrogen, even with six annual fertilizer applications. In a controlled experiment conducted in South Florida over a 12-month study period, only 1.4% of the applied fertilizer N was leached from the St. Augustine grass. In contrast, a mixed-species ornamental landscape receiving only three fertilizer applications leached 32% of the applied nitrogen. No significant runoff was observed from either landscape type over the course of the experiment. The relatively high leaching rate associated with the mixed-species landscape was attributed partly to the fact that the landscape plants used in the experiment had not reached maturity.

4.0 LAND USE TRENDS IN THE LITHIA/BUCKHORN SPRINGS FOCUS AREA

Using previous estimates of groundwater travel time within the BKT (Figure 39 in Jones and Upchurch, 1993), it can be assumed that land uses in the Focus Area over the past 10-20 years are responsible for the bulk of the nitrate currently discharging in the springs. However, it must be noted that estimating groundwater travel times in karst aquifers is highly problematic due to the presence of network(s) of preferential flow paths consisting of sinkholes, fractures, and conduits. This heterogeneity can result in a wide range of travel times in a single aquifer, even through groundwater pathways of similar length (White, 1988). Because the minimum and maximum groundwater travel times from the Focus Area to the springs have not been established, current land uses and/or the residual effects of land uses/practices going back 40 years or more cannot be ruled out as sources of the nitrate now discharging through the springs.

Figure 3 shows the 1979, 1990, 1999, and 2005 land use distribution within the Focus Area and a ½-mile buffer. These dates were chosen to provide representative snapshots of land uses during the period of time most likely corresponding to the origination of groundwater nitrate currently discharging from Lithia and Buckhorn Springs. The 1979 land use was generated by SDI from 1"=200' scale black and white aerial photographic maps prepared in January-June 1979 by ACA, Inc. for Hillsborough County. The basis for the 1990 land use map on Figure 3 is SWFWMD's "SWLU90" geodataset obtained from the Florida Geographic Data Library. The 1999 land use was generated by SDI from the 1999 1-meter USGS color infrared DOQQs. The 2005 land use map was generated by SDI from the 2004 1-meter true color DOQQs and field reconnaissance conducted in May 2005.

Using the Jones and Upchurch 10 to 20 year estimate of groundwater travel time, the Focus Area land uses and practices during the mid-to-late 1970's and early 1980's would have been responsible for the much of the nitrate discharging from the springs at the time of the 1993 publication. Similarly, the Focus Area land uses during the late 1980's and early 1990's (and the resulting elevated concentrations of nitrate in the groundwater depicted on Figure 1) would be the source of much of the nitrate currently discharging through the Springs. In addition, a comparison of Focus Area land uses from the 1980's to the present might help to provide a qualitative indicator of expected future trends in nitrate concentrations in the springs.

Table 1 presents the areas covered by each land use type in the Focus Area in 1979, 1990, 1999, and 2005. For the purposes of this investigation, medium to high density residential land use was considered a single category defined as two or more residential units per acre. Low density residential was defined as fewer than two units per acre. A declining trend in agricultural land use (particularly citrus) and an increasing trend in medium to high density residential land uses are apparent from the numbers in the table and from visual inspection of Figure 3.

Table 1. Comparison of 1979, 1990, 1999, and 2005 Land Use in the Focus Area

Land Use	**1979 (acres)**	**1990 (acres)**	**1999 (acres)**	**2005 (acres)**
Citrus	1,496	940	469	97
Pasture	501	183	173	53
Other agricultural	172	46	110	5
Other open lands (mining, recreational, native lands, water, wetlands)	495	318	345	436
Residential – medium to high density	1,130	1,931	2,390	3,010
Residential – low density	574	690	652	616
Commercial and services	68	96	108	134
Other urban lands	45	277	234	130
Total	**4,481**	**4,481**	**4,481**	**4,481**

The remainder of this section provides a discussion of the temporal trends in the individual land use categories.

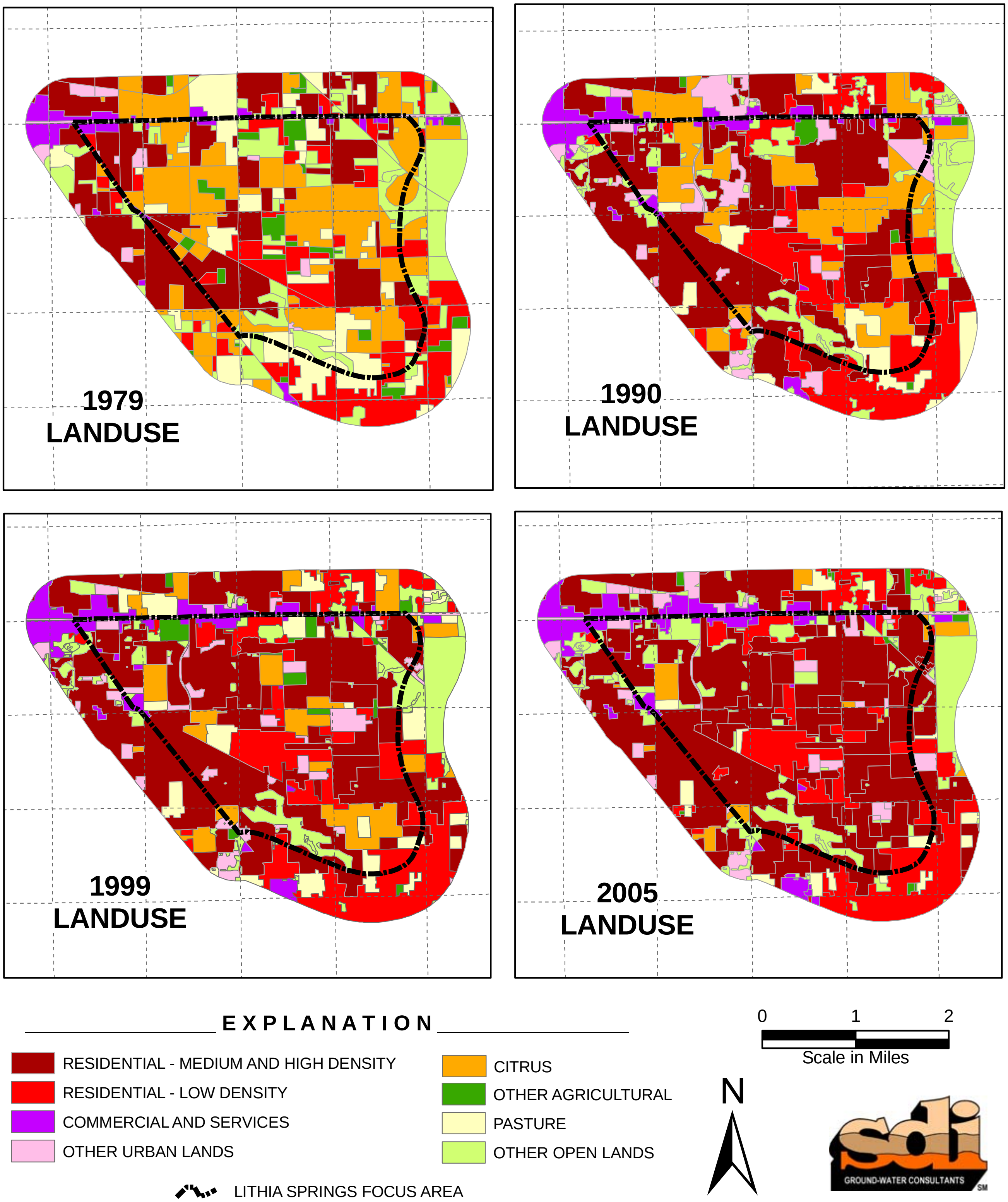


Figure 3. Past and Present Total Land Use

4.1 CITRUS AND OTHER CROPLAND

Citrus has been produced in the Brandon area since the late 1800's (Rodriguez, 1990/ Figure 4), and by the late 1940's citrus was a major land use in the Brandon Karst Terrain (Jones and Upchurch, 1993). By 1968, nitrate levels in Lithia Springs were in an upward trend (Figure 2). Analysis of historical aerial photographs indicates that in 1968, approximately 1,840 acres of citrus was in production in the Focus Area.

Figure 4. Brandon Area Citrus Grower in the 1890's Fertilizing Citrus Seedlings
(Source: Brandon, Florida, 1890-1990: A Photographic Essay by Lisa W. Rodriguez. University of South Florida Libraries, Tampa Bay History Collection)

By 1979 the acreage in citrus production had declined to less than 1,500 acres, although a significant amount of land (about 170 acres) was in vegetable/ row crop production that year, up from only about 30 acres in 1968. The combined acreage in 1979 of citrus and other cropland decreased by about 11% from 1968 levels.

During the 1980's, many of the groves were cleared to make way for residential development, and by 1990 only 940 acres were devoted to citrus, which is about half the acreage that was present in 1968 (Figure 5). By 1990, the acreage devoted to other crops had dropped back below 50 acres. Vegetable/ row crops continued to represent a relatively insignificant percentage of the total land use in the Brandon Karst Terrain throughout the 1990's and early 2000's. Between 1990 and 2005, the acreage in citrus production in the Focus Area declined steadily to a total area of less than 100 acres today (Figure 5).

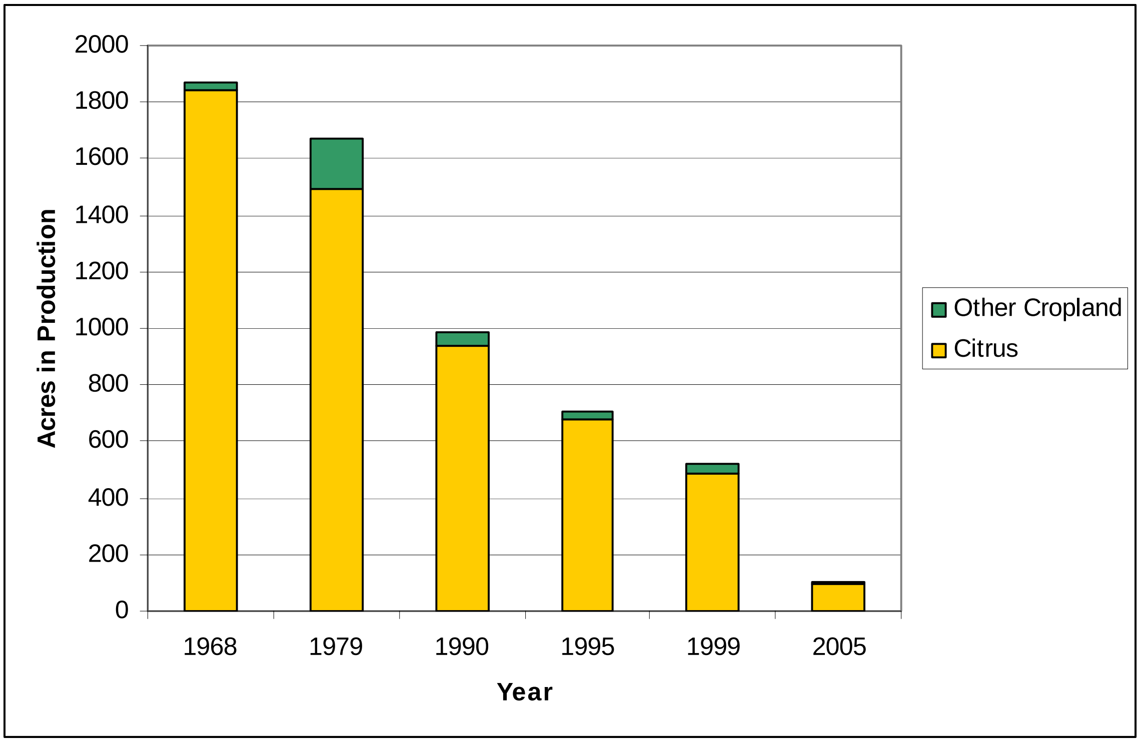


Figure 5. Acreage of Citrus and Other Cropland within the Focus Area

4.2 SEPTIC TANKS

In their 1993 report, Jones and Upchurch estimated that in 1990 there were 11,000 septic tanks within the entire Brandon Karst Terrain. Their estimate was based on aerial photograph analysis and the extent of the Hillsborough County sewer system at the time. For the current study, SDI prepared an updated, comprehensive map of the septic tank locations within the Focus Area (Figure 6). Initially, a GIS geodataset prepared for Hillsborough County in 2003 by the Florida Center for Community Design and Research (FCCDR) was evaluated, along with the septic tank permit mapping prepared by Parsons for their 2004 Alafia River report (Parsons, 2004). However, examination and comparison of the two data sets revealed several data gaps and inconsistencies. In particular, many of the parcels in the FCCDR database with a "confirmed sanitary sewer" attribute were found to have recent septic tank permits on file with the County Health Department. It was also discovered that the septic permit database only goes back to 1997, which limits its usefulness since most of the septic tank installations pre-date 1997. In order to fill the identified data gaps and reconcile the inconsistencies, maps of the current extent of the central sewer system were obtained from the Hillsborough County Water Department (HCWD, 2005). Each occupied parcel (as evident on the aerial photographs) without an available central sewer connection was assumed to be served by a septic tank, and so the status attribute was changed to “septic tank”.

The FCCDR map also identified mobile home parks that are served by small individual wastewater facilities. These parcels are identified with the green shading on the updated map, Figure 6. The status attribute of the Valrico Hills MHP was changed by SDI from “confirmed sanitary sewer” to “domestic wastewater facility” after it was determined, by inspection of the Water Department’s sewer line maps, that the park is not connected to the County’s central system. Conversely, all 355 single-family residential parcels within the Brandon-Valrico Hills subdivision were changed from “unconfirmed septic” to “confirmed sewer” based on the extent of the sewer system and the known presence and current operation of the Brandon-Valrico Hills Wastewater Treatment Plant that serves the subdivision. The location of the wastewater treatment plant is indicated on Figure 6.

Currently, there are about 2,600 septic tanks within the Focus Area. It should be emphasized that this estimate includes only the Focus Area, and relatively high densities of septic tanks exist in other areas of the Southern BKT (Jones and Upchurch, 1993).

A map of the high- and low-density developed areas served by septic tanks in 1965 (Figure 3 in Jones and Upchurch, 1993) was consulted to develop an estimate of the number of septic tanks in the Focus Area in 1965. A comparison of the 1965 septic tank map with the current parcel layer suggests there were less than 400 septic tanks in the Focus Area in 1965. In addition, the current septic tank parcel GIS layer was compared with the 1979 and 1990 land use mapping. The comparison indicates that between 1979 and 1990, the number of septic tanks in the Focus Area increased from about 1,800 to over 2,500. In contrast, nearly all residential subdivisions built since 1990 within the Focus Area are served by central sewer. While some new septic tanks have been installed since 1990, some of these are replacements of older failing systems and some are for new homes built on previously vacant lots in older subdivisions. Probably less than 100 new septic tanks fall into the latter category. On the other hand, no evidence was found of central sewer lines being extended

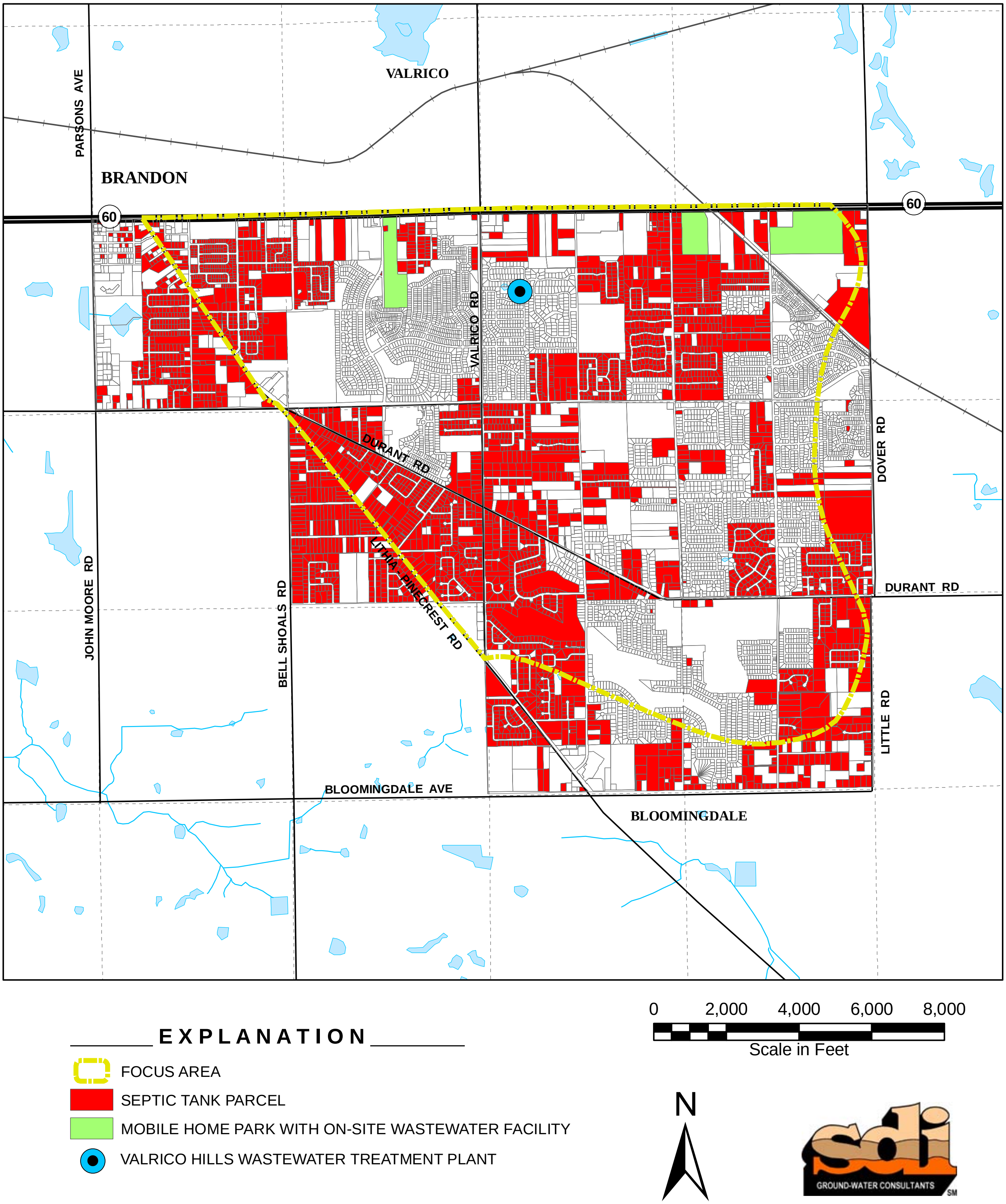


Figure 6. Present Parcels Served by Septic Tanks

into septic tank areas built out prior to 1990. Therefore, the number of septic tanks within the focus area has remained relatively constant over the past 15 years.

4.3 SMALL WASTEWATER TREATMENT PLANTS

Hillsborough County's central sewer system extends into much of the Focus Area. The system conveys wastewater to the regional Valrico Wastewater Treatment Plant, where it undergoes advanced treatment. However, one residential development and three older mobile home parks in the Focus Area are still served by small DWWTPs that do not provide more than secondary treatment. All of these facilities were constructed prior to 1990, and the oldest one (Brandon Trailer Park) dates to the 1960's. Locations of the small DWWTPs are shown on Figure 6. Table 2 lists the facility names and the number of homes connected to each plant, estimated from current aerial photographs.

Table 2. Package Wastewater Treatment Plants in the Focus Area

Facility Name	Estimated # of Homes Connected	Effluent Disposal Method
Brandon-Valrico Hills WWTP	355	Percolation Pond
Brandon Trailer Park	208	Percolation Pond
Southern Pines MHP	40	Percolation Pond
Valrico Hills MHP	383	Percolation Pond
Total	**986**	

It should be noted that the Hillsborough County Water Department has purchased the Brandon-Valrico Hills WWTP and has plans to connect the Brandon-Valrico Hills wastewater customers to the County's Regional Valrico AWWTP. This connection is expected to be completed by the end of October 2006 (Hillsborough County Government Online, 2005). The County also has plans to construct a new sanitary sewer force main along SR 60 from Miller Road to Dover Road, by November 2008. The new sewer line will run adjacent to the Southern Pines MHP and the Valrico Hills MHP, which would facilitate future connection of these residences to the County's regional system.

4.4 GOLF COURSES

The Buckhorn Springs Golf Course at the extreme southern end of the BKT is the only golf course within the Focus Area. Hillsborough County Property Appraiser's records indicate that the course's club house was constructed in 1975, and so it can be assumed that 1975 is the year the golf course began operations.

The Bloomingdale and River Hills golf courses lie south of the Brandon Karst Terrain and north of the Alafia River and Lithia Springs. Though these areas are not considered part of the Brandon Karst Terrain, the courses are also situated on soils with high leaching potential. It is possible that fertilizers from these courses could be contributing some nitrate to the springs due to their soil types and close geographic proximity to the springs.

Buckhorn Springs Golf Course was a subject of a USGS study by Swancar (1996), which investigated the quality of groundwater at several golf courses in Florida. Elevated levels of nitrate (as compared to background levels) were cited in three of the six Hillsborough County monitor wells in the golf course. Two of the other three wells were consistently dry over the course of the study. In multiple samples taken periodically over a 10-month period in 1992 and 1993, two of the wells, which were situated down gradient of one tee and one green in the northwest portion of the course, had average nitrate levels exceeding 5 mg/L. Swancar attributed the elevated nitrate concentrations in these wells to the use of fertilizers, rapid infiltration, and aerobic groundwater conditions (Swancar, 1996). It is important to note, however, that these wells were situated near tees and greens, which likely received more fertilizer than fairways. Therefore the groundwater conditions at the two wells with the highest nitrate concentrations are not necessarily representative of the entire course. Treated wastewater used for irrigation on the course was ruled out by Swancar as a source of nitrogen in the groundwater, because the advanced nitrification/ denitrification treatment process used at the Valrico WWTP removes most of the nitrogen from the waste stream.

4.5 RESIDENTIAL AND COMMERCIAL

The medium- to high-density residential land use category has exhibited a strong increasing trend, increasing almost threefold since 1979. In contrast, acreage devoted to low density residential land use increased slightly in the 1980's but decreased slightly in the 1990's and early 2000's. Commercial and services land use increased steadily between 1979 and 2005, although it continues to represent a relatively small fraction of the total land use. Based on a 2002 GIS parcel layer generated by the Hillsborough County Property Appraiser's office, there were 6,391 occupied residential parcels and another 134 occupied commercial, office, and private institutional properties within the Focus Area.

5.0 FUTURE LAND USE

The latest zoning map GIS layer was obtained from Hillsborough County to identify likely future land use changes in the Focus Area. Overlaying this map layer onto the current (2005) land use map revealed that most of the remaining agricultural land, including the lone remaining sizeable citrus grove (the 80-acre grove at the northeast corner of Lumsden Road and Lithia-Pinecrest), is zoned for "planned development". Therefore, it can be assumed that the transition from agricultural to urban land uses may continue to progress.

6.0 SOILS AND HYDROGEOLOGY

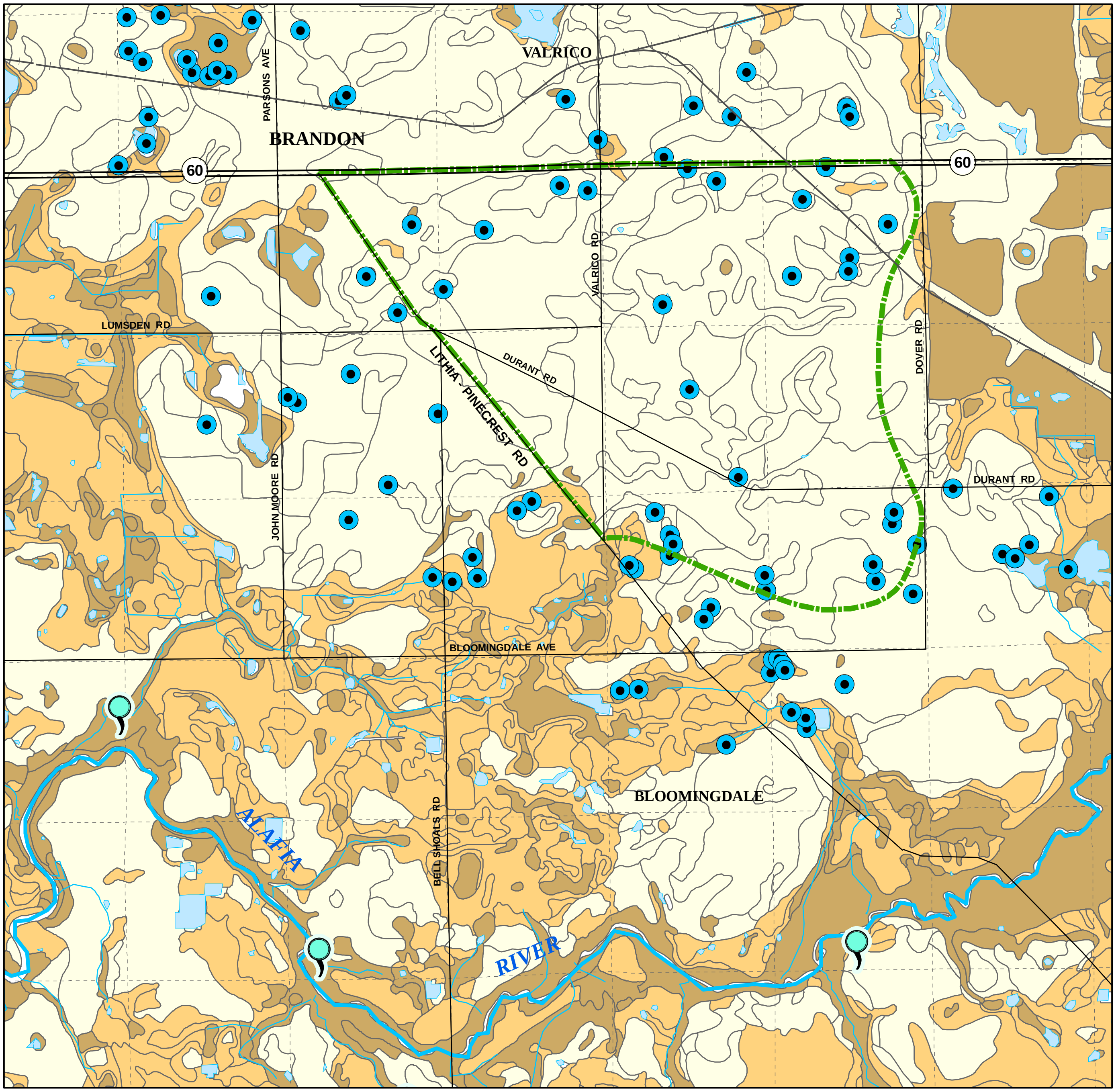
Soils within the Focus Area are primarily fine sands of the Lake, Candler, Fort Meade, and Gainesville series. These soils are all classified as well-drained to excessively drained, with rapid to very rapid infiltration rates, and seasonal high water tables exceeding depths of 6 feet. Little or no stormwater runoff can be expected from these soils, except where covered by impervious surfaces such as roads and buildings. The SWFWMD's SSURGO GIS database classifies these soils as having a high potential for leaching of nutrients and pesticides because of their rapid infiltration rates and lack of spodic horizons or clay layers. These four soil types are also among the 23 soils classified by the Florida Department of Agriculture and Consumer Services (FDACS) associated with a risk of groundwater contamination through leaching of agricultural chemicals (Tucker and others, 1995).

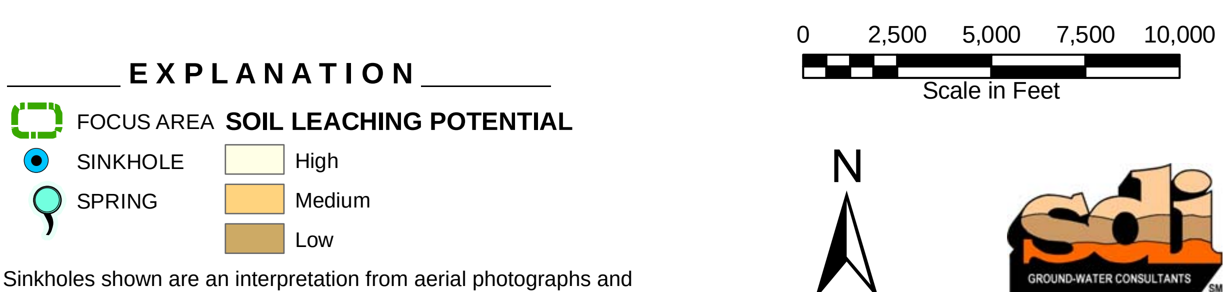
Figure 7 shows the coverage of soils in and around the Focus Area. The soil series are color coded according to the leaching potential as identified in the SWFWMD SSURGO database, with the exception of Zolfo Fine Sand, which covers a small portion of the southwest part of the Focus Area. Zolfo Fine Sand was reclassified from the SSURGO "high" leaching potential category to "medium" leaching potential by SDI for the purposes of this report. In contrast with the other soils in the Focus Area, Zolfo Fine Sand is characterized as poorly drained, with a permanent water table that is seasonally within two feet of land surface. Examination of measured water level data from a pair of Tampa Bay Water monitor wells (BD-14WT and BD-14FL) within this soil type indicate the presence of a confining layer between the surficial and the Floridan aquifers. In addition, Zolfo Fine Sand is not among the 23 soils categorized by FDACS as at risk for leaching of agrichemicals.

Jones and Upchurch (1993) provided a thorough description of the covered karst geology within the southern BKT. The area is characterized by the absence of a surficial drainage network. Infiltrated water is conveyed internally through a groundwater system consisting of fractured limestone, sinkholes, and solution conduits. By making the simplifying assumption that the karstic groundwater system consists of an equivalent porous medium, the travel time of groundwater from the Focus Area to Lithia Springs was estimated to range from 10 years at the southern end to a little over 20 years near SR 60 (Figure 39 in Jones and Upchurch, 1993). However, as noted in Section 4, estimating groundwater travel times in karst aquifers is highly problematic. In covered karst, the time required for pollutants to travel from the bottom of the soil root zone to one of the spring vents depends on the thickness of the sands overlying the limestone and the initial proximity to a preferential groundwater flow pathway comprising a segment of the karst drainage network that discharges to the springs.

Sinkhole locations within the Focus Area were interpreted from closed depressions apparent on the 1”=200’ SWFWMD aerial maps with one-foot topographic contours. Additional sinkhole locations were mapped within an approximate one-mile buffer surrounding the Focus Area (the sinkhole mapping did not extend to the Alafia River). Figure 7 indicates the sinkhole locations in and around the Focus Area. Where uncertainties existed in differentiating man-made ponds from natural sinkholes, the depressions were field checked.

The northwest-southeast linear orientations of sections of the Alafia River suggest a structural control by fractures in the underlying limestone. It is likely that these linear fracture orientations are also prevalent in the focus area. The sinkhole locations plotted on Figure 7 are indicative of solution features along preferential linear pathways such as fractures.





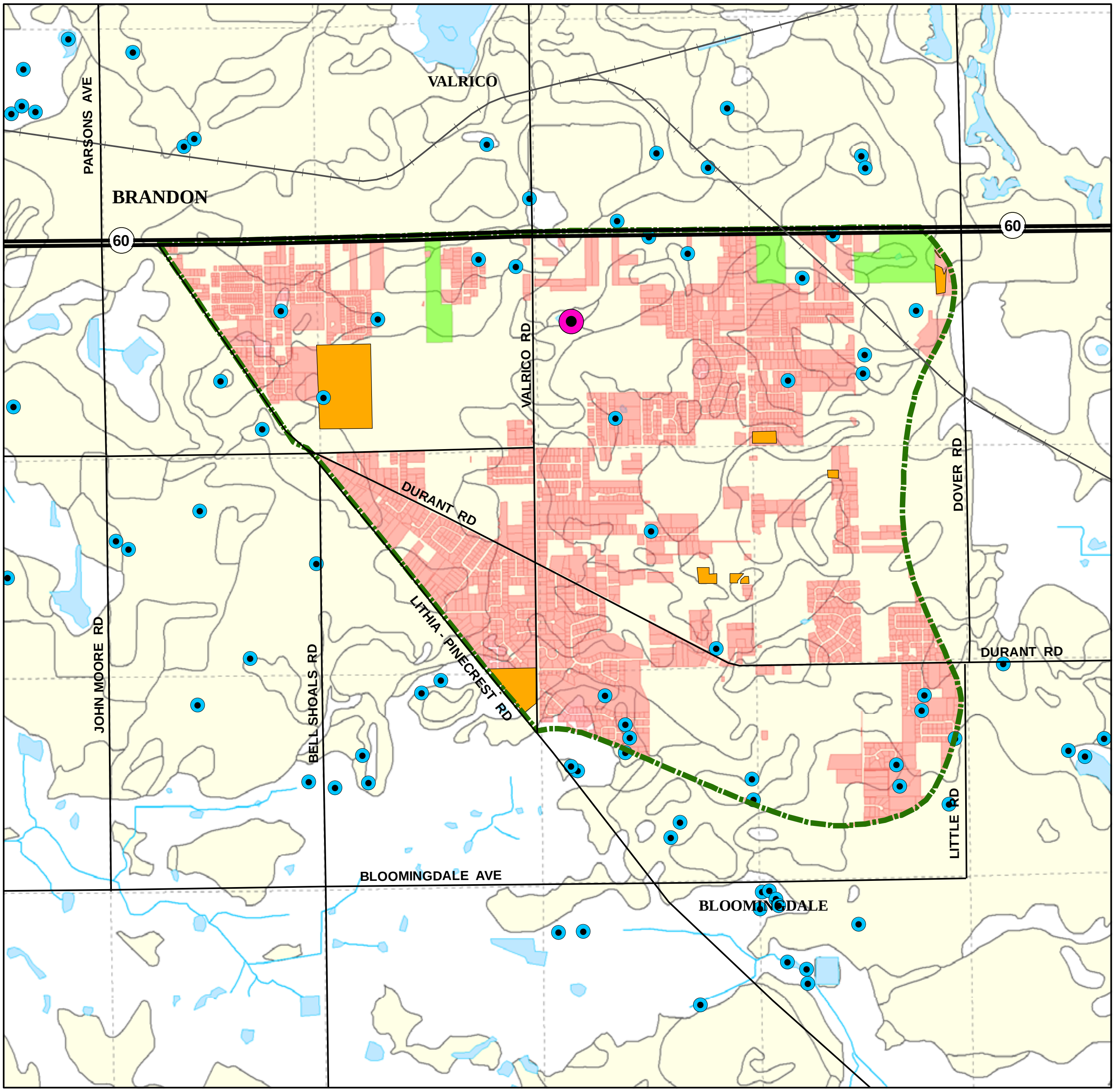
Note: Sinkholes shown are an interpretation from aerial photographs and 1' topographic contour mapping. They have not been field verified.

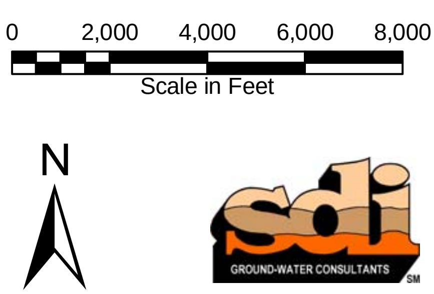
Figure 7. Sinkholes and Soils Classified by Leaching Potential

7.0 VULNERABILITY MAPPING

By superimposing the high-risk land uses over the soils attributes and geological features associated with a high risk of leaching and rapid migration of contaminants, it is possible to identify those areas that currently would contribute the highest nitrate loading to the groundwater system. High-risk land uses are defined, for the purposes of this study, as those land uses identified in Section 3 that tend to contribute the greatest quantities of nitrogen on an acre-per-acre basis. On Figure 8, the high leaching potential soils and sinkholes are overlain by the current citrus groves, septic tank parcels, wastewater treatment plants, and mobile home parks with on-site wastewater disposal facilities.

As previously noted, almost the entire Focus Area is underlain by soils classified as having a high leaching potential. Contaminated water leached through the soil typically does not travel far before likely encountering one of the preferential groundwater flow paths coinciding with sinkholes or interpreted limestone fractures prevalent throughout the Focus Area. Because of the high potential for leaching and migration of contaminants throughout the entire Focus Area, high-risk land uses are the controlling factor in groundwater vulnerability to nitrate loading.





EXPLANATION

- FOCUS AREA
- SINKHOLES
- SEPTIC TANKS
- MOBILE HOME PARK WITH ON-SITE WASTEWATER FACILITY
- CITRUS GROVES
- HIGH SOIL LEACH RATE
- WASTEWATER TREATMENT PLANT

Figure 8. Groundwater Nitrate Vulnerability Map, Lithia and Buckhorn Springs Focus Area

8.0 SUMMARY OF PAST AND PRESENT NET NITRATE LOADINGS TO THE FOCUS AREA GROUNDWATER SYSTEM

8.1 CITRUS

Nitrate loading associated with the historical fertilization of citrus groves was substantial in the past. An assumed historical 1940's to 1960's rate of nitrogen application of 300 pounds per acre would correspond to a net loading rate to the groundwater of approximately 100 pounds per acre per year. At that rate, this land use would have supplied about 92 tons of nitrate annually to the groundwater within the Focus Area in the 1968 time frame. By comparison, it is estimated that the total amount of nitrate contributed annually to the Alafia River by Lithia and Buckhorn Springs combined is about 157 tons (Jones and Upchurch, 1993).

In contrast with the historical loadings, current loadings from the remaining groves in the Focus Area are relatively insignificant. Higher fertilizer costs and improved understanding of citrus fertilization requirements by 1990 likely resulted in a decrease in the average per-acre average rate of nitrogen application. The current typical rate of about 190-200 pounds per acre per year is also representative of the 1990 time frame (Tucker and others, 1995; Jones and Upchurch, 1993). Using the nitrogen uptake and removal rates cited in Section 3, this fertilization rate corresponds to an average net loading to the groundwater system of about 45 pounds per acre. Multiplying this rate by the 1990 acreage in citrus production (Figure 5) yields a net loading of nitrate to the groundwater system from citrus fertilization of about 22 tons per year, which represents approximately one-fourth the amount contributed from that source in 1968. In 2005, the relatively small area still in citrus production likely contributes only about 2 tons of nitrate per year to the groundwater system. Nitrate loadings from other agricultural lands is also insignificant due to the small area of these lands remaining.

8.2 SEPTIC TANKS

As estimated in Section 4.2, there are about 2,600 septic tanks within the Focus Area. At the estimated loading rate of 40 pounds of nitrogen per year per septic tank, this source contributes about 50 tons of nitrogen annually to the groundwater system. It should be emphasized that this estimate includes only the Focus Area, and that relatively high densities of septic tanks exist in other areas of the Southern BKT (Jones and Upchurch, 1993). Net annual nitrate loading from this source is estimated to have increased from about 10 tons in the late 1960's to about 30 tons in the late 1970's. By 1990, the loading from septic tanks in the Focus Area is estimated to have been near the current rate of 50 tons per year.

The number of septic tanks within the focus area has remained relatively constant over the past 15 years. This is a significant finding because at the estimated rates of nitrate loading to the groundwater, septic tanks continue to contribute more than twice the annual amount attributed to citrus in the 1990 time frame, and the acreage in citrus production has declined to almost zero since then.

8.3 SMALL WASTEWATER TREATMENT PLANTS

Effluent discharges from small wastewater treatment plants are a significant source of nitrate in the Focus Area groundwater system. If each percolation pond contributes 30 pounds of nitrogen per year per home connected to the system (as estimated in Section 3.4), then the combined nitrogen loading rate to the groundwater system from the four treatment plants is approximately 15 tons per year. Based on interpretations of the aerial photographs previously cited, the net loading of nitrogen from this source is estimated to have increased from about 3 tons per year in the late 1960's/ early 1970's to the current rate of about 15 tons per year by the late 1980's. However, Hillsborough County's planned efforts to de-commission the Brandon-Valrico Hills WWTP should help to significantly reduce the contributions from this source in the near future.

8.4 GOLF COURSES

Nitrate loadings from fertilizers applied to the Buckhorn Springs Golf Course are relatively small compared to the septic tank loadings, although the estimated loading rate from golf courses would increase to about 8 tons per year if the nearby Bloomingdale and River Hills golf courses were included in this estimate. Based on the estimated representative fertilization rates and leaching rates cited in the previous section, each of these golf courses are contributing approximately 2-3 tons of nitrate annually to the groundwater system.

8.5 RESIDENTIAL AND COMMERCIAL LANDSCAPING

Fertilization of residential and commercial landscaping was difficult to quantify, however this source probably contributes less than 15 percent of the total loading of nitrogen to the groundwater system. Because of the uncertainties involved in estimating actual rates and frequencies of fertilizer applications, the makeup of the residential and commercial landscaping in the Focus Area, and in estimating the nitrate leaching rates, developing a reliable estimate for nitrogen loading to the groundwater system from this source is highly problematic.

However, for the purpose of comparing the relative nitrate contribution associated with this source to other sources in the Focus Area, an "order of magnitude" estimate can be made using the rates cited in Section 3 as a guide. As an example, if an average nitrogen application rate of 15 pounds per subdivision lot per year is assumed along with an assumed composite leaching percentage of 10 percent, each lot would contribute approximately 1.5 pounds of nitrogen to the groundwater system each year. Based on a 2002 GIS parcel layer generated by the Hillsborough County Property Appraiser's office, there were 6,391 occupied residential parcels and another 134 occupied commercial, office, and private institutional properties within the Focus Area. A net loading rate of 1.5 pounds of nitrogen per year from each parcel would translate into a total load of about five tons per year. However, due to the uncertainties mentioned above, this estimate is best reported as a range, likely on the order of 2 to 10 tons per year.

8.6 NITROGEN BUDGET

Figure 9 presents a graphical comparison of the estimated mass loading of nitrogen into the Focus Area groundwater system with the measured combined mass loading of nitrogen out of Lithia Springs Major, Lithia Springs Minor, and the Cargill diversion. For clarity in the presentation, five-year averages were used. The estimated mass loading of nitrogen into the Focus Area groundwater system is based on the combined past and present net loadings from the anthropogenic sources described previously. Loading from natural sources (including rainfall and decay of naturally occurring organics) was estimated to be about 10 tons per year, based on a historical background nitrate concentration in the springs of 0.2 mg/L measured by the USGS in 1923 and 1946, and the historical average discharge rate of 51 cfs. This constant value was included in the graph of nitrogen loading into the Focus Area groundwater system.

It should be noted that this comparison does not include mass loading into other areas of the BKT that could be contributing to Lithia Springs, nor does it include mass loading out of Buckhorn Springs, Green Springs, or directly to the Alafia River. However, the graphs do provide a representative comparison that captures the majority of the nitrate loading into and out of the system. Mass loading into the groundwater system was projected forward into the 2005-2009 time frame by assuming that the Brandon-Valrico Hills WWTP will be taken off-line in 2006 and the acreage devoted to agriculture will continue to decline.

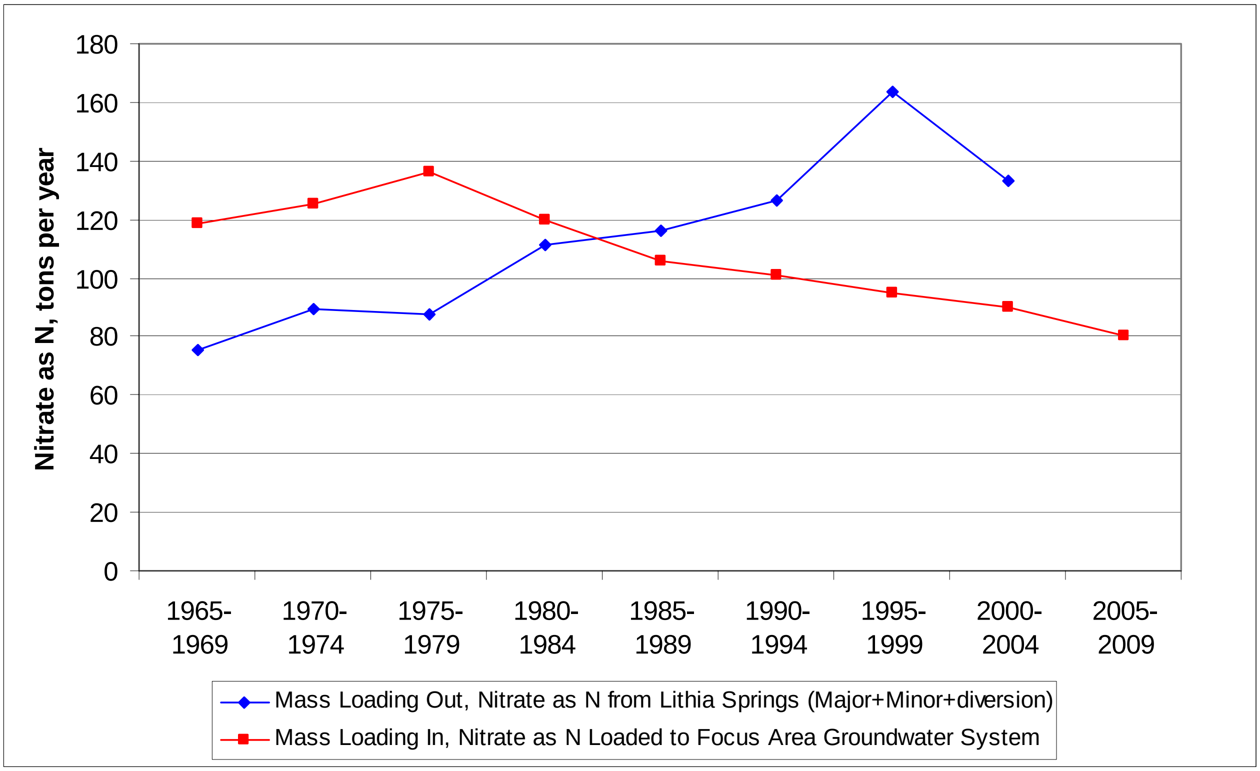


Figure 9. Comparison of Past and Present Mass Loading of Nitrate into the Focus Area Groundwater and Out of Lithia Springs

From the graphs, the mass loading into the system appears to have peaked in the late 1970's and has declined every 5-year period since. The mass loading out through the springs appears to have peaked in the late 1990's, however, this apparent peak has yet to been confirmed with a second data point after the early 2000's. Nevertheless, it is safe to assume that the average travel time of groundwater in the system is on the order of 20 years or more. The apparent downward trend in mass loading out needs to be confirmed with additional observations over the next five years or more.

Table 3 summarizes the current annual loading of nitrate contributed from various sources to the groundwater system within the Focus Area, as estimated in the previous discussions. The sources are tabulated in order of decreasing significance. From the table, it is evident that septic tanks currently contribute more nitrate to the groundwater system within the Lithia and Buckhorn Springs Focus Area than all of the other sources combined.

Table 3. Estimated Current (2005) Net Annual Loading Rates of Nitrate to Groundwater within the Focus Area by Source

Source	Estimated net loading rates of nitrate (as N) to groundwater within the Focus Area
Septic Tanks	50 tons per year
Small Wastewater Treatment Plants	15 tons per year
Natural Sources	10 tons per year
Residential and Commercial Landscaping	2-10 tons per year
Golf Courses	3 tons per year*
Citrus	2 tons per year
Other Agricultural Lands	insignificant
Total	**80-90 tons per year**

*Estimate includes Buckhorn Springs Golf Course only

9.0 SUMMARY AND CONCLUSIONS

Recent studies (SDI, 2004) suggest that although Lithia Springs contributes on average only 11% to 12% of the total discharge of the Alafia River at Bell Shoals, it is responsible for approximately 35% to 40% of the total nitrate loading at Bell Shoals. Jones and Upchurch (1993) documented the problem of high nitrogen levels in the discharge from Lithia and Buckhorn Springs, identifying the southern portion of the Brandon Karst Terrain (BKT) as the source area for the springs (see Figure 1). Past loading from fertilizers applied to citrus crops was concluded to be a primary cause of nitrogen in the BKT. This nitrogen, as well as nitrogen from other local point- and non-point sources, is able to quickly migrate downward into the upper Floridan Aquifer System (UFAS) in the BKT due to lack of confinement between the surficial aquifer and the UFAS. As agricultural lands in the Brandon area are converted to residential and commercial land uses, nitrogen loading from agriculture has been decreasing over time while nitrogen loading from other anthropogenic sources could increase (Jones and Upchurch, 1993).

The primary objective for this study was to provide an updated and more detailed discussion of the land uses, nitrate loading, and nitrate migration potential to the springs. The area of the BKT having the highest concentrations of nitrate in the groundwater was selected as the Focus Area for this study. This area generally lies south of SR 60 and northeast of Lithia Pinecrest Road, and it is also the part of the BKT that is geographically closest to Lithia Springs.

The information and analysis presented in the previous sections is intended to update and expand on the relevant discussions presented in the 1993 Jones and Upchurch report. A secondary objective for this study was to use GIS to prepare and analyze more recent and more detailed mapping information, and to evaluate currently available data sources and tools that might be applied to additional watershed areas if desired.

After combining the mapping data with published results of recent research into nitrate loading and leaching potential conducted by the USGS, SWFWMD, the University of Florida and others, SDI estimated the amount of nitrate leaching through the root zone and into the groundwater system from the various land uses and land practices for selected periods of time. Based on the analysis of loadings in the Focus Area, no additional watershed evaluation is recommended at this time. Several important water quality sampling and potential management activities were identified, however, and are discussed briefly in the following paragraphs.

Overall, the total nitrate loading to the Focus Area groundwater system is estimated to have decreased from almost 140 tons per year in the late 1970’s to about 100 tons in 1990 (Figure 9). The decrease in loading is due to a reduction in the acreage devoted to citrus and other agricultural lands. However, some of the reduction in nitrate loading from citrus fertilization was offset by an increase in loading from other sources, primarily septic tanks installed during the 1970’s and 1980’s. Between 1979 and 1990, the combined acreage of citrus and other cropland decreased by 40%. Coincidentally, during this same 11-year period the number of septic tanks in the Focus Area increased by the same percentage.

Because the number of septic tanks has not increased significantly over the past 15 years as the acreage in citrus production has continued to give way to sewered residential and commercial development, the total mass loading of nitrate into the Focus Area groundwater system has continued to decline, to an estimated 2005 value of less than 90 tons per year (Figure 9). The continuous decline in nitrate loading from the late 1970’s to the present would be expected to eventually result in a gradual decrease in nitrate concentrations within Lithia and Buckhorn Springs.

The measured difference in the mass of nitrate discharging through Lithia Springs from the late 1990’s to the early 2000’s suggests that a decrease may be already underway (Figure 9). However, caution must be used when interpreting this peak and subsequent decline because it has not been confirmed with a second data point, which could be computed after approximately five years of additional data collection. It is recommended that Tampa Bay Water continue to collect water quality and flow data at Lithia Springs, and perform this analysis when the additional data are available.

The magnitude and timing of the expected decrease in nitrate concentrations within the springs depends on how much residual nitrate now remains in the groundwater system from the former citrus groves, the actual distribution of groundwater travel times within the karst groundwater system, and the extent to which the residual nitrate influences the current water quality of the springs. The 2004 SDI report recommended that Tampa Bay Water work with SWFWMD to re-sample the wells included in the 1993 Jones and Upchurch Study, which might give an indication of the amount of residual nitrate in the system.

Although some decrease in the average nitrate concentrations within Lithia and Buckhorn Springs can be expected, the continued loading of nitrogen from septic tanks in and around the Focus Area will likely keep nitrogen concentrations in the springs well above background levels. Mass balance calculations suggest that the nitrate loading rate to the groundwater system must be reduced to less than 50 tons per year in order to eventually reduce the nitrate concentration in the springs to around 1.0 mg/L.

Additional study is needed to explore the issues of how much of a reduction in nitrate loading is needed/desired and how much of a reduction is feasible. If deemed necessary, substantial reductions in nitrate loading from septic tanks could be achieved through conversion to central sewer, retrofits to existing septic systems, or a combination of both. Conversion to central sewer may not be economically feasible in low-density residential areas. Nitrogen-removing onsite treatment systems, for both new and existing septic systems, are now commercially available and could be explored as an option for areas where central sewer would be too costly. Engineering and economic analyses would be required in order to determine the best combination of central sewer and septic system retrofitting. In portions of the Wekiva River watershed, the Florida Department of Health recommended retrofits to existing septic systems to meet a discharge limit of 10 mg/L of total nitrogen (approximately a 75% reduction), for areas where central sewer will not be made available in the near future (Florida Department of Health, 2004).

REFERENCES

Champion, Kyle M., and David J. DeWitt, 2000, Origin of Nitrate in Ground Water Discharging from Crystal Springs; Pasco county, Florida. Southwest Florida Water Management District.

Crandall, C. A., 2000, Distribution, Movement, and Fate of Nitrate in the Surficial Aquifer Beneath Citrus Groves, Indian River, Martin, and St. Lucie Counties, Florida. U.S. Geological Survey WRI 00-4057.

Erickson, J., J. Cisar, G. Snyder, and J. Volin, 2002, Documenting the Nutrient Leaching and Runoff Losses from Urban Landscapes. University of Florida, Ft Lauderdale Research and Education Center. Paper No. 1429, Presented at 17th WCSS, August 2002.

Florida Center for Community Design and Research, 2003, Map of Areas Served by Septic Tanks in Hillsborough County. Prepared for Hillsborough County.

Florida Department of Health, 2004, Wekiva Basin Onsite Sewage Treatment and Disposal System Study. Prepared by the Bureau of Onsite Sewage Programs, Division of Environmental Health.

Gilbert, T. A. and B S. Oman, 1993, Nitrogen Removal in Renovated Municipal Wastewater Rapid Infiltration Basins. University of Wisconsin Water Resources Institute, accessed at: http://wri.wisc.edu/wgrmp/33dnr97.htm

Graham, Wendy, and Adair Wheaton, 1999, "Ridge Citrus Water Quality Project – Annual Progress Report – (1998-1999)." Florida Department of Agriculture and Consumer Affairs, Southwest Florida Water Management District, Florida DEP.

Hillsborough County Government Online, 2005, PIMS CIP Information accessed at: http://www-gis.hillsboroughcounty.org/gis/pims/ShowProjects.cfm?project=Waste+Water

Hillsborough County Water Department (HCWD), 2005, Wastewater System, South Central Area (Map series) Engineering and Environmental Management Section.

Jones, G.W. and Upchurch, S.B., 1993, Origin of Nutrients in Ground Water Discharging from Lithia and Buckhorn Springs. Southwest Florida Water Management District, Brooksville, FL

McNeal, B.L., C.D. Stanley, L.A. Espinoza, and L.A. Schipper, 1994, "Nitrogen Management for Vegetables and Citrus: Some Environmental Considerations." Soil and Crop Science Society of Florida, Proceedings 53 (1994):51-53.

McNeal, B.L., C.D. Stanley, W.D. Graham, P.R. Gilreath, D. Downey, and J.F. Creighton, 1995, "Nutrient-Loss Trends for Vegetable and Citrus Fields in West-Central Florida: I. Nitrate." Journal of Environmental Quality 24.1 (1995): 95-100.

Parsons, 2004, Alafia River Watershed Water Quality Protection Plan, Phase 1. Final Report, May. Prepared for Tampa Bay Water.

Petrovic, A.M., 2004, Impact of Soil Texture on Nutrient Fate Acta Horticulture. (ISHS) 661:93-98 http://www.actahort.org/books/661/661_10.htm

Rodriguez, L.W., 1990, Brandon, Florida, 1890-1990: A Photographic Essay University of South Florida Libraries, Tampa Bay History Collection. http://www.lib.usf.edu/ldsu/digitalcollections/T06/journal/v12n2_90/v12n2_90_31.pdf

Schumann, A.W., 2003, Nutrient BMP's for the Ridge Citrus Production Region, Presented at the Nutrient Management for Optimum Citrus Tree Growth and Yield Short Course, October 29, 2003. University of Florida Citrus Research and Education Center, Lake Alfred, FL.

SDI Environmental Services, Inc., 2004, Investigation of Water Quality in Potential Source Water Areas of Lithia and Buckhorn Springs, Technical Memorandum, December. Prepared for Tampa Bay Water.

Smith, G. S., 1985, Fertilizing Your Florida Lawn. University of Florida Institute for Food and Agricultural Sciences, ENH-20

Stanley, C.D., R.A. Clarke, B.L. McNeal, and B.W. Macleod, 2003, Impact of Agricultural Land Use on Nitrate Levels in Lake Manatee, Florida. September. University of Florida IFAS Document SL 209.

Stricker, James A., and R.P. Muraro, 1981, "Determining the Most Profitable Level of Nitrogen Fertilization for Citrus". Proceedings of the Florida State Horticultural Society, 94; (1981): 8-11.

Swancar, A., 1996, Water Quality, Pesticide Occurrence, and Effects of Irrigation With Reclaimed Water at Golf Courses in Florida. U.S. Geological Survey WRI 95-4250.

Tihansky, A.B., and L.A. Sacks, 1997, Evaluation of Nitrate Sources Using Nitrogen-Isotope Techniques in Shallow Ground Water Within Selected Lake Basins in the Central Lakes District, Polk and Highlands Counties, Florida. U.S. Geological Survey WRI 97-4207.

Tucker, D.P.H., A.K. Alva, L.K. Jackson, and T.A. Wheaton, eds., 1995, Nutrition of Florida Citrus Trees. University of Florida IFAS Document SP 169.

Wheaton, T.A. and Wendy Graham, 2000, Spatial and Temporal Distribution of Groundwater Nitrate in Relation to Citrus Production in Central Florida. Final Report. Prepared for the Florida Department of Agriculture and Consumer Services. 81 pages.

White, W. B., 1988, Geomorphology and Hydrology of Karst Terrains. Oxford University Press, New York.

Yingling, J. (ed.), 2002, Annotated Nitrate Bibliography. Southwest Florida Water Management District, Brooksville. Prepared for the Nutrient Remediation Workgroup. http://www.swfwmd.state.fl.us/waterres/nrw/Annotated%20Nitrate%20Bibliography.pdf