Florida DEP - Division of Water Facilities

Ground-Water Quality and Agricultural Land Use in the Polk County Very Intense Study Area (VISA)

AMR 1998-2

INTRODUCTION

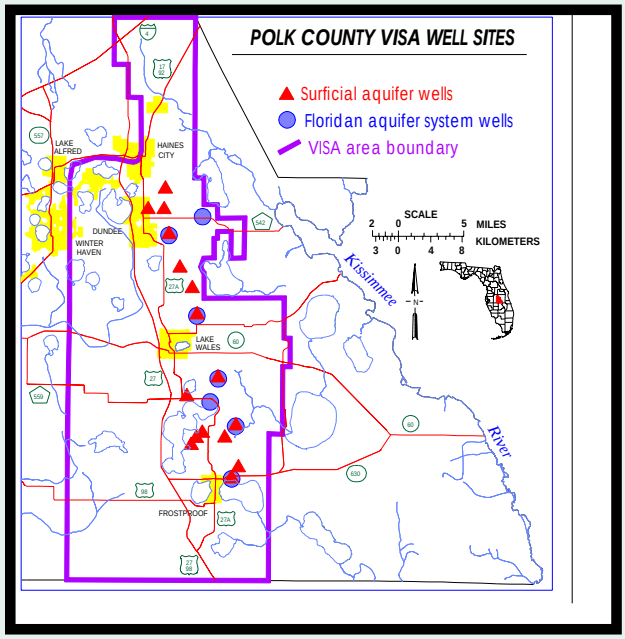
The Very Intense Study Area (VISA) Monitoring Network, established in the late 1980's, was designed to quantify the effects of various land use types on regional (non-point source) ground water quality. These areas were chosen based on 1) predominance of a particular land use type or group, 2) relative aquifer vulnerability, and 3) geographic distribution.

Most of the sampling for the VISA program was performed by Florida's five Water Management Districts, under the direction of the Florida Department of Environmental Protection's (DEP) Ambient Monitoring Program. Standardized procedures were used by all sampling teams to decrease potential sampler-induced variability. A more detailed description of the VISA program can be found in the January issue of the *Ambient Newsletter.*

POLK COUNTY VISA

The Polk County VISA was selected to evaluate the impact of intensive citrus agricultural production on ground water quality in east-central Polk County. The study findings will also help the Florida Department of Environmental Protection (FDEP) predict impacts to ground water in other, similar citrus-producing areas of the state. To document the effects of citrus production on ground water quality, agrichemicals in ground water and general water-quality characteristics were quantified in the VISA wells. These results were then compared with those from background network wells in adjacent areas minimally affected by citrus farming or other human activities. Background network wells, used for the comparison, are not located in citrus groves. The Polk County VISA contains 23 wells *(Figure 1)*. All the VISA wells are located immediately adjacent to, or within citrus groves.

Figure 1 - Polk County VISA



GEOLOGICAL OVERVIEW

Polk County is part of the Central Highlands physiographic province (White, 1970), which is characterized by discontinuous highlands in the form of subparallel ridges separated by broad valleys. The Polk Upland, a broad, approximately square area surrounded on three sides by lowlands and on the eastern side by the higher Lake Wales Ridge, covers most of Polk County. Rising from the Polk Upland are the Winter Haven and Lakeland ridges (White, 1970). Nearly all the county's citrus production occurs on the higher ridges.

The Polk County VISA is located along the Lake Wales Ridge, which forms the eastern boundary of the Polk Upland. The region has three aquifers systems: two are laterally extensive, while the third is not. The uppermost aquifer system—the unconfined, surficial aquifer system—is composed of unconsolidated to poorly indurated siliciclastic deposits, and is generally less than 250 feet thick (Barcelo *et al.,* 1990). The intermediate aquifer system consists of discontinuous, water-bearing beds in the semiconfining Hawthorn Group. The lower potable aquifer, the loridan aquifer system, is composed of the Suwannee Limestone, the Ocala Limestone, and portions of the Avon Park Formation (limestone) at its base. The thickness of the Floridan can exceed several hundred feet.

In the VISA, the Lake Wales Ridge is characterized by a number of sinkholes that have breached the semiconfining unit. The Southwest Florida Water Management District (SWFWMD) has determined that a continuous intermediate aquifer system does not exist, and the surficial and Floridan aquifer systems are hydraulically connected in much of the VISA area (DeHaven, 1993).

Within the VISA, the surficial aquifer system is used primarily for domestic supply, lawn irrigation, and low-volume agricultural irrigation. The intermediate aquifer system, where present, is used for domestic supply. The most important aquifer, the Floridan, supplies nearly all the water used by municipalities and for citrus irrigation.

In general, the surficial aquifer system is highly susceptible to contamination, as derived from DRASTIC aquifer vulnerability methodology (Aller et al, 1985). This is mainly because of its high recharge rates and the unconfined conditions. The VISA contains 17 surficial-aquifer system wells.

The vulnerability indices for the Floridan aquifer system generally fall within the low-to-moderate range because of greater ground water depths and the partial confinement of the aquifer (Gilboy, 1988). However, the Floridan is threatened because it directly connects through active and buried sinkholes to the surficial aquifer. Furthermore, because DRASTIC methodology does not take into account karst conditions, vulnerability may be understated. The VISA contains 7 Floridan aquifer system wells.

AGRICULTURE IN THE VISA

Polk County has long been a large agricultural producer. Until about 1890, the major crops included corn, sweet potatoes, rice, and sugar cane. With the development of commercial fertilizers and better transportation facilities, agricultural production shifted to citrus after 1890 (Fowler, 1927). The area still produces other crops, including a wide variety of vegetables and other fruits, but these have always been secondary to citrus. By 1924 Polk County had nearly 4.3 million citrus trees, half of which were fruit bearing (Fowler, 1927). This number had increased to over 8 million by 1954 (Stewart, 1966). As the first selection criterion, the SWFWMD decided that citrus agriculture is, and has been, a major land use in the county. In January 1990, Polk County contained 86,882 acres of citrus groves alone (Florida Agricultural Statistics Service, 1990), which was then the second highest acreage per county in the state and the highest in the SWFWMD. Figure 2 shows the extent of citrus agriculture within the county.

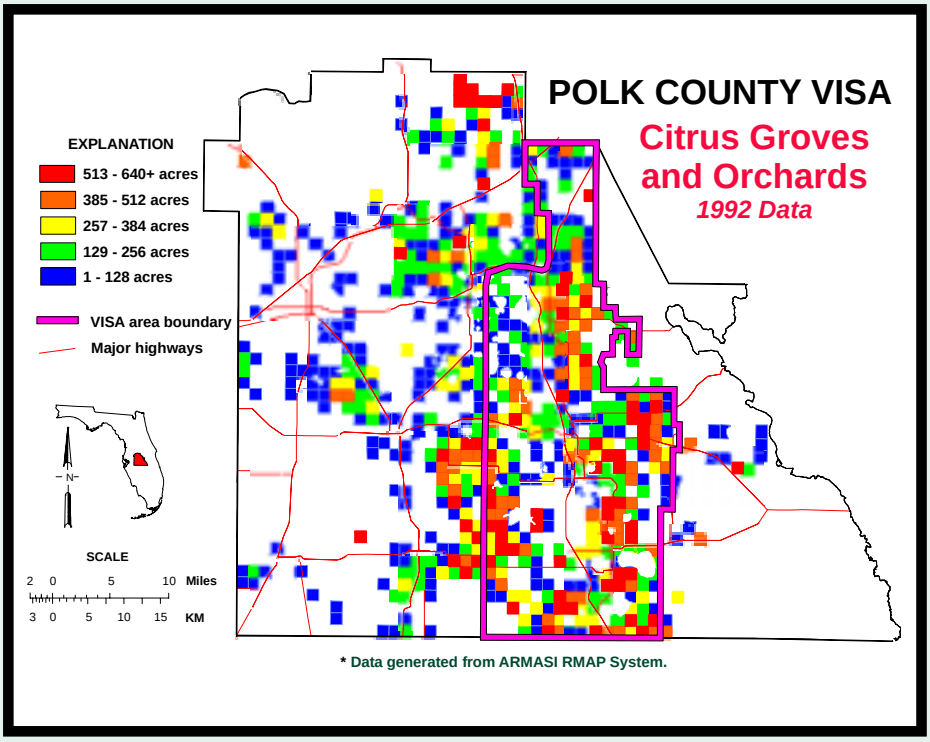
Citrus production is concentrated on the ridges in Polk County—and especially on the Lake Wales Ridge—for many reasons. One primary factor is that the upper parts of the ridges stay warmer than the valleys during freezes or frosts because cold air is heavier than warm air. This is important because citrus trees and fruit are very susceptible to cold damage.

Soils on the ridges are also suited to citrus growing. In general, they are made up of strongly acidic, fine sands; the most common and important types are Norfolk fine sand and Norfolk sand. The Norfolk soils are mainly composed of loose sands ranging in thickness from about 4 to 6 feet. Blanton fine sands, found at lower elevations on the ridges, are also loose but thicker than Norfolk soils, ranging from 5 to 10 feet thick. They are the most highly prized citrus-growing soils because of their excellent aeration and water drainage, with the Norfolk sands more important because they are found at higher elevations on the ridges.

Both soils are depleted in natural plant nutrients and must be heavily fertilized to sustain a healthy citrus crop. Heavy fertilization in citrus groves began at the turn of the century, and in the 1920s, 50 pounds of nitrogen-phospho-rus-potash (3-8-8) fertilizer were applied to each mature tree per year, totaling approximately 54,000 tons countywide. The groves were usually fertilized once in the fall, and then again in February and later in the spring (Fowler, 1927). Common rates of nitrogen application for citrus are estimated at 175 pounds/acre/year (Jones and Upchurch, 1993). Using this rate and the 1990 figure for citrus acreage in Polk County (86,882 acres), a total of about 7,600 tons of nitrogen would be applied as fertilizer in the county per year.

In addition to fertilizers, a variety of pesticides, herbicides, and metal compounds are applied to the land and the citrus trees. Commonly used chemicals include aldicarb, bromacil, chlorpyrifos, copper, diazinon, dicofol, diuron, endosulfan, ethion, fenamiphos, glyphosate, malathion, manganese, metalaxyl, methyl bromide, paraquat, sulfur, and zinc (Knapp, 1983; Haag *et al,* 1996).

Figure 2 - Polk County Land Use



SAMPLING RESULTS

The Polk County VISA was sampled in April 1990, July 1993, and April 1996, for herbicides, pesticides, nutrients, trace metals, and major constituents. Additionally, seven wells were sampled quarterly from January 1994 through January 1995 for selected pesticides, herbicides, and nitrate. Associated sampling of adjacent background wells was done in the month immediately preceding and/or following VISA sampling. Due to funding limitations, pesticides were not analyzed for in the background.

Pesticides

Several insecticides and herbicides were detected in the VISA (Table 1). For the surficial aquifer system, 17 of 17 wells (100%) tested positive for at least one or more of these compounds during the period of study. Bromacil was the most commonly detected compound (94%), followed by simazine (76%), norflurazon (53%), and diuron (53%). Interestingly, these compounds were detected only in 1993-1996 sampling events, and not in the initial 1990 sampling. Instead, the 1990 sampling event revealed trace quantities of chlorinated pesticides, including endosulfan, DDT/DDD, and lindane. Sample analysis for pesticides and herbicides in 1990 was done by a commercial laboratory; the DEP Central Laboratory analyzed all subsequent samples. The change in laboratories may account for the change in pesticide composition; alternatively, changes in pesticide application throughout the VISA area may be responsible.

Insecticides and herbicides were detected in 6 of 7 wells tapping the Floridan aquifer system (Table 1). As with wells of the surficial aquifer system, chlorinated pesticides were detected in the initial sampling; later sampling events were characterized by detections of organophosphorous and organonitrogen pesticides. Generally, concentrations of these compounds were much less than for wells tapping the surficial aquifer system. Decreases in concentration of these compounds in the Floridan are attributed to dilution and dispersion. As mentioned above, the Floridan in the VISA lies unconfined to partially confined below the relatively inert and permeable surficial sediments, allowing surface contaminants more or less direct access to the Floridan aquifer system.

During 1993-1994, sampling of private drinking water wells in Polk and Highlands counties by the Department of Health (formerly Health and Rehabilitative Services) indicated relatively high frequencies of bromacil detections in private drinking water wells, many of which were above the health advisory level (Andrew Reich, DOH, personal communication). This, and evidence from the 1993 Polk County VISA

Table - 1 Insecticide and Herbicide Detections*

surficial aquifer system	# wells sampled	# detected (%)	# exceeds (%)
Aldicarb sulfone	17	4 (23.5%)	0
Aldicarb sulfoxide	17	5 (29.5%)	1 (5.9%)
Atrazine	17	1 (5.9%)	0
Gamma BHC (Lindane)	17	4 (23.5%)	0
Bromacil	17	16 (94.1%)	3 (17.7%)
DDD (p,p')	17	1 (5.9%)	0
DDT (p,p')	17	4 (23.5%)	0
Dieldrin	17	1 (5.9%)	0
Diuron	17	9 (52.9%)	1 (5.9%)
Endosulfan	17	2 (11.8%)	1 (5.9%)
Endosulfan sulfate	17	1 (5.9%)	1 (5.9%)
Fenamiphos	17	1 (5.88%)	0
Metalaxyl	17	4 (23.5%)	0
Norflurazon	17	9 (52.9%)	0
Propoxur	17	1 (5.9%)	1 (5.9%)
Simazine	17	13 (76.5%)	1 (5.9%)
Floridan aquifer	**# wells sampled**	**# detected (%)**	**# exceeds (%)**
1,2-Dibromoethane (EDB)	7	2 (28.6%)	2 (28.6%)
Gamma BHC (Lindane)	7	2 (28.6%)	0
Bromacil	7	4 (57.1%)	0
DDT (p,p')	7	1 (14.3%)	0
Dieldrin	7	1 (14.3%)	0
Endosulfan	7	1 (14.3%)	1 (14.3%)
Endosulfan sulfate	7	3 (42.9%)	3 (42.9%)
Metalaxyl	7	1 (14.3%)	0
Norflurazon	7	2 (28.6%)	0
Simazine	7	1 (14.3%)	0

* Raw data are available upon request.

documenting the occurrence of bromacil in the Floridan aquifer system, resulted in the withdrawal of bromacil for use on ridge type soils in Florida. Levels of bromacil in the surficial aquifer system appear to hav attenuated between 1993 and 1996 (Table 2), perhaps in response to decreased application or perhaps due to degradation of parent product. With only two sample periods, additional monitoring of the VISA is needed to determine if bromacil concentrations are in fact decreasing.

Table 2 - Surficial Aquifer Bromacil Concentrations (µg/L)

Project Description	No. Stations	Minimum Value	Lower Quartile	Median Value	Upper Quartile	Maximum Value
1993 Polk VISA	17	0.1500	19.0000	32.0000	60.0000	130.0000
1996 Polk VISA	16	0.1400	4.5000	18.0000	38.0000	130.0000

Nitrate (NO_3 + NO_2, mg/L as N) -Surficial aquifer system

Surficial nitrite plus nitrate concentrations measured from the VISA were compared to those from nearby background wells using the two-sample Mann-Whitney test. Median values and test results are shown in Table 3. As can be seen from the table, concentrations of nitrate in VISA (citrus) wells are significantly higher than those from adjacent background (non-citrus) wells. Furthermore, median nitrate concentrations for each of the VISA sampling events are substantially above the drinking water standard of 10 mg/L, indicating widespread nitrate contamination in ground water underlying the citrus-growing areas of the Lake Wales Ridge. Tihansky and Sacks (1997), using isotopic studies combined with land-use analysis, concluded that the nitrate in shallow ground water wells in citrus areas is of inorganic (fertilizer) origin. In addition, they found that citrus land-use areas have higher concentrations of nitrate than undeveloped or residential land-use areas, further supporting the VISA findings.

To determine if median nitrate concentrations in the surficial aquifer system underlying the Polk VISA were changing over the study period, a Kruskal-Wallace test (a multi-sample equivalent to the Mann-Whitney test) was done (Table 4). This test failed to reject the null hypothesis that median concentrations from the three sampling events were equal (P=0.319), indicating that from 1990 to 1996, median nitrate concentrations in the Lake Wales Ridge area have not changed significantly. This conclusion is illustrated by a plot of nitrate concentrations over the time period for a subset of surficial aquifer system VISA wells which, in addition to the regularly scheduled VISA projects, were sampled quarterly from 1994 - 1995 (Figure 3). As can be seen from the plot, nitrate concentrations for the wells, although somewhat variable, remain above the drinking water standard during the entire period of observation.

In the previous issue of the Ambient Newsletter (1998:1-2), nitrate results from the Lafayette County VISA were presented, and demonstrated to also be significantly greater than background conditions. To determine if nitrate levels in the Polk County VISA were greater than those from the Lafayette County VISA, a Mann-Whitney test was run (Table 5). This test rejected the null hypothesis of equal medians, concluding that nitrate levels from the Polk VISA were from 4-20 mg/L higher than those from the Lafayette VISA.

Table 3 - NO_3 + NO_2 (mg/L as N) VISA vs Background

1990	# Wells	Median	P	Conclusions
VISA	17	20		
Background	NOT AVAILABLE			VISA > Background
1993	**# Wells**	**Median**	**P**	**Conclusions**
VISA	17	20		
Background	12	0.07	0.0000	
1996	**# Wells**	**Median**	**P**	**Conclusions**
VISA	15	17		
Background	13	0.08	0.0000	VISA > Background

Table 4
Surficial aquifer NO_3+NO_2 (mg/L as N) Test for difference over time

Sampling Date	Number of Wells	Median Value
July 1990	16	15.0000
April 1993	17	20.0000
April 1996	15	18.0000
p=0.332 1990=1993=1996		

Figure 3 - Nitrate concentration over time

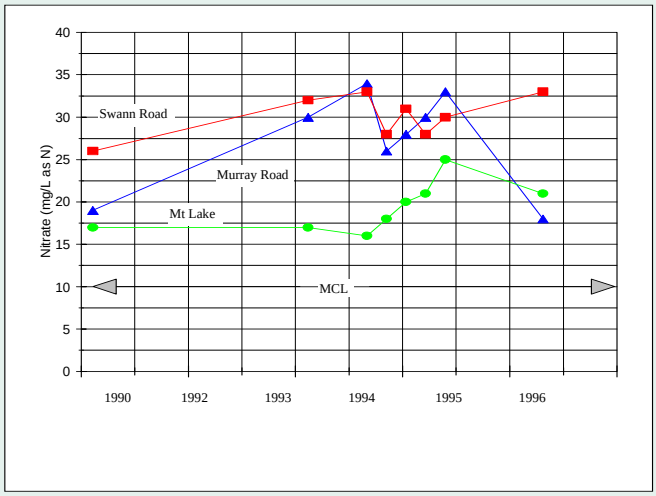


Table 5 - $NO_3 + NO_2$ (mg/L as N) Polk surficial vs Lafayette Floridan

VISA	# of samples	Median	P	Conclusion
Polk	49	17.0		
Lafayette	77	1.2	0.0000	Polk > Lafayette
H_0: Polk = Lafayette -- H_A: Polk > Lafayette				

Table 6 - VISA vs Background Floridan aquifer system

1993	# Wells	Median	P	Conclusions
VISA	7	0.23		
Background	15	0.07	0.0781	VISA = Background
1996	**# Wells**	**Median**	**P**	**Conclusions**
VISA	7	0.49		
Background	10	0.02	0.2168	VISA = Background
H_0: VISA = Background -- H_A: VISA > Background				

A variety of factors could be responsible for this difference.
1) Although land-use in both VISAs is categorized as agricultural, land use in the Lafayette VISA is primarily dairy, pasture, and poultry, in contrast to the citrus groves of the Polk VISA. The difference in land use results in different amounts, rates, and chemical forms of nutrient application.
2) Differential vegetative uptake of available nitrogen may influence the amount of nitrate available for infiltration.
3) The Lafayette VISA consists of well-developed soils overlying a carbonate aquifer while the Polk VISA consists of sandy soils overlying well-drained sandy sediments. These geological differences influence infiltration and subsequent movement of nitrate through the aquifers.
4) Differential denitrification in these unconfined aquifers could also account for observed differences in nitrate concentrations. Denitrification has been suggested as an important mechanism in removing nitrate from the shallow Floridan aquifer system underlying the Lafayette VISA area (Katz et al 1997). In contrast, the well-oxygenated water of the surficial aquifer system underlying the Polk VISA has been suggested to inhibit denitrification processes inthis area (Tihansky and Sacks 1997).

Nitrate ($NO_3 + NO_2$, mg/L as N) - Floridan aquifer system

Nitrate plus nitrite concentrations measured from Floridan wells were also compared, using the two sample Mann-Whitney test, to those from nearby background wells of the same aquifer system. Median values and test results are shown in Table 6. Although median nitrate concentrations in the Floridan wells increased two-fold from 1993 to 1996, in neither case was there a significant difference (a = 0.05) between the VISA and background wells. Only one VISA well from the Floridan aquifer system had above-standard concentrations of nitrate; the remainder were below 10 mg/L.

Major Constituents & Field Measurements

Specific conductance and pH, along with major cations and anions, were also analyzed during each VISA sampling event. In Florida, ground water of the surficial aquifer system is typically low in dissolved solids. As ground water evolves along the typical flow path, it becomes enriched in dissolved solids, a consequence of chemical weathering of aquifer material (Freeze and Cherry, 1979). As a result, ground water of the intermediate and Floridan aquifer systems has a higher dissolved solids content than that generally found in the surficial aquifer system (Maddox et al 1992).

Data from the Polk County VISA indicate this pattern is actually reversed. Wells tapping the surficial aquifer system have a median specific conductance (indicative of dissolved solids content) nearly twice that of wells tapping the underlying upper Floridan aquifer (Table 7). This reversal of the natural geochemical signature is probably a consequence of heavy irrigation with deep Floridan water. Evaporation/transpiration processes further enrich the irrigation water in dissolved solids, prior to infiltration into the permeable surficial sands. This heavy irrigation likely works to enhance recharge to the Floridan from the overlying surficial aquifer system, creating an irrigation-driven circulation of contaminant-laden water from the surficial aquifer system into the upper units of the Floridan aquifer system.

Table 7 - Major constituents

Parameter Description	Measuring Units	Median Surficial	Median Floridan
Specific Conductance, Field	µS/cm	392.0000	203.0000
Calcium, Dissolved	mg/L	28.0000	19.0000
Chloride, Dissolved	mg/L	20.5000	9.3000
Magnesium, Dissolved	mg/L	13.0000	5.9000
Potassium, Dissolved	mg/L	13.0000	2.4000
Sulfate, Dissolved	mg/L	41.0000	3.2000

CONCLUSIONS

Ground water within the Polk County VISA has been found to be contaminated by herbicides, pesticides, and nitrate. Pesticide concentrations were found to exceed ground water guidance concentrations in 48% of VISA wells. Nitrate concentrations within the VISA area are generally above the standard and significantly above background, and do not appear to be changing over time. These problems are associated with intense agricultural land use, combined with relatively vulnerable ground water resources.

The extent of pesticide and nitrate contamination in the Polk County VISA underscores the need for development and implementation of pesticide and fertilizer best management practices. According to Mike Thomas, a professional engineer with the Stormwater/ Nonpoint Source Management Section of DEP, best management practices for fertilization in the ridge area are currently under development. However, interim measures to reduce nitrogen inputs were placed into rule in 1996 (DACS 5E-1.023). Although adoption of these measures by citrus growers is voluntary, incentives are in place to encourage their use. Continued monitoring of the Polk County VISA could prove useful in evaluating the effectiveness of best management practices in reducing agricultural contamination of ground water.

The data used in the generation of this report are availble from the "Ambient Home Page", or by contacting the Ambient Monitoring Section at 850/921-9427.

Florida Department of Environmental Protection - Divisiuon of Water Facilities
Ambient Monitoring Program

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