WATER-QUALITY AND HYDROLOGY OF THE HOMOSASSA, CHASSAHOWITZKA, WEEKI WACHEE, AND ARIPEKA SPRING COMPLEXES, CITRUS AND HERNANDO COUNTIES, FLORIDA

- ORIGIN OF INCREASING NITRATE CONCENTRATIONS -

Ambient Ground-Water
Quality Monitoring Program,

Southwest Florida Water Management District

October, 1997

=============================

Authors

Gregg W. Jones	Manager, AGWQMP
Dr. Sam B. Upchurch	ERM-South
Kyle M. Champion	Hydrologist, AGWQMP
David J. Dewitt	Professional Geologist, AGWQMP

Contributors

Edwin J. Miller	Water Resource Technician
Eric C. DeHaven	Professional Geologist
Roberta Starks	Environmental Scientist
Chris Tomlinson	Water Resource Technician
Jason Hood	Water Resource Technician
Chris Anastasiou	Water Resource Technician
Lisa Dejongh	Water Resource Technician

EXECUTIVE SUMMARY

1. Thirty springs in the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring Complexes, located in the area from central Citrus to northern Pasco Counties, were investigated for evidence of deteriorating water quality during a period from 1993 to 1997. The quality of ground water in a large portion of the recharge area of the spring complexes was also investigated by analyzing water samples from 121 monitor wells.

2. Water discharges from the 30 springs in the four spring complexes at the total rate of approximately 900 cubic feet per second (cfs). This is equivalent to approximately 580 million gallons per day (mgd).

3. Water discharging from springs in the four complexes originates in four separate ground-water basins that encompass a total of 1,600 square miles. Individually, the ground-water basins for the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring Complexes encompass 960, 190, 390, and 60 square miles, respectively.

4. The chemistry of water discharging from the springs in the four complexes indicates that the water has moved through relatively short, shallow flow systems. That is, the water has probably not been in the aquifer for more than a few decades at most.

5. Much of the water discharging from the springs may have traveled rapidly through the Floridan aquifer in fractures, which are conduits in the limestone where large amounts of ground water can be transported to the springs.

6. The chemistry of ground water in the study area is affected by a number of geologic, hydrologic, atmospheric, and anthropogenic factors. These include 1) the thickness of Hawthorn Group clays in the Brooksville Ridge, 2) major sinkhole features, 3) the fresh-water/salt-water transition zone along the coast, 4) Lake Tsala Apopka, 5) the chemistry of rainfall, 6) the presence of extensive agricultural and urban development, and 7) the presence of large limestone quarries northwest of Brooksville.

7. Data collected as part of the study, as well as historic data collected by other agencies, indicate that nitrate concentrations have been steadily increasing in the springs since the late 1960's. The mean nitrate concentration of the Weeki Wachee Main Spring, the largest spring in the complexes in terms of discharge, is 0.53 mg/l. This is over 50 times higher than background levels (< 0.01 mg/l).

EXECUTIVE SUMMARY (continued)

8. Approximately 360 tons of nitrate as N is contained each year in ground water discharging from the springs in the four spring complexes.

9. Nitrate concentrations were evaluated in the 121 wells sampled in the four ground-water basins. Five percent had concentrations that exceeded 2.5 mg/l, 9 percent had concentrations between 1.0 and 2.5 mg/l, 12 percent had concentrations between 0.5 and 1.0 mg/l, 37 percent had concentrations between 0.1 and 0.5 mg/l, 17 percent had concentrations between 0.01 and 0.1 mg/l, and 20 percent had concentrations below the detection limit (0.01 mg/l). These figures indicate that the portion of the study area where nitrate is significantly elevated above naturally occurring levels (<0.01 mg/l) is extensive. No samples met or exceeded the 10 mg/l (as N) drinking water standard.

10. Fourteen sources of nitrate were investigated in the study area. These include: 1) naturally occurring organic decay, 2) rainfall, 3) residential turf/landscape fertilization, 4) golf course turf fertilization, 5) sewage effluent disposal, 6) land disposal of sewage sludge, 7) effluent from septic tanks servicing residential and commercial development, 8) land disposal of septage sludge, 9) row crop fertilization, 10) citrus fertilization, 11) pasture fertilization, 12) poultry, 13) dairies, and 14) cattle.

11. Nitrogen isotopic data suggest that the dominant source of nitrate presently discharging in ground water from the springs is inorganic. Organic sources, although regionally less significant, may still elevate nitrate concentrations to high levels on a local scale. Organic sources include: 1) naturally occurring organic decay, 2) sewage effluent disposal, 3) land disposal of sewage sludge, 4) effluent from septic tanks servicing residential and commercial development, 5) land disposal of septage sludge, 6) poultry, 7) dairies, and 8) cattle.

12. Residential and golf course turf/landscape fertilization were identified as the principal source of nitrate in the springs. Supporting data include: 1) the inorganic nature of the source, 2) the close proximity of the source to the springs, and 3) the rapid increase in nitrate concentrations in the springs that began in the late 1960's, which correlates well with the development of the large, coastal, residential subdivisions that contain the largest densities of residential and golf course turf and landscape.

13. There is little that can be done to reduce present nitrogen loading from the springs to the coastal estuaries because that nitrogen has been applied to the study area for many years and is now entrained in the ground-water flow system. Any attempt to reduce nitrate loading in the recharge area may not result in reduced nitrate levels in the springs for a decade or longer.

EXECUTIVE SUMMARY (continued)

14. An investigation of the application of inorganic nitrogen fertilizers in the coastal subdivisions in the study area should be initiated in the near future. The study should focus on identifying the specific areas of application, the amount applied, and the amount of nitrogen reaching ground water following application. The study should also attempt to reduce the use of fertilizers by developing best management practices and by promoting xeriscaping - the replacement of turf with native species of plants that require less fertilizer and water.

15. The importance of sources, such as residential and golf course turf/landscape fertilization, septic tank effluent, and sewage effluent disposal will greatly increase as rapid residential and commercial development proceeds in the study area. It is therefore, extremely important that best management and alternative landscape practices be developed that reduce the use of fertilizer. Waste disposal practices that are compatible with the region's karst geology and its accompanying extreme vulnerability to ground-water contamination must also be implemented. These practices include:

    a. Avoidance of high-densities of septic systems.
    b. Planning for the development of centralized, advanced waste-water treatment (AWT) systems.
    c. More stringent design, construction, and monitoring of large-scale percolation or spray field systems. These systems should stay on line only until it is feasible to construct the centralized AWT systems.
    d. Proper storage and treatment of storm water.

16. The springs should continue to be sampled quarterly for nutrients, major analytes, and trace organics and annually for nitrogen-isotopic ratios to determine the effects of changing land use and to determine the effectiveness of remedial efforts.

17. The District should work with Citrus, Hernando, and Pasco Counties and other interested agencies to formulate land-use plans that would minimize additional nitrogen loadings to the study area.

TABLE OF CONTENTS

INTRODUCTION . . . 1

DESCRIPTION OF THE STUDY AREA . . . 5
GEOGRAPHIC SETTING, TOPOGRAPHY, AND DRAINAGE . . . 5
LAND USE . . . 7
GEOLOGY . . . 11
GROUND-WATER HYDROLOGY . . . 15

DESCRIPTION OF SPRING COMPLEXES IN THE STUDY AREA . . . 27
HOMOSASSA SPRING COMPLEX . . . 27
CHASSAHOWITZKA SPRINGS COMPLEX . . . 32
WEEKI WACHEE SPRING COMPLEX . . . 36
ARIPEKA SPRINGS COMPLEX . . . 41

STUDY DESIGN, METHODS, AND DATA COLLECTION . . . 45
DELINEATION OF THE STUDY AREA . . . 45
STUDY-AREA WIDE MONITOR-WELL NETWORK . . . 47
WATER QUALITY SAMPLING OF MONITOR WELLS AND SPRINGS . . . 49
CHARACTERIZATION OF THE FLOW SYSTEM . . . 50

GROUND-WATER CHEMISTRY: STUDY AREA . . . 53
CONCEPTUAL MODEL . . . 53
HYDROCHEMICAL FACIES . . . 55
MAJOR ANALYTES . . . 56
NITROGEN GEOCHEMISTRY . . . 66
ADDITIONAL NUTRIENTS AND IRON . . . 73

GROUND-WATER CHEMISTRY: SPRING COMPLEXES . . . 79
HYDROCHEMICAL FACIES . . . 79
MAJOR ANALYTES, NITROGEN SPECIES, ADDITIONAL NUTRIENTS, AND IRON . . . 81

GROUND-WATER CHEMISTRY: ISOTOPIC CONTENT . . . 91
URANIUM . . . 91
NITROGEN . . . 92
TRITIUM . . . 97

NITROGEN LOADING OF THE GROUND-WATER SYSTEM . . . 99
NATURALLY OCCURRING ORGANIC DECAY . . . 99

TABLE OF CONTENTS (continued)

RAINFALL 99
GOLF COURSES 100
TURF/LANDSCAPE FERTILIZATION 102
SEWAGE TREATMENT PLANTS 103
SEPTIC TANKS 113
AGRICULTURE 118
STORM-WATER RUNOFF 125

NITROGEN LOADING SUMMARY 129
DOMINANT SOURCE CRITERIA 129
EVALUATION OF SOURCES 131

CONCLUSIONS 133

RECOMMENDATIONS 137

REFERENCES CITED 139

APPENDICES 149

LIST OF FIGURES

Figure		Page No.
1	Location of the Major Spring Complexes and the portion of their Ground-Water Basins Located within the Study Area.	2
2	Nitrate Concentrations from Samples Collected between 1946 and 1997 in the Homosassa, Chassahowitzka, and Weeki Wachee Main Springs.	3
3	Physiographic Provinces in or near the Study Area.	6
4	Land Use in the Study Area (1990).	9
5	Geologic Map Showing Stratigraphic Units at or Near Land Surface.	12
6	North-South and East-West Geologic Cross Sections through the Study Area.	13
7	Thickness of Confining Units in the Study Area.	17
8	Recharge Estimates for Different Physiographic Regions of the Study Area.	19
9	West to East Cross Section through the Salt-Water/Fresh-Water Transition Zone Near Homosassa Springs.	21
10	West to East Cross Section through the Salt-Water/Fresh-Water Transition Zone Near Weeki Wachee Springs.	22
11	Approximate Position of the 250 mg/l Line of Equal Chloride Concentration at a Depth of 100 Feet Below Sea Level in the Upper Floridan Aquifer.	24
12	Generalized Thickness of the Potable Water Zone in the Floridan Aquifer in the Northern Portion of the Southwest Florida Water Management District.	25
13	Monthly Mean Spring Flow of Weeki Wachee Spring, Crab Creek Spring, Bobhill Spring, and Salt Spring, April 1988 through March 1989.	28
14	The Homosassa Spring Complex and Vicinity.	29

LIST OF FIGURES (continued)

Figure		Page No.
15	The Homosassa Spring Cavern System.	31
16	The Chassahowitzka Spring Complex and Vicinity.	34
17	The Weeki Wachee Spring Complex and Vicinity.	38
18	The Twin Dees Cavern System.	40
19	The Aripeka Spring Complex and Vicinity.	42
20	Extent of the Recharge Areas for the Major Spring Complexes in the Study Area and the September 1994 Potentiometric Surface of the Floridan Aquifer.	46
21	Location of Wells Sampled in the Study Area.	48
22	Closed Depression features Greater Than 20 Acres in Area and Selected Fracture Traces in the Study Area.	51
23	Location of Quarries and Areas in the Brooksville Ridge where Hawthorn Clays are Thin to Absent.	54
24	Characterization of Floridan Aquifer Waters from Well Samples Using Piper and Stiff Diagrams.	57
25	Bicarbonate Concentrations in Floridan Aquifer Ground Water.	59
26	Calcium Concentrations in Floridan Aquifer Ground Water.	60
27	pH level in Floridan Aquifer Ground Water.	61
28	Chloride Concentrations in Floridan Aquifer Ground Water.	62
29	Sulfate Concentrations in Floridan Aquifer Ground Water.	64
30	TDS Concentrations in Floridan Aquifer Ground Water.	65
31	Ammonium Concentrations in Floridan Aquifer Ground Water.	70

LIST OF FIGURES (continued)

Figure		Page No.
32	Nitrate Concentrations in Floridan Aquifer Ground Water.	72
33	Total Organic Carbon Concentrations in Floridan Aquifer Ground Water.	74
34	Total Phosphorus Concentrations in Floridan Aquifer Ground Water.	76
35	Iron Concentrations in Floridan Aquifer Ground Water.	77
36	Characterization of Water Discharging from Springs in the Study Area Using Piper and Stiff Diagrams.	80
37	Uranium Isotopic Ratios and Concentrations in Wells and Springs in the Study-Area.	93
38	$\delta^{15}N$ Isotopic Ratios in Wells and Springs in the Study-Area.	95
39	Golf Courses in the Study Area.	101
40	Wastewater Treatment Facilities in the Study Area.	104
41	Sludge Spreading Sites in the Study Area.	112
42	Septic Tank Density per Square Mile in the Study Area.	115
43	Septage Spreading Sites in the Study Area.	117
44	Location of Dairies in the Study Area.	123

LIST OF TABLES

Table		Page No.
1	Generalized Stratigraphic and Hydrostratigraphic Units in the Study Area.	14
2	Discharge Information for Springs in the Homosassa Complex.	33
3	Discharge Information for Springs in the Chassahowitzka Complex.	37
4	Discharge Information for Springs in the Weeki Wachee Complex.	41
5	Discharge Information for Springs in the Aripeka Complex.	44
6	Chemical Analytes Used in the Study.	49
7	Summary of Nitrate Concentrations in Study-Area Wells.	73
8	Analyte Concentration Means at Low Tide for Springs in the Homosassa Complex.	83
9	Analyte Concentration Means at Low Tide for Springs in the Chassahowitzka Complex.	85
10	Analyte Concentration Means at Low Tide for Springs in the Weeki Wachee Complex.	87
11	Analyte Concentration Means at Low Tide for Springs in the Aripeka Complex.	89
12	Wastewater-Treatment Facilities in the Homosassa Springs Ground-Water Basin.	105
13	Wastewater-Treatment Facilities in the Chassahowitzka Springs Ground-Water Basin.	107
14	Wastewater-Treatment Facilities in the Weeki Wachee Springs Ground-Water Basin.	108
15	Wastewater-Treatment Facilities in the Aripeka Springs Ground-Water Basin.	109

LIST OF TABLES (continued)

Table		Page No.
16	Sludge Disposal Information and Nitrogen Loading Estimates for Facilities in the Study Area.	114
17	Septage Disposal Information and Nitrogen Loading Estimates for Facilities in the Study Area.	118
18	Event Mean Nitrogen Concentration and Runoff Coefficient for Important Land Uses in the Study Area.	126
19	Storm-Water Nitrogen Contribution from Four Land Uses in the Study Area.	127
20	Nitrogen Sources, Estimated Quantities Produced, and Effect of Source on Nitrate Concentrations in the Springs.	130

LIST OF APPENDICES

Appendix		Page No.
I	Specifications of Monitor Wells.	149
II	Water Quality Data for Sampled Monitor Wells.	151
III	Water Quality Data for Sampled Springs.	155
IV	Data References for Figure 12; Generalized Thickness of the Potable Water Zone in the Floridan Aquifer in the Northern Portion of the Southwest Florida Water Management District.	163
V	Assumptions and Calculations Used in the Determination of Nitrogen Loading from Pasture Fertilization.	165

INTRODUCTION

This report describes the results of a comprehensive investigation of the water quality of the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring complexes[1] and their recharge areas in Citrus, Hernando, and Pasco Counties (Figure 1). The main emphasis of the report is on the rapidly increasing nitrate concentrations in the springs and the land uses in the recharge areas that are the source of the nitrate. The report also covers the influence of the hydrogeology, rainfall, and the fresh-water/salt-water transition zone on ground-water quality. Finally, the report places considerable emphasis on the structure and function of the karst flow system that conveys ground water to the springs.

Nitrate concentrations have been rapidly increasing in a number of major springs within the Southwest Florida Water Management District (SWFWMD). Jones and Upchurch (1993) showed rapidly increasing, elevated nitrate concentrations (2.0 - 3.0 mg/l) in Lithia and Buckhorn Springs in Hillsborough County resulting from the long-term operation of dairy farms and the cultivation of citrus. Jones *et al.* (1996) showed similar trends with somewhat lower nitrate concentrations (1.0 mg/l) in Rainbow Springs in Marion County resulting from the fertilization of thousands of acres of pasture. Similar increasing trends are evident in the Homossasa, Chassahowitzka, and Weeki Wachee Spring complexes. Figure 2 is a graph of nitrate concentrations (as N) in samples collected between 1946 and 1997 from the Homosassa Main, Chassahowitzka Main, and Weeki Wachee Main Springs. The most dramatic increase in nitrate occurs in Weeki Wachee Main where concentrations have increased from less than 0.02 mg/l in 1946 to 0.52 mg/l in 1994. This represents more than a 25-fold increase. Springs in the Aripeka complex have been sampled very infrequently over the last 50 years and, therefore, do not have sufficient data to indicate increasing trends.

Nitrate concentrations in ground water in undeveloped areas of Citrus, Hernando, and Pasco Counties have been compared with nitrate concentrations in ground water discharging from the springs. These data clearly indicate that the spring-water concentrations exceed natural, background ground-water concentrations. Since enrichment of nitrate to the level that occurs in the spring water is not a result of natural processes, human-induced contamination of the ground water must be occurring somewhere within the recharge area of the springs.

Although the nitrate concentrations (0.18 - 0.62 mg/l) in the coastal springs of Citrus, Hernando, and Pasco Counties are considerably lower than those of Lithia, Buckhorn, and Rainbow Springs, they are still of great concern. This is because even at these low concentrations, water discharging at the rate of approximately 900 cfs from the main

[1]For the purposes of this report, a spring complex is defined as a group of springs, often spread over an area of several square miles, that are discharge points for ground water in a discrete ground-water basin.

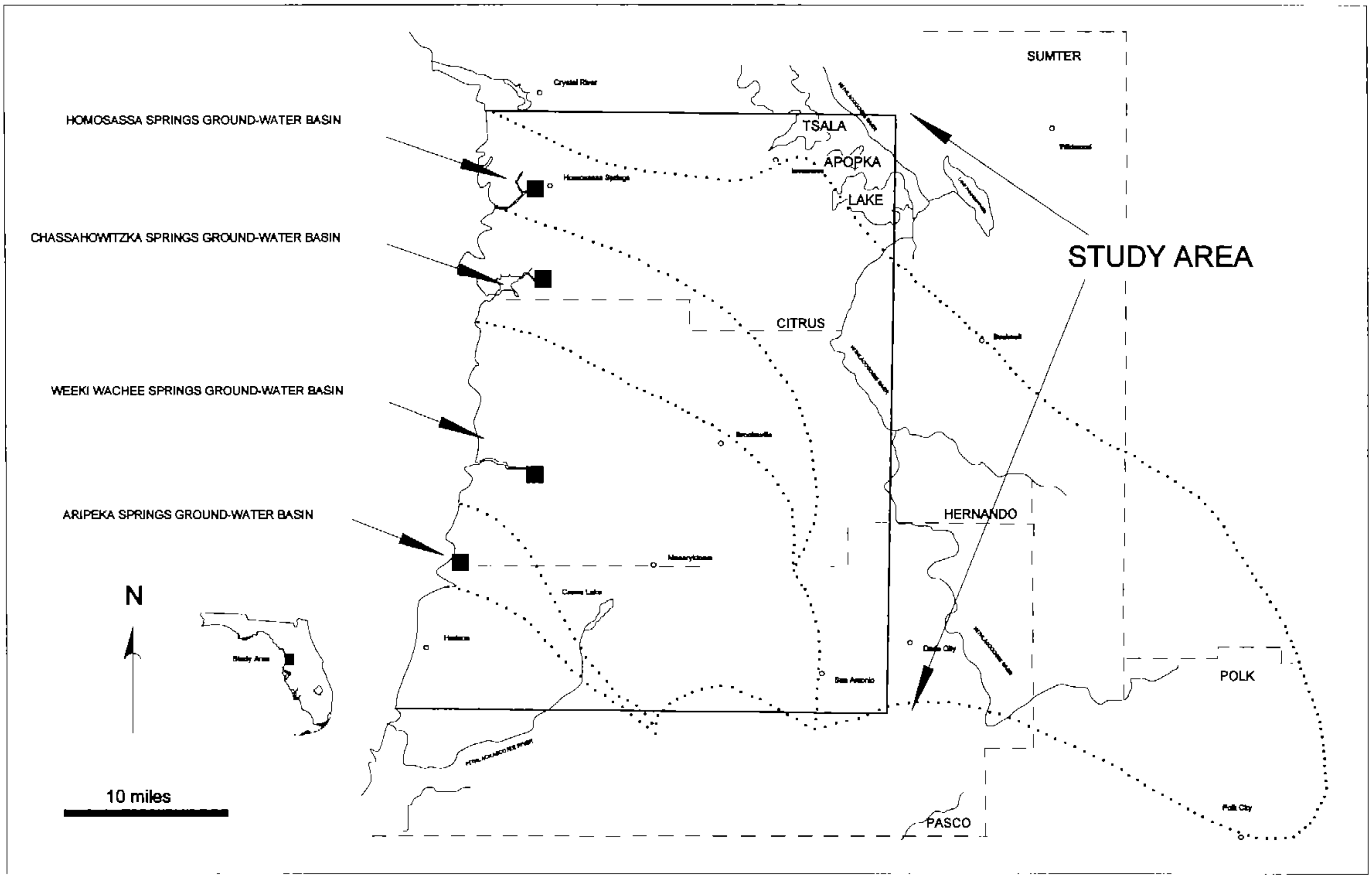


Figure 1. Location of the Major Spring Complexes and the Portion of their Ground-Water Basins Located within the Study Area

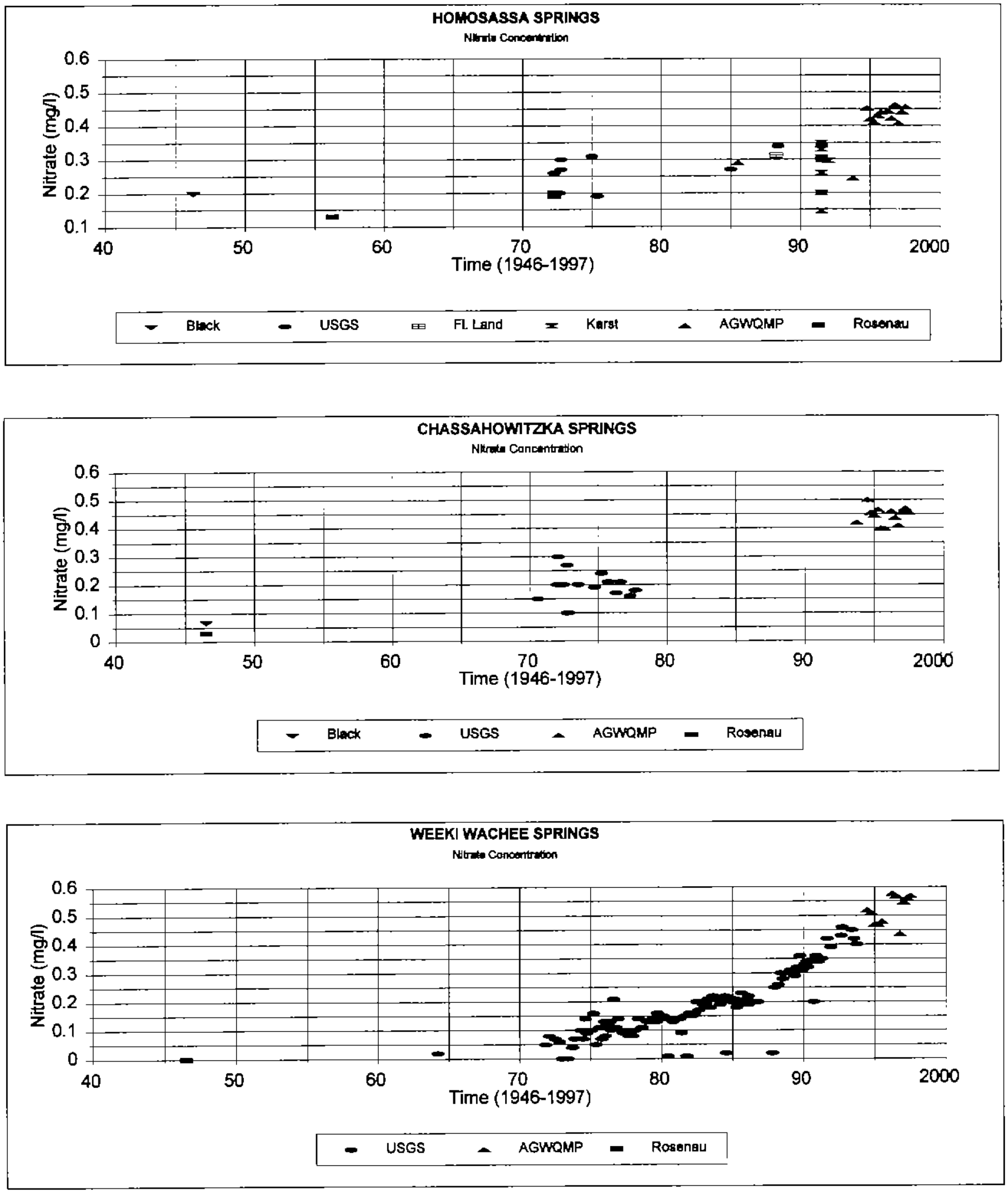


Figure 2. Nitrate Concentrations from Samples Collected between 1946 and 1997 in the Homosassa, Chassahowitzka and Weeki Wachee Main Springs (Black 1951; Rosenau et al., 1977; Florida Land Design and Engineering, 1989; Karst Environmental Services 1992; U.S. Geological Survey, 1994).

springs and smaller surrounding springs contains an annual nitrate load of over 360 tons. This nitrate is rapidly delivered by the coastal rivers to the extensive estuaries along the Gulf Coast. The effect of this quantity of a limiting nutrient on the aquatic vegetation in the estuaries has not been quantified. However, it is highly likely that as nitrate concentrations continue to increase, algae blooms will increase in frequency and duration. This will result in a decline in the diversity of other aquatic plant and animal species as the algae blooms deplete oxygen and block sunlight.

Although there are a great many additional springs in coastal Citrus, Hernando, and Pasco Counties that are discharging nitrate-enriched water, the magnitude of their cumulative discharge may be small enough to discount the nitrate load they produce.

With the goal of preventing deterioration of the water quality of the estuaries in Citrus, Hernando, and Pasco Counties, the Withlacoochee and Coastal Rivers Basin Boards of the SWFWMD authorized an investigation to determine the sources of the increasing nitrate. The investigation, which began in January of 1994 and lasted three years, was carried out by the Ambient Ground-Water Quality Monitoring Program (AGWQMP) of the SWFWMD. The scope of the investigation involved delineating the areas where nitrate is entering the aquifer system, identifying the land uses that are contributing the nitrate, and determining what can be done to slow or reverse the nitrification of ground water in the area.

DESCRIPTION OF THE STUDY AREA

The study area encompasses a large portion of the ground-water basins that contribute recharge to the coastal spring complexes in portions of coastal Citrus, Hernando, and Pasco Counties. The following sections explain the geographic setting, topography, and drainage; the spring systems; geology and hydrogeology, including karst and land uses in the study area.

GEOGRAPHIC SETTING, TOPOGRAPHY, AND DRAINAGE

The study area is located on the coast of west-central Florida and includes the southern half of Citrus County, the western two thirds of Hernando County, and the northern third of Pasco County (Figure 1). Land surface elevations range from sea level along the coast to heights of over 250 feet above NGVD along the crest of the Brooksville Ridge.

White (1970) delineated five major physiographic features in Citrus, Hernando and Pasco Counties, four of which lie within the study area. These include the Coastal Swamps, the Gulf Coastal Lowlands, the Brooksville Ridge, and the Tsala Apopka Plain (Figure 3). The physiographic areas are primarily a function of topographic relief and underlying sediments. The following is a brief discussion of each area.

The Coastal Swamp area parallels the coast and extends inland from two to five miles. It is characterized by both tidal marshes and coastal swamps. Elevations are less than ten feet, and poorly drained, organic soils directly overlie limestones of the Floridan aquifer system in much of the coastal swamp area.

The Coastal Lowlands lie between the Coastal Swamp and the Brooksville Ridge and range from about two to eight miles in width. Elevations range from sea level to about 100 feet above NGVD. The topography consists of relatively flat plains to rolling hills. The hills are made up of aeolian sand dunes.

The Brooksville Ridge trends northwest-southeast through the central part of Citrus County and eastern Hernando and Pasco Counties. The Brooksville Ridge measures approximately 17 miles in width in central Hernando County and reaches its southern terminus in northeastern Pasco County. Sediments comprising the Brooksville Ridge are remnant Mio-Pliocene marine deposits that have been modified by sub-aerial erosion, karst processes, and subsequent formation of marine terraces (White, 1970; Healy, 1975). Elevations along the ridge range from 70 to about 275 feet above NGVD. The margins of the ridge are characterized by deep, sandy soils, while the ridge interior contains a mixture of poorly to well-drained sandy-clayey soils. The entire Brooksville Ridge area is underlain by a clayey unit that varies between 10 and 30 feet in thickness but allows good hydraulic connection to the underlying Floridan aquifer system through karst features and fractures.

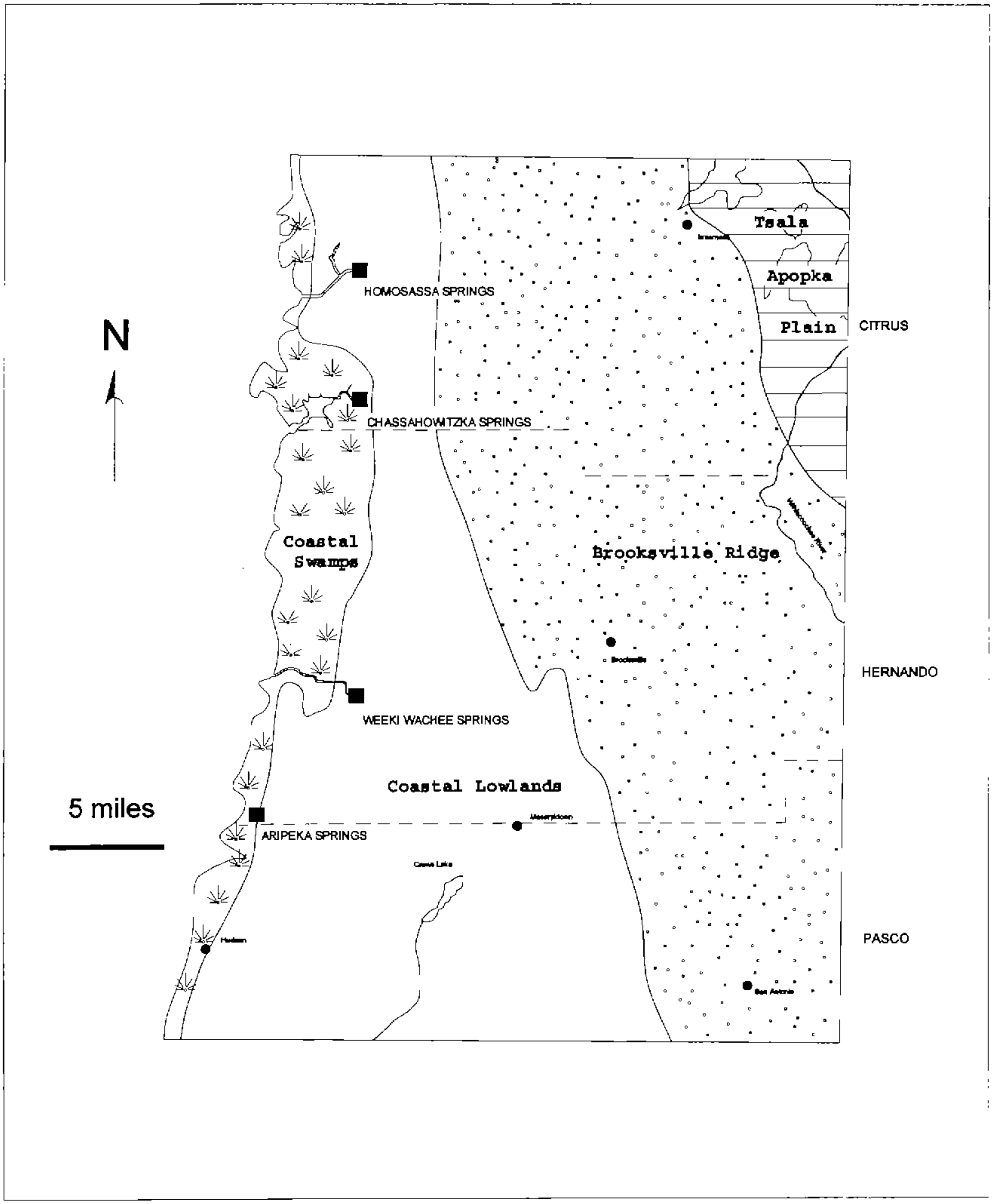


Figure 3. Physiographic Provinces in or near the Study Area (Modified from White, 1970).

The ridge has an irregular surface due to karst activity (Vernon, 1951) and elevations may vary more than 100 feet over short distances.

The Tsala Apopka Plain lies between the Brooksville Ridge and the Withlacoochee River. It has a large number of interconnected lakes that are divided by peninsulas and islands. Siliciclastic deposits cover the limestone surface and elevations range from 35 to 75 feet above NGVD. The soils are generally sandy and weakly cemented with organic matter.

The main surface drainage features in the study area are the Withlacoochee, Homosassa, Chassahowitzka, and Weeki Wachee Rivers. The Withlacoochee River originates in the Green Swamp, southeast of the study area, and flows northwest to the Gulf of Mexico near Yankeetown in Levy County. The Homosassa, Chassahowitzka, and Weeki Wachee Rivers are located in the coastal portion of the study area. Because the source of these latter three rivers is a major spring, the flow of these rivers, prior to mixing of sea water moving upriver under the influence of tides, is predominantly ground water.

The lack of rivers and streams in the interior of the study area results from a well-developed underground drainage system in the limestone that underlies the study area. Precipitation falling on the Brooksville Ridge rapidly moves underground through numerous sinkholes and begins moving seaward through an extensive system of conduits.

LAND USE

Land use in the study area was determined from detailed analysis of aerial photography flown in 1989-91 (Figure 4). Despite a great deal of growth in the last 30 years, the counties still retain a rural character. Covered by coastal swamps, dense woodlands, lakes, and pastures, the counties are rapidly changing as residential development expands.

The northern portion of the study area is dominated by low- to medium-density residential and commercial land use, considerable livestock pasturage and extensive upland forest, and coastal wetlands. The extreme western portion of this area is characterized by sparsely populated coastal swamps and wetlands (mostly owned by the State and Federal governments). Residential and commercial development along U.S. Hwy 19 has been concentrated in a narrow corridor between the coastal swamps and the upland forest of the Brooksville ridge. The Withlacoochee State Forest represents much of this upland forest; it is regularly logged and virtually uninhabited. Northeast of the forest, the City of Inverness supports a large residential community, commercial development and recreational land uses. The extreme eastern portion of the area, dominated by lakes and wetlands of the Tsala Apopka plain, contains scattered row and tree crops, pasture, and some minor residential and commercial land use.

1990 Land Use map figure foldout extracted

The central portion of the study area, while still relatively rural, contains a number of rapidly growing communities. These communities are characterized by dense residential and commercial development, and several golf courses. In the vicinity of Spring Hill and Weeki Wachee, residential development occupies a large portion of the area between U.S. Hwy 19 and the Brooksville ridge, particularly along Hwy 50 and Hwy 574. Pasture and forest, on the other hand, are prevalent over the central and eastern portions of the area. The City of Brooksville lies in the center of the area and is characterized by residential and commercial land uses. Mining for limestone aggregate is a major land use northwest of the City of Brooksville, and a small segment of the Withlacoochee State Forest occurs in the extreme eastern portion of the area in the vicinity of Croom.

The southern portion of the study area contains widespread residential and commercial development, pasture, forest, and wetlands. The extreme western portion of the area is characterized by coastal hardwood forests and coastal swamps. The U.S. 19 area contains medium-density residential communities and commercial developments, and scattered forests. The central portion of the area contains pasture, forest, open land, and numerous lakes and wetlands. The eastern portion of the area contains a great deal of pasture, some forest, lakes, and scattered row and tree crops.

It is important to note that within the entire study area there has been a very pronounced increase in both on-site sewage treatment (septic tank/drain field facilities) and of sewered communities in a relatively short period of time.

GEOLOGY

Figure 5 is a geologic map showing stratigraphic units at or near land surface and Figure 6 depicts north-south and east-west geologic cross sections through the study area. Table 1 contains the generalized hydrogeology of the northern SWFWMD area. It is apparent from the figures that the geology of the study area is relatively simple. Thick sequences of limestone are exposed at or very near (10 to 20 feet) the land surface in the eastern and western portions of the study area. Where limestone is near land surface, the thin veneer of sediment that covers the limestone consists of Quaternary-age, unconsolidated to poorly-indurated siliciclastic deposits dominated by quartz sand. These sands are primarily marine terrace deposits and coastal dune trains. Dunes are prevalent in the Coastal Lowlands and along the flanks of the Brooksville Ridge.

The limestone units include the Suwannee Limestone of Oligocene age and the Ocala Limestone of Eocene age. Underlying these exposed limestone units is the Avon Park Formation of Eocene age. The Avon Park Formation is the deepest formation containing potable water. The Suwannee and Ocala Limestones and the Avon Park Formation comprise the Floridan aquifer in the study area.

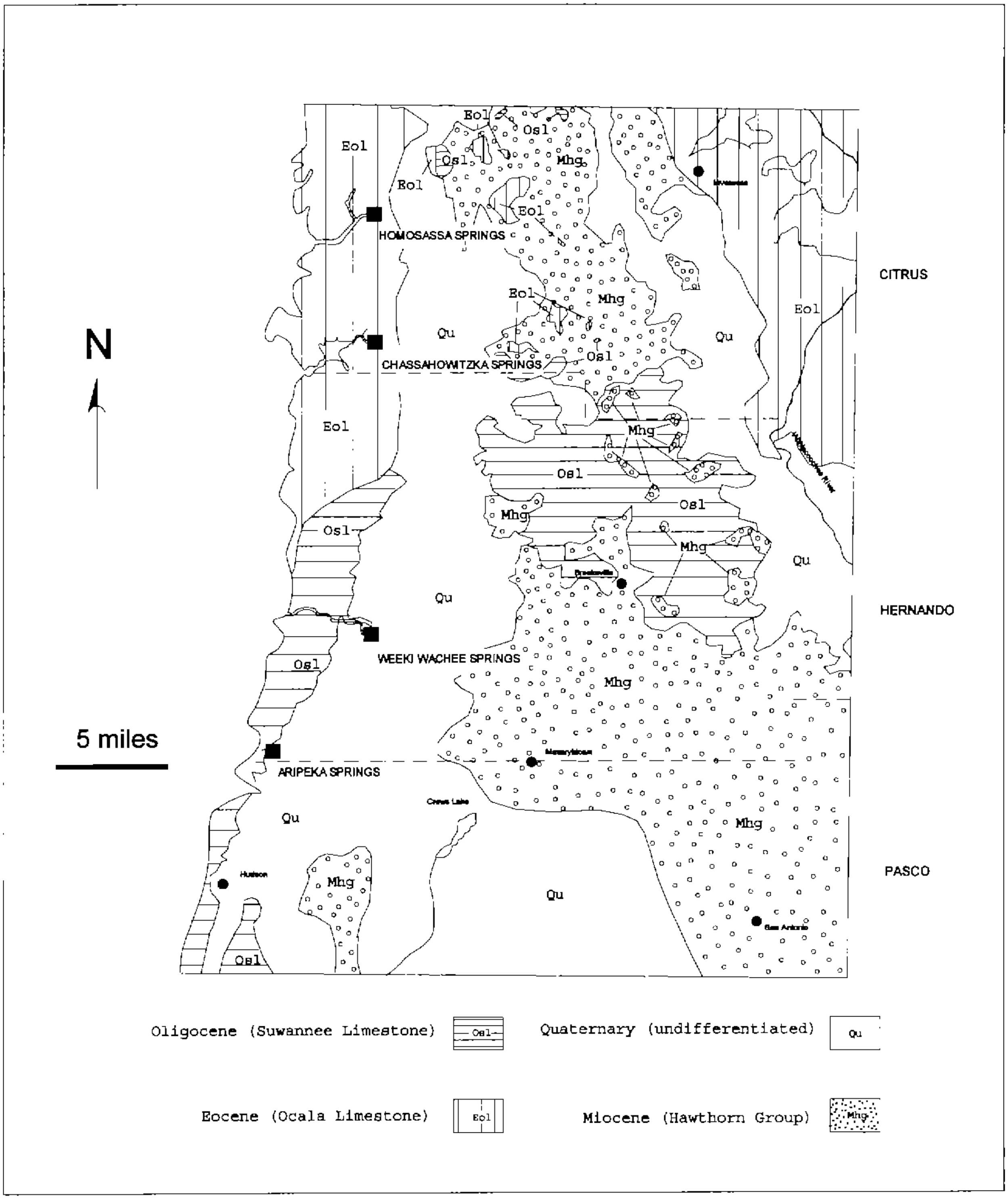


Figure 5. Geologic Map Showing Stratigraphic Units at or Near Land Surface (Modified from Campbell and Scott 1992, 1993; Arthur 1993).

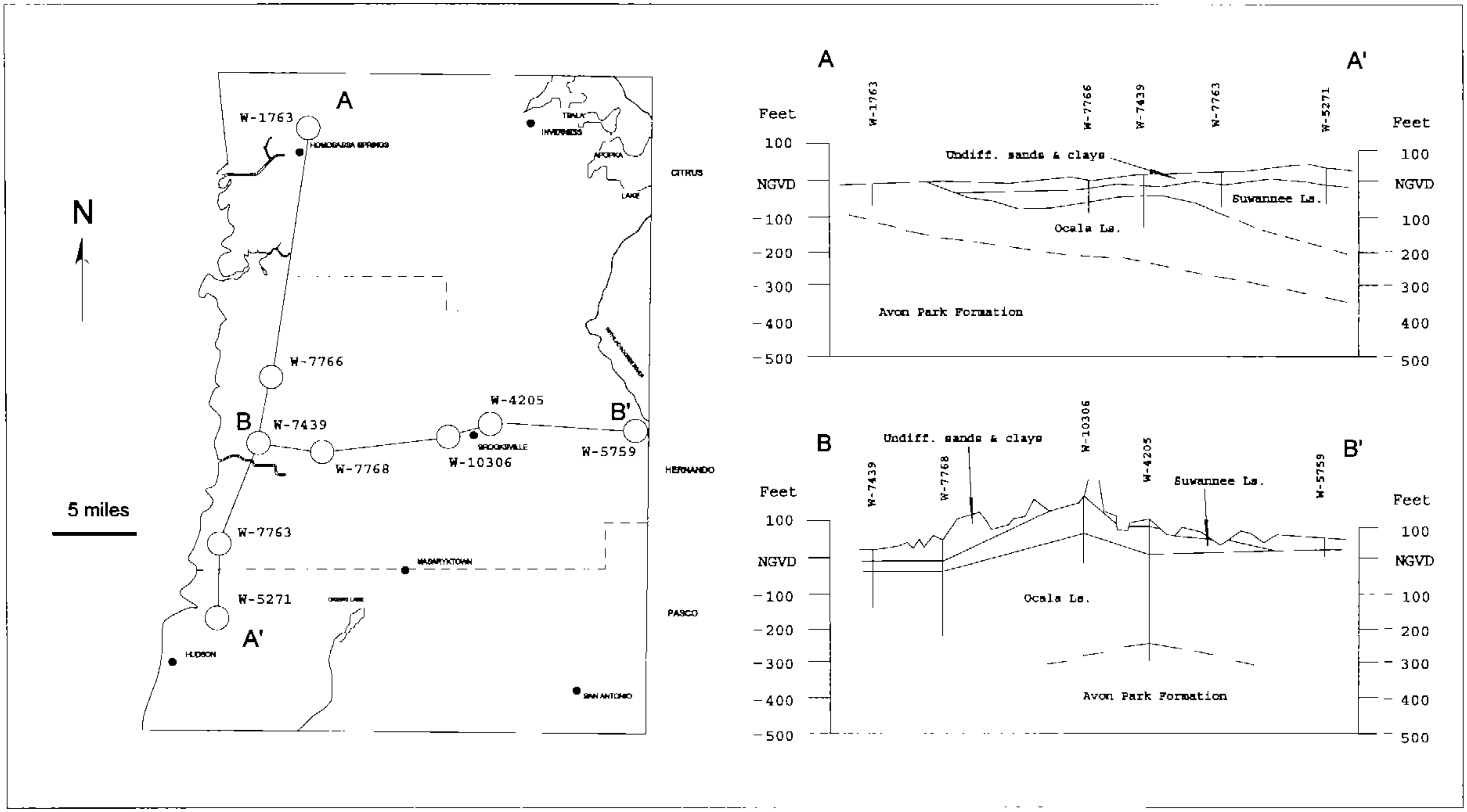


Figure 6. North-South and East-West Geologic Cross Sections through the Study Area (Modified from Fretwell,1983; SWFWMD,1987).

Table 1. Generalized Hydrogeology of the Northern SWFWMD Area (Modified from Fretwell, 1985).

SYSTEM	SERIES	STRATIGRAPHIC UNIT	THICKNESS (FEET)	LITHOLOGY	WATER PRODUCING CHARACTERISTICS
Quaternary	Holocene and Pleistocene	Undifferentiated deposits	0 - 100	Soil, sand, and clay of marine and estuarine terraces, alluvial, lake, and windblown deposits.	Generally not a source of water
Tertiary	Pliocene and Miocene	Hawthorn Group	0 - 100	Predominantly clay; some grayish-green, waxy; some interbedded sand and limestone, phosphatic clay, marl, calcareous sandstone, limestone residuum.	Confining layer in some places; generally not a source of water
Tertiary	Oligocene	Suwannee Limestone	0 - 150	Limestone, cream to tan colored, fine-grained, fossiliferous, thin-bedded to massive, porous.	Many domestic and irrigation wells produce water from the lower part
Tertiary	Eocene (upper)	Ocala Limestone	100 - 500	Limestone, white to tan fossiliferous, massive, soft to hard, porous.	Yields large quantities of water to wells completed above evaporites
Tertiary	Eocene (middle)	Avon Park Formation	200 - 800	Limestone and dolomite. Limestone is light to dark-brown, highly fossiliferous, and porosity is variable in lower part. Dolomite is gray to dark-brown, very fine to microcrystalline and contains porous fossil molds, thin beds of carbonaceous material, and peat fragments. Formation generally contains evaporites in lower part.	Yields large quantities of water to wells completed above evaporites.

In the central portion of the study area (Brooksville Ridge area), the Floridan aquifer is overlain by undifferentiated, Quaternary quartz sand and Pliocene and Miocene sediments of the Hawthorn Group. The Hawthorn Group sediments were deposited in a variety of environments and consist of sand, silty sand, and waxy green clay. Phosphorite pebbles and fossil oyster bars are common. Much of the Hawthorn in the Brooksville Ridge has been highly weathered, which complicates recognition of the facies originally deposited there. Between the town of Brooksville and the Hernando/Citrus County line to the north, the Hawthorn sediments have largely been eroded off the Brooksville Ridge and limestone is exposed at or near land surface in many of the high areas.

Weathering of phosphorite in the Hawthorn Group sediments has resulted in dissolution of carbonate-fluorapatite and re-precipitation of carbonate-hydroxylapatite in localized crusts and nodules that are associated with the sinkholes on the east side of the ridge (Upchurch, 1993). These deposits of re-precipitated phosphate, which were locally termed "hard-rock phosphate", were extensively mined from the late 1880's through 1966 (Dinkins, 1969). The last mine to close, the Holder Mine, was located in Citrus County just south of the Withlacoochee River and east of U.S. 41. None of the mines were large because the deposits were localized on karst features. Open-pit mining was initially by hand, with hand cobbing and sorting, but by the turn of the century steam- and then internal-combustion-engine shovels were used. The deposits, and mines, extended from northern Hernando County into Levy County. The mines were located along U.S.41, at the foot and on the eastern flank of the Brooksville Ridge.

GROUND-WATER HYDROLOGY

Karst

A prerequisite to comprehending the ground-water hydrology of the study area is an understanding of the dominant role karst processes play in moving ground water through the Floridan aquifer. The four physiographic provinces in the study area (Coastal Swamps, Gulf Coastal Lowlands, Brooksville Ridge, and Tsala Apopka Plain) are areas of intensive karst development. These areas are characterized by numerous sinkholes, lack of surface drainage, and undulating topography. In karst areas, the dissolution of limestone has created and enlarged cavities along fractures in the limestone which eventually collapse and form sinkholes. Sinkholes capture surface-water drainage and funnel it underground, which promotes further dissolution of limestone. This leads to progressive integration of voids beneath the surface and allows larger and larger amounts of water to be funneled into the underground drainage system. Dissolution is most active at the water-table or in the zone of water-table fluctuation where carbonic acid contained in atmospheric precipitation and generated by reaction with soil carbon dioxide reacts with limestone and dolostone (Carroll, 1970). Because the altitude of the water table shifted in response to changes in sea level, many vertical and lateral paths have developed in the underlying carbonate strata in the area. Many of these paths or conduits lie below the present water table and greatly facilitate ground-water flow.

Surficial Aquifer

The surficial aquifer system consists of Miocene to Holocene siliciclastic deposits that are contiguous with the land surface. The clastics are usually quartz sand, silty sand, and kaolinitic to smectitic clay. The surficial aquifer is most likely to occur as a distinct hydrostratigraphic unit along the Brooksville Ridge where low permeability clays of the Hawthorn Group or its residuum (Pliocene and Miocene sand, silty sand, waxy-green clay and phosphorite pebbles) retard the downward movement of water into the Floridan aquifer. However, collapse of the underlying limestone has produced numerous breaches in the clays that act as vertical conduits for the movement of water from the surficial to the Floridan aquifer. In addition, as discussed previously, the Hawthorn sediments are not widespread between the town of Brooksville and the Hernando/Citrus County line.

In areas where saturated sand lies directly above limestone, water in the sand is hydraulically connected to the Floridan aquifer. Since the majority of study area has no extensive confining layer, most of the region does not have a surficial aquifer, although surficial sands exist. Figure 7 shows that approximately 25-30 percent of the study area is characterized by potential confining beds greater than 25 feet in thickness.

Floridan Aquifer

The Floridan aquifer system is divided into two major hydrostratigraphic horizons. The upper Floridan, which contains potable water, and the lower Floridan which is saline. The upper Floridan, henceforth termed the Floridan aquifer, is the focus of this report. The Floridan aquifer is the principal source of water for the springs in the study area as well as domestic, agricultural, and industrial supplies.

The Floridan aquifer is composed of several geologic formations that act as a single hydrologic unit (Yobbi, 1992). In the northern and central portions of the study area the fresh-water-bearing part of the Floridan aquifer is composed of the Avon Park Formation, the Ocala Limestone, and the Suwannee Limestone, in ascending order. In the southern portion of the study area the Tampa Member of the Hawthorn Group overlies the Suwannee Limestone, and is present at or near the land surface. The top of the Floridan aquifer is usually defined as the uppermost vertically persistent permeable limestone or dolostone. Where the confining beds that separate the surficial and Floridan aquifers are present, the top of the Floridan coincides with the base of the confining beds. The lower part of the Avon Park Formation contains evaporites consisting of gypsum and anhydrite that reduce permeability of the rock and are considered to be the base of the upper Floridan aquifer. In general, the Floridan aquifer is unconfined in the study area. However, clay layers in the Brooksville Ridge are sufficiently thick to cause localized, semi-confined conditions to exist.

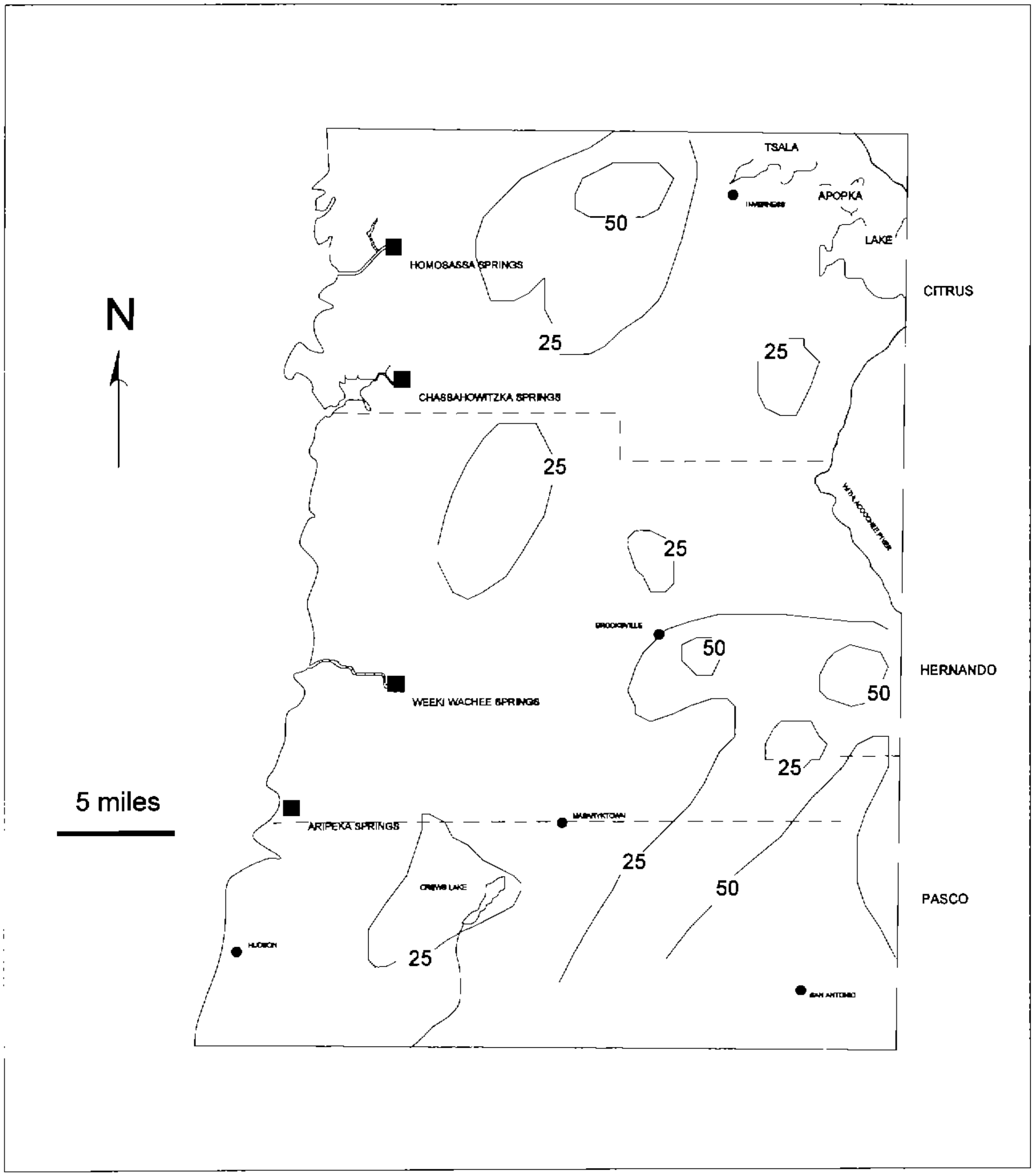


Figure 7. Thickness of Confining Units in the Study Area (Modified from Buono *et al.*, 1979; Faulkner, 1970).

Recharge

A number of previous investigations (Aucott, 1988; Ryder, 1985; Adams, 1985; Stewart, 1980) report Floridan aquifer recharge estimates for regions included in the study area. The following summary references these investigations in describing the recharge characteristics of the Floridan aquifer and applies recharge estimates to the physiographic provinces depicted in Figure 3. A composite of generalized recharge values applied to the study area physiography is shown in Figure 8.

Recharge potential for the Floridan aquifer in the study area is primarily controlled by the thickness and composition of surficial sediments overlying the aquifer, and the presence of karst topography. Other factors affecting recharge rates include the development of surface drainage, variations in head gradients between surface water, the surficial aquifer, and the Floridan aquifer, and aquifer permeability. Generally, high recharge rates occur where limestone is near land surface or where overlying sediments are lacking in low permeability confining materials. Occurrences of sinkholes with associated internal drainage of surface water also induces higher recharge to the Floridan aquifer. Lower recharge rates occur where confining materials overlying the aquifer retard downward vertical movement of water, or where an upward gradient between the Floridan and surficial aquifers exists.

Recharge is variably low to nonexistent along the Coastal Swamps province, with estimated recharge values of -9 inches (discharge), to 11 inches per year. This is primarily an area of regional Floridan aquifer discharge with only localized recharge over very short distances contributing to spring discharge. Recharge within the Tsala Apopka Plain is similarly low due to a diminished downward vertical gradient between surface waters or the surficial aquifer and the Floridan Aquifer (Rutledge, 1978). Ground-water discharge also is present along sections of the Withlacoochee River south and east of Tsala Apopka. Accordingly, recharge estimates range from -1 inches to 9 inches per year in the region.

Moderate to high estimated recharge exists over a large portion of the study area covering the Coastal Lowlands and Brooksville Ridge physiographic provinces. Potential recharge of 3 inches to 16 inches exists within the Coastal Lowlands, with 7 to 11 inches reported over land areas proximal to the spring complexes. Recharge estimates in the Brooksville Ridge area are very high, ranging from 9 inches to 22 inches per year.

Recharge in the Brooksville Ridge area is highest because it is a karst terrain with internal drainage to the upper Floridan aquifer (Kimrey and Anderson, 1987). Sinkholes are abundant, the land surface is generally very well drained and the water table is relatively deep. Surface waters are not abundant and there are no permanent streams or extensive wetland areas. These factors maximize recharge because infiltration is rapid and surface runoff is non-existent.

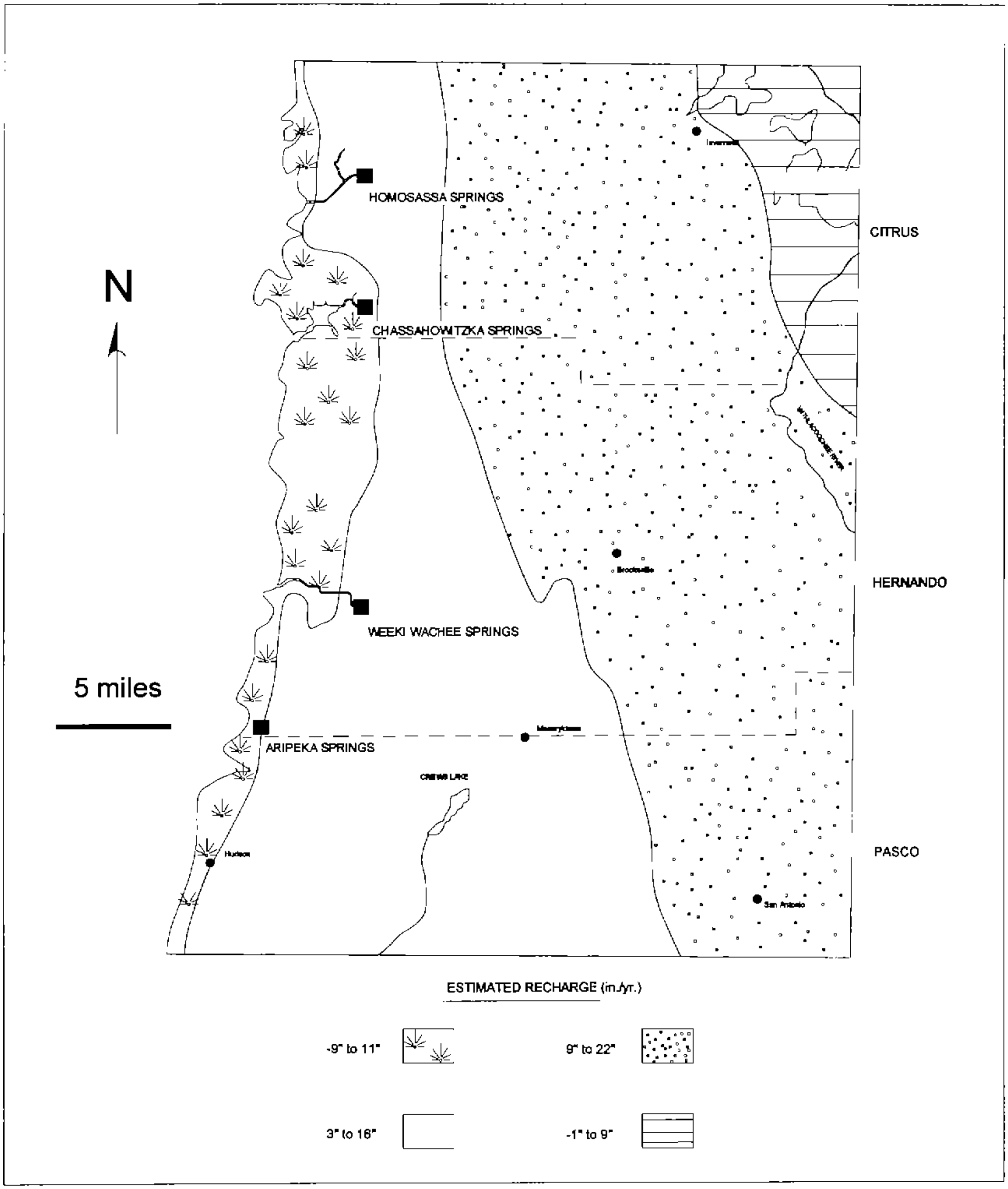


Figure 8. Recharge Estimates for Different Physiographic Regions of the Study Area (Modified from Stewart, 1980; Ryder, 1985; Adams, 1985; and Aucott, 1988).

Fresh-Water/Salt-Water Transition Zone

Most of the springs in the study area lie in or near the fresh-water/salt-water transition zone; a brackish zone in the Floridan aquifer where seaward-moving fresh water meets landward-moving salt water. As a result of their proximity to the transition zone, many of the springs in the study area discharge brackish water. The high salt content of many brackish springs indicates that Gulf water has intruded through interconnected solution conduits gulfward of the springs (Yobbi, 1992). In general, springs located further inland are further from the transition zone and, therefore, have fresher water.

The position of the transition zone results from the dispersive characteristics of the geologic strata, fresh-water flow, tidal effects, recharge, and pumping of wells (Wentworth, 1951). The transition zone is bounded on the seaward side by chloride concentrations that can be as high as 19,000 mg/l and on the landward side by chloride concentrations of 25 mg/l (Causseaux and Fretwell, 1979). A sharp boundary does not exist in coastal aquifers because of mechanical dispersion and tidal or water level fluctuations caused by changes in recharge or pumpage with time. Instead, a dynamic equilibrium has been established that causes fresh water and salt water to mix and form a transition zone between fresh water and salt water (Yobbi, 1992). Salt water is not static in the transition zone but flows from the sea floor into the zone of transition and back to the sea floor (Cooper et al., 1964).

The transition zone moves horizontally and vertically in the upper Floridan aquifer in response to changes in fresh-water head and tides in the gulf. As a result of the movements of the transition zone, the water quality and magnitude of discharge of the springs continuously change. Tidal fluctuations result in diurnal fluctuations in water quality and discharge. Salinity is generally lowest at low tide when the transition zone is further seaward. Discharge generally peaks at low tide and is a function of the difference in head between the aquifer and the spring pool.

Changes in fresh-water head are largely seasonal. The discharge of most springs peaks in late summer and early fall (which corresponds to the end of the peak rainfall season) and gradually declines toward winter and spring. However, spring flow during wet periods is not always proportional to the increase in rainfall as a result of storage in the aquifer. The increase in fresh-water flow in the wet season has the effect of pushing the transition zone seaward. This results in a decrease in salinity in the springs.

The AGWQMP has been investigating the position and thickness of the transition zone through its Coastal Ground-Water Quality Monitoring Network since 1992. Figures 9 and 10 are west to east cross sections through the transition zone near Homosassa Springs in Citrus County and Weeki Wachee Springs in Hernando County, respectively. From the figures it is apparent that the transition zone in Citus County is more shallow and extends further inland than the transition zone in Hernando County. According to Yobbi (1992) this is a result of a decrease in the hydraulic head gradient with distance from the

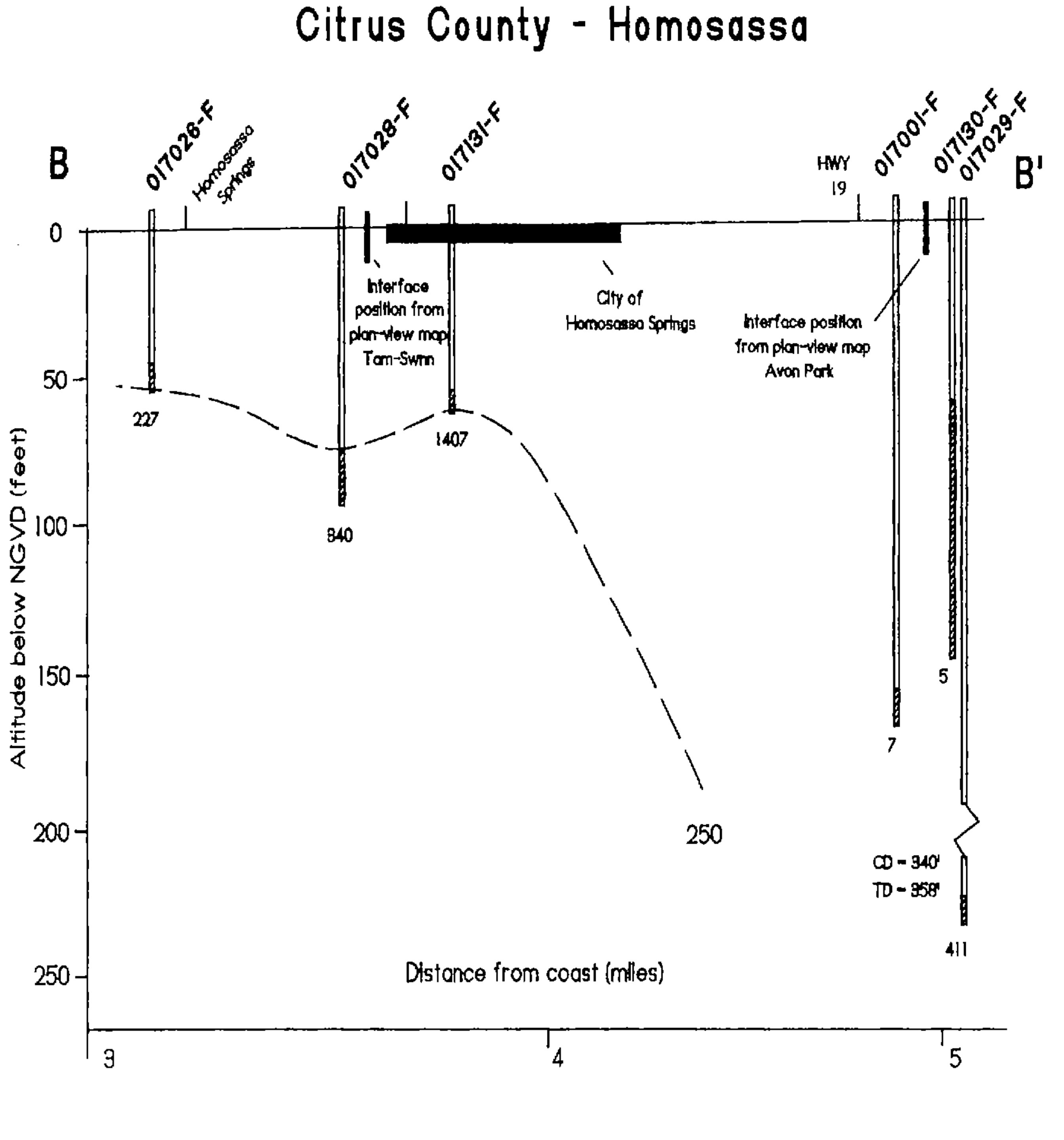


Figure 9. West to East Cross Section through the Salt-Water/Fresh-Water Transition Zone Near Homosassa Springs (DeHaven, 1995).

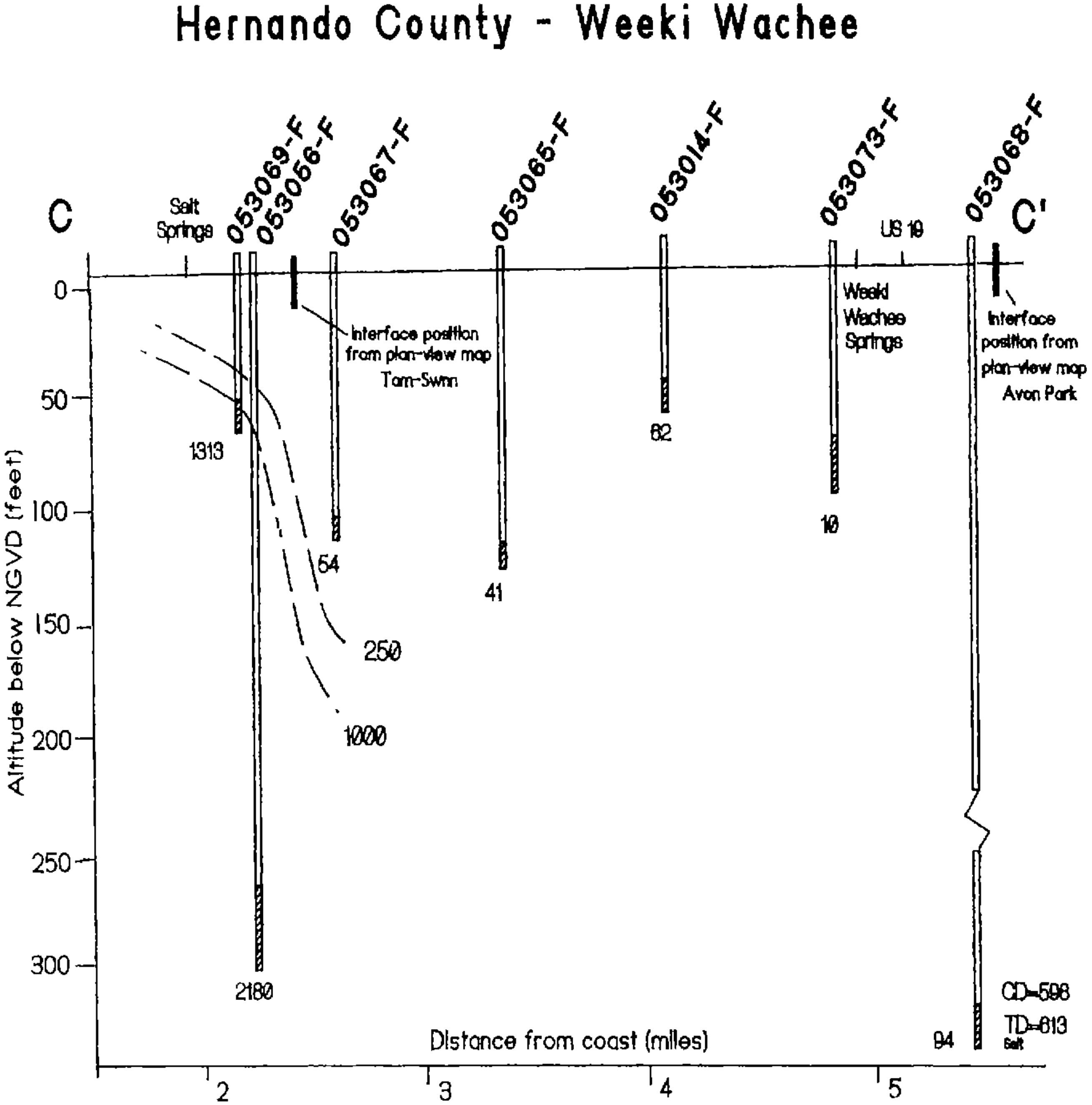


Figure 10. West to East Cross Section through the Salt-Water/Fresh-Water Transition Zone Near Weeki Wachee Springs (DeHaven, 1995).

coast in Citrus County that allows higher chloride concentrations with depth.

Yobbi (1992) showed the approximate position of the 250 mg/l line of equal chloride concentration at a depth of 100 feet below sea level in the Upper Floridan aquifer based on samples collected from wells and springs (1964 through 1980) (Figure 11). Chloride concentrations in ground water exceeding 250 mg/l generally occur at a depth of less than 100 feet seaward of this line and greater than 100 feet inland of this line.

Data presented in Yobbi (1992), water quality data collected by the AGWQMP (DeHaven, 1995) from its coastal monitor well network, and surface geophysical surveys (Bisdorf and Zohdy, 1979; Stewart and Gay, 1983;) indicate very prominent landward reentrants of the transition zone in the vicinity of the major coastal springs. The reentrants result from the concentration of discharge at the major springs, which has the effect of reducing fresh-water head. This allows salt water to migrate inland in the vicinity of the springs.

Thickness of the Potable Water Zone

Figure 12 depicts a generalized thickness of potable ground water in the Floridan aquifer across the study area. The potable thickness map is based on a compilation of historical water-quality data, including monitor-well samples, drilling data and geophysical logs, over a time period from 1976 to 1996. These data are compiled in Appendix IV. Criteria for delineating the depth of potable water include either chloride or sulfate concentrations in excess of the 250 mg/l drinking water standards. The depth to nonpotable ground water was determined from well casing depths when sample data showed nonpotable conditions, or from water-quality profiles obtained during test drilling at monitor sites. Accompanying geophysical log data were also used, where available, to verify water-quality changes in test wells.

Thickness of the potable-water zone in the Floridan aquifer in the study area ranges from more than 900 feet in south-central Pasco County, to less than 200 feet along the Withlacoochee River in southeastern Citrus County, and less than 100 feet along the coast. A general uniform thinning of the potable zone of the Floridan aquifer occurs from south to north across the study area. The vertical extent of potable ground water across the inland area appears to be controlled by the occurrence of gypsum-bearing carbonates of the middle confining unit, and the presence of sulfate-rich waters derived from the dissolution of sulfate minerals at the top of the unit (Hickey, 1990). Average thickness of the potable zone in the Floridan aquifer is 400 to 600 feet in Hernando County and 200 to 300 feet in Citrus County.

Geometry of the potable ground-water body along the coastal margin is controlled by the dynamics of the fresh-water/salt-water transition zone, as stated in the previous section. Although not intended to accurately define the transition zone, the potable

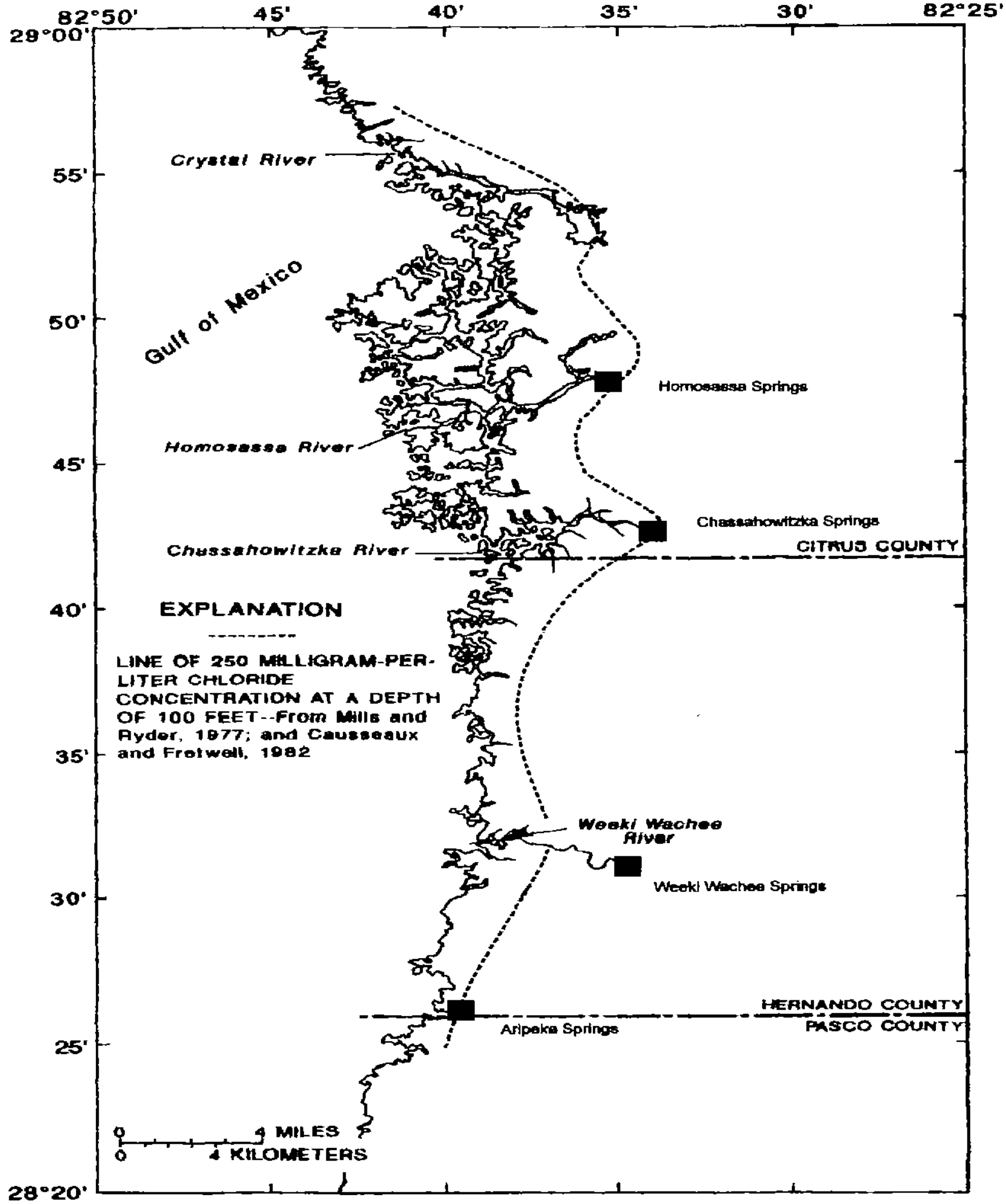


Figure 11. Approximate Position of the 250 mg/l Line of Equal Chloride Concentration at a Depth of 100 Feet Below Sea Level in the Upper Floridan Aquifer (Modified from Yobbi, 1992).

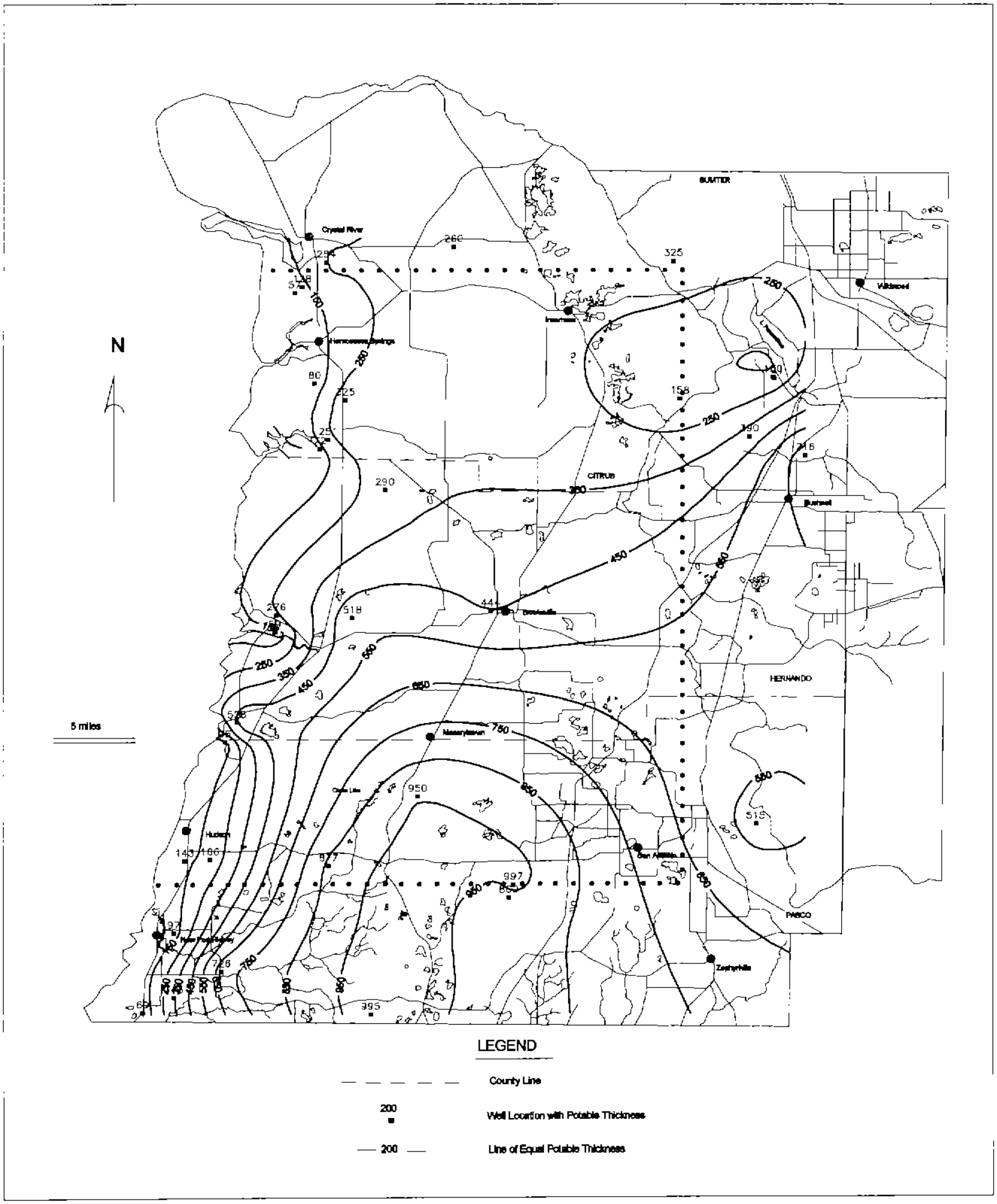


Figure 12. Generalized Thickness of the Potable Water Zone in the Floridan Aquifer in the Northern Portion of the Southwest Florida Water Management District (see Appendix IV for data sources).

thickness shown in Figure 12 generally coincides with the 100-foot depth of non-potable water delineated in Figure 11. Potable-water lens thickness contours trend coast-parallel with a well-defined reentrant at the Weeki Wachee River, a slight inland trend south of Aripeka, and a broad reentrant around the Chassahowitzka and Homosassa Rivers.

Although Klein (1975) and Causey and Leve (1976) determined the thickness of the potable zone in the study area to be considerably greater than the data presented in Figure 12, the authors believe that data acquired since 1976 allows for a more accurate assessment. The conclusion that the potable-water zone is considerably thinner than what is described by previous investigators is supported by Ryder (1985).

DESCRIPTION OF SPRING COMPLEXES IN THE STUDY AREA

The Homosassa, Chassahowitzka, Weeki Wachee and Aripeka Spring complexes lie in a discharge zone for the Floridan aquifer along the eastern edge of the coastal swamps of Citrus and Hernando Counties[2] (Figure 1). The Homosassa, Chassahowitzka, and Weeki Wachee Spring complexes each have a large, first magnitude main spring (discharge exceeds 100 cfs). Within a few miles of the main spring are numerous smaller springs that can collectively discharge as much or more than the main spring. The Aripeka Spring complex does not have a large main spring and the overall discharge of the complex is much lower than that of the other complexes. Yobbi (1992) determined that spring flow is seasonal, with a peak discharge in late summer and early fall, followed by a gradual decrease in flow toward winter and spring (Figure 13).

The following sections describe the location, vent characteristics, and average-annual discharge of each major spring in the four complexes. Discharge data for the springs were obtained from Wetterall, 1965, Rosenau *et al.*, 1977, and Yobbi, 1988 and 1992.

HOMOSASSA SPRING COMPLEX

The Homosassa Springs complex is located in western Citrus County approximately one mile west-southwest of the town of Homosassa Springs on U.S. Hwy 19 (Figure 1). The Homosassa complex (Figure 14) is composed of the main spring, which includes three large vents contained within a collapsed-cavern feature and many smaller secondary vents spread over an area of nearly four square miles. The Homosassa River, having originated at the main springs, receives additional flow from the secondary vents; many of which are located along the southeast fork of the Homosassa River. After receiving additional flow from the spring-fed Halls River, the Homosassa River flows westward for approximately five miles before emptying into the Gulf of Mexico.

The AGWQMP sampled all the significant, known vents in the main spring and along the southeast fork. Due to the difficulty of finding and accessing discrete discharge points only the spring at the head of Hall's River was sampled.

Individual Spring Characteristics

Homosassa Main #1,#2, and #3.

The Homosassa Spring complex was studied in 1992 by Karst Environmental Services; a ground-water consulting firm. A portion of the study involved the mapping of

---

[2]King's Bay (Crystal River), a major coastal spring complex in northern Citrus County, was studied previously by Jones and Upchurch (1994) and is not included in this report.

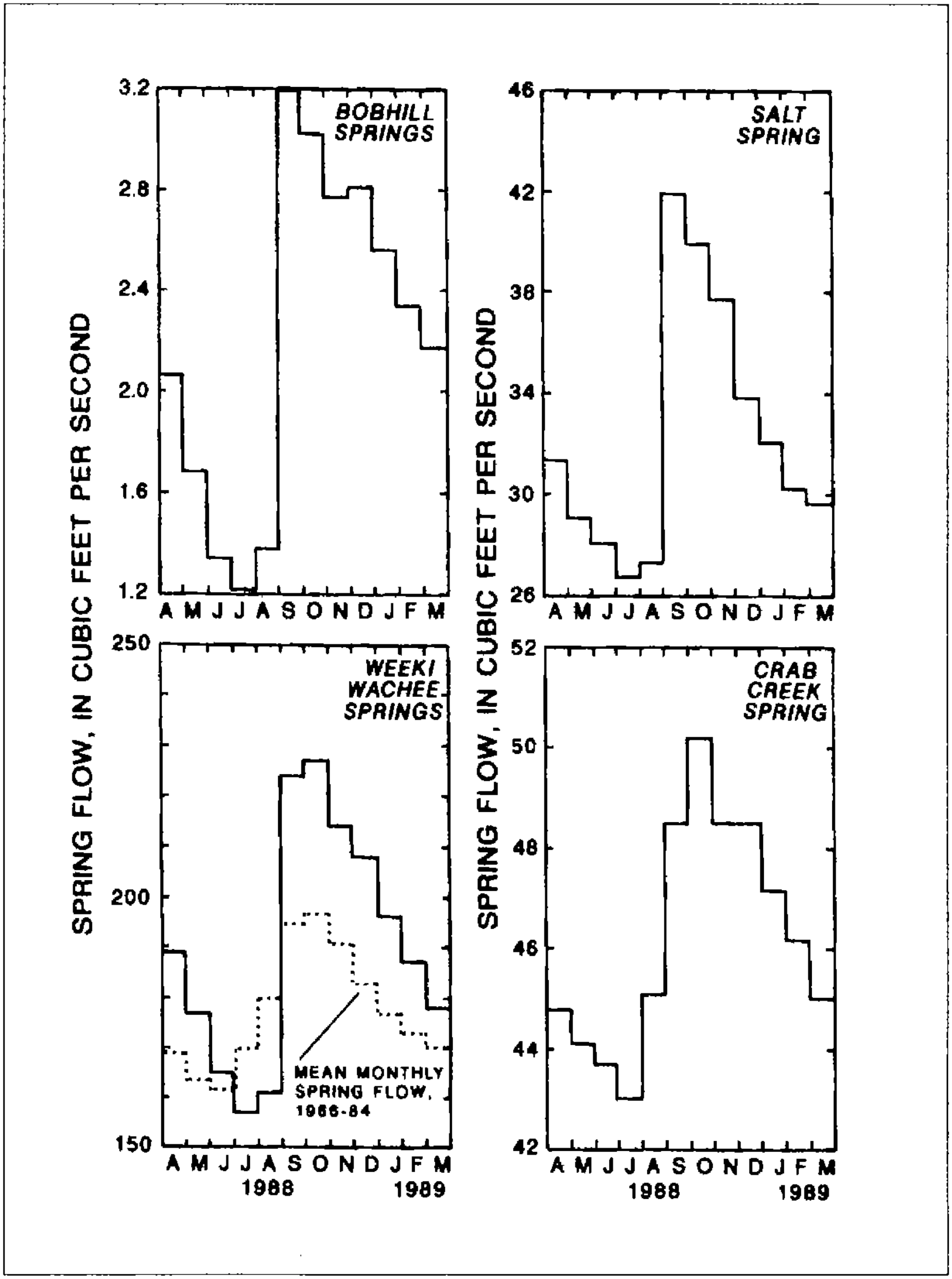


Figure 13. Monthly Mean Spring Flow of Weeki Wachee Spring, Crab Creek Spring, Bobhill Spring, and Salt Spring, April 1988 through March 1989 (Yobbi, 1992).

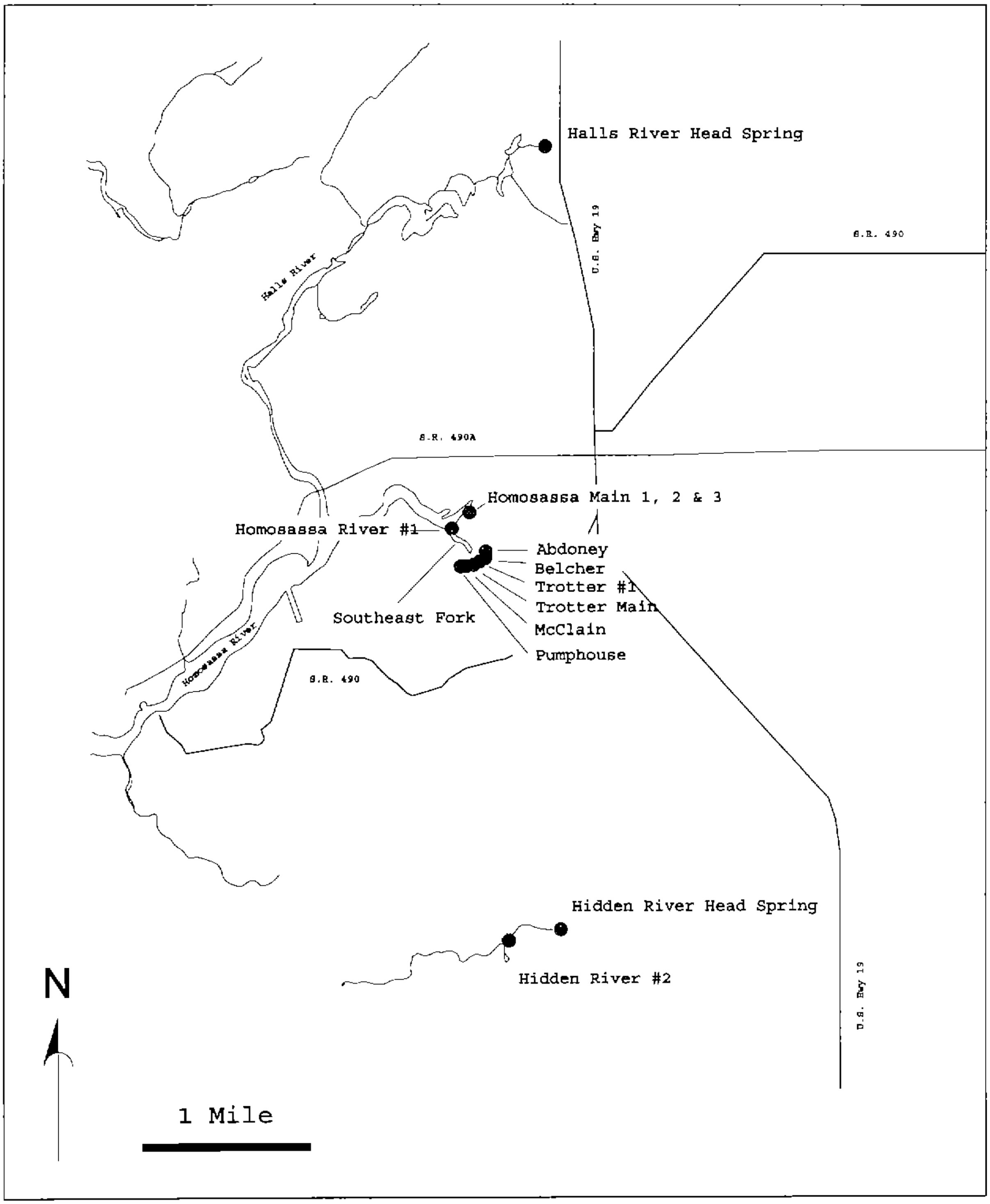


Figure 14. The Homosassa Spring Complex and Vicinity.

the main-spring cave system by a team of divers. Their investigation revealed that the accessible portion of the system is not extensive (Figure 15). Most of the accessible portion is within the Ocala Limestone. However, the contact between the Ocala Limestone and the Avon Park Formation was observed to occur at a depth of 48 feet below sea level (Karst Environmental Services, 1992). The maximum depth reached by the divers in the cave was 70 feet. Although extremely narrow passages continued deeper into the system, they were judged to be beyond the safe reach of the divers. The divers also determined that most of the flow emanates from three vents, each of which discharges water that is chemically distinct from the others. Subsequent samplings of the spring were greatly improved by the installation of sampling tubes into the individual vents (Karst Environmental Services, 1992). The water quality of the three main vents changes significantly over a tidal cycle. The spring as a whole discharges brackish water (1000-10,000 mg/l total dissolved solids (TDS)) during low tide.

Homosassa River #1

This spring is located just off the north shore of the Homosassa River approximately 150 yards southwest of the main spring. The spring is at the bottom of a shallow depression approximately 50 feet across and 10 feet deep. The actual vent of the spring is small, very little flow is discernable near the vent, and there is no evidence of a boil or slick on the surface. The water quality of the spring probably changes significantly over a tidal cycle.

Southeast Fork

The southeast fork of the Homosassa River is fed by small springs that issue from numerous fractures in the limestone bedrock approximately 1000 feet south of the main spring area. Springs on the southeast fork that were sampled for this study include Abdoney, Belcher, McClain, Pumphouse, Trotter Main, and Trotter #1. The springs along the southeast fork always discharge fresh water (TDS < 1000 mg/l) and the quality of their water does not change over a tidal cycle (Yobbi, 1992). It is reported that these springs often become tannic during heavy rainstorms. A spring-fed stream, which sinks approximately 400 feet south of the southeast fork and reemerges as the Trotter Springs and possibly Pumphouse Spring, is probably the source of the tannins.

Hidden River

Hidden River, located approximately two miles south of Homosassa Springs, flows for approximately two miles overland before it sinks underground and apparently enters the Homosassa River downstream from Homosassa Springs (Cherry *et al.,* 1970).

Hidden River Head Spring is located at the upstream end of Hidden River, approximately four feet below the water surface in a small, circular depression, five feet in

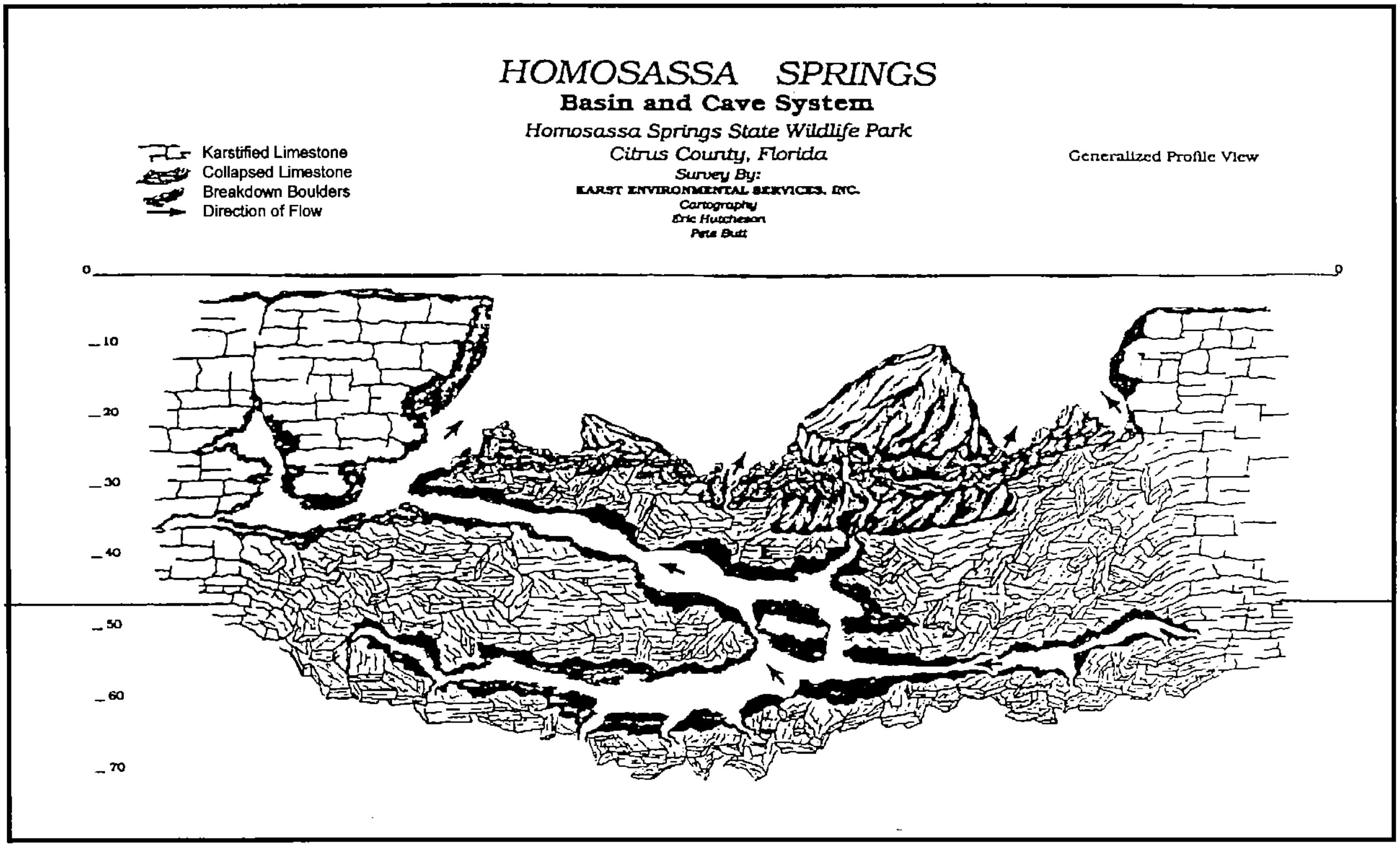


Figure 15. The Homosassa Spring Cavern System (Karst Environmental Services, 1992).

diameter. There does not appear to be a significant change in water quality over a tidal cycle. Hidden River Spring #2 is located a few hundred feet downstream of the head spring and is configured very similar to the head spring. Although data are limited, the water quality of this spring may change over a tidal cycle.

Hall's River Head Spring

Hall's River Head Spring is located at the upstream end of Halls River, a 2.5 mile long tributary of the Homosassa River, that intersects the Homosassa River about a mile west of the main-spring area. There are numerous springs along the river that are difficult to locate because the river is wide, shallow, and thickly vegetated. Only the spring at the head of the river, which is readily accessible, was sampled during this study. The spring is located approximately two miles northeast of Homosassa main spring, a few hundred feet west of U.S. 19, just south of a small stone building. The spring pool is circular, approximately 200 feet across, and contains a few sand boils but no obvious vent or boil. Water in the pool is the exceptionally clear, blue-green color of Florida springs. The water is brackish during low tide and it's quality changes significantly over a tidal cycle (Yobbi, 1992).

Discharge

The average discharge of the springs in the Homosassa Spring complex included in this investigation is approximately 354 cfs. Table 2 contains discharge information for the sampled springs in the complex.

CHASSAHOWITZKA SPRINGS COMPLEX

The Chassahowitzka Springs complex is located in southwestern Citrus County approximately six miles south of the town of Homosassa Springs (Figure 1). The Chassahowitzka complex (Figure 16), much like the Homosassa complex to the north, is composed of a single, large main spring and numerous smaller springs spread over an area of nearly five square miles. The Chassahowitzka River emanates mostly from the main spring, but receives additional flow from several short spring runs (Baird, Salt, Crab, and Potter Creeks) in its first two miles. The river then flows southwestward for approximately four miles before emptying into the Gulf of Mexico.

The AGWQMP sampled many of the significant, known springs in the Chassahowitzka complex including Chassahowitzka #1, Chassahowitzka Main, Crab Creek, Baird Creek, Potter Creek, Ruth, Beteejay, and Blue Run. Significant springs not sampled by the AGWQMP include Salt Creek, Rita Maria, and a number of springs located very close to the Gulf.

Table 2. Discharge Information for Springs in the Homosassa Complex.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN
HOMOSASSA MAIN SPRING AREA			
Homosassa Main 1,2, and 3	104.0	11	1988-1989
Homosassa River	unknown (< 10 ?)	0	N/A
SOUTHEAST FORK OF THE HOMOSASSA RIVER			
Abdoney Belcher McClain Pumphouse Trotter #1 Trotter Main	69.1 (Springs have not been measured individually - this is the combined discharge of these and other springs on the Southeast Fork)	89	1931-1974
HIDDEN RIVER			
Hidden River Head Hidden River #1	9.3 (Springs have not been measured individually - this is the combined discharge)	7	1988-1989
HALL'S RIVER			
Hall's River - Long, shallow river, difficult to access - discrete discharge points are rare	162.0 (This is the combined discharge of an unknown number of springs and seeps)	12	1964-1966

Individual Spring Characteristics

Chassahowitzka Main

The main spring of the Chassahowitzka Springs complex is located approximately 200 feet east of the boat ramp at the Chassahowitzka Campgrounds. The vent is situated in 20 feet of water near the center of the channel. The sandy riverbed slopes gently inward toward the spring and then steepens into a 50-foot wide cone (Wetterhall, 1965). The conduit system of the main spring has not been mapped because the entrance is too narrow to admit divers. The discharge of the spring produces a large boil above the main spring, especially during low tide. The main spring discharges brackish to fresh water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

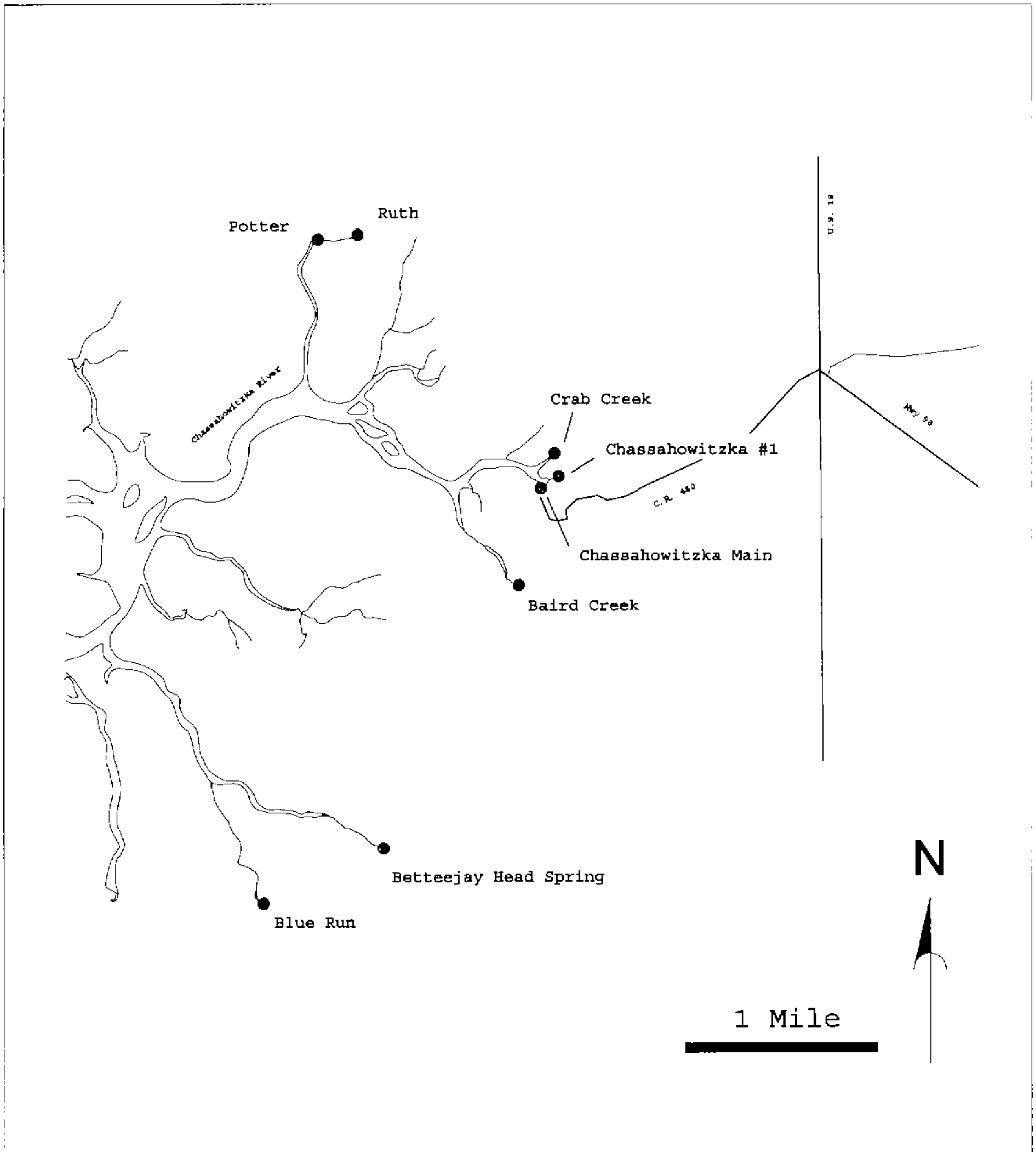


Figure 16. The Chassahowitzka Spring Complex and Vicinity.

Chassahowitzka #1

Approximately 100 feet upstream from the main spring is a limestone-floored tributary that extends northeast for approximately 250 feet. Numerous springs emanate from small solution features in the limestone bedrock of the stream bed. This short spring run was probably the eastern-most point of the Chassahowitzka River before canals were dredged that extend further to the east. Chassahowitzka #1, is located near the end of the tributary and has alternately been referred to as Bubba Spring. The spring consists of two large holes in the limestone separated by approximately 15 feet. Swimmers can easily enter an opening and swim out the other in a matter of seconds. The spring emanates from a small opening at the bottom of the passage mid way between the two entrances and discharges a large portion of the flow above the main spring. AGWQMP data indicate that Chassahowitzka #1 discharges fresh water during low tide and it's water quality does not change significantly over a tidal cycle (Yobbi, 1992).

Crab Creek

Crab Creek Spring is located approximately 650 feet due north of the main spring at the head of Crab Creek. The spring discharge produces a noticeable boil at the water surface, especially during low tide. Wetterhall (1965) describes the vent as being three feet in diameter and lying in approximately 13 feet of water. Crab Creek Spring discharges brackish water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Baird Creek

Baird Creek Spring is located at the head of Baird Creek, approximately 0.5 mile south of the Chassahowitzka main spring. The spring emanates from a large fracture in the limestone bedrock, and lies in several feet of water. Baird Creek Spring discharges brackish water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Potter Creek

Potter Creek Spring is located approximately 1.5 miles northwest of the main spring at the head of Potter Creek. The spring is in the center of a 100 foot diameter pool at the head of the creek in approximately 17 feet of water. The spring discharges brackish water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Ruth

Ruth Spring is located approximately 300 feet northeast of Potter Creek Spring near the head of a short spring run. The spring emanates from a large fracture in the limestone bedrock and lies in several feet of water. Ruth Spring discharges brackish water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Beteejay Head Spring

This spring is probably the one Rosenau *et al.* (1977) refered to as unnamed spring #9. According to Rosenau *et al.* (1977), the spring is at the head of Crawford Creek about 2.7 miles upstream from the mouth of the creek at the Chassahowitzka River. Although the spring was inaccessible and described from aerial photographs when Rosenau *et al.* (1977) investigated it, a private access road now exists and a house has been constructed adjacent to the spring. The spring discharges from the upstream end of a nearly circular pool that is approximately 100 feet in diameter. The spring usually discharges fresh water and its water quality does not change over a tidal cycle. However, a sample collected in April of 1997 has chloride, sodium, and TDS concentrations that exceed drinking-water standards. Since April is nearing the end of the dry season and the spring of 1997 was particularly dry, it is possible that the fresh-water/salt-water transition zone moved further inland than it would during years with more normal rainfall. It follows that if the transition zone moves further inland during dry times, the water-quality of the springs may become tidally influenced until normal water levels are restored.

Blue Run

This spring is probably the one Rosenau *et al.* (1977) refered to as unnamed spring #12. According to Rosenau *et al.* (1977), the spring is at the head of Blue Run, a tributary of Crawford Creek, about 0.7 miles upstream from its confluence with Crawford Creek. The head pool of the spring is about 100 feet wide and 600 feet long. The spring discharges brackish water at low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Discharge

The average discharge of the springs in the Chassahowitzka Spring complex included in this investigation is 268 cfs. Table 3 contains discharge information for the springs.

WEEKI WACHEE SPRING COMPLEX

The Weeki Wachee Spring complex is located in southwestern Hernando County approximately eleven miles southwest of the City of Brooksville (Figure 1). The complex is composed of a single, large main spring and numerous smaller springs spread over an area of nearly five square miles (Figure 17). The Weeki Wachee River originates at the main spring and flows westward for approximately five miles before emptying into the Gulf of Mexico. The river receives additional flow from Twin Dees , Salt, and Mud River Springs

Table 3. Discharge Information for Springs in the Chassahowitzka Complex.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN
Chassahowitzka Main	139.0	81	1930-1972
Chassahowitzka #1	30.0 - this is the combined discharge of springs along the tributary creek.	13	1988-1989
Baird	5.6	8	1988-1989
Crab Creek	48.7	20	1988-1989
Potter Creek	18.6	14	1988-1989
Ruth	13.3	14	1988-1989
Beteejay Head Spring	6.4	3	1988-1989
Blue Run	6.6	13	1988-1989

as well as numerous additional small springs.

Springs in the Weeki Wachee complex sampled by the AGWQMP include Weeki Wachee Main, Twin Dees, Salt, and Mud River. Significant springs in the complex that were not sampled by the AGWQMP include Hospital Hole and Hospital. Hospital is apparently plugged and no longer flows.

Individual Spring Characteristics

Weeki Wachee Main

The main spring of the Weeki Wachee Spring complex is located approximately 800 feet southwest of the intersection of Hwy 50 and U.S. Hwy 19. The spring always discharges fresh water and its water quality does not change over a tidal cycle. The spring pool is circular, nearly 150 feet in diameter, and 10 feet deep where the main vent begins. The vent is a north-south trending, vertical fracture that narrows progressively to a depth of approximately 185 feet. At this point, the fracture is 20 feet long and only 3 feet wide. The force of the entire flow of the spring passing the constriction creates a nearly impenetrable barrier to divers. However, on several occasions in 1980, groups of divers passed the constriction with great difficulty (Exley, 1985; personal communication, Steve Straatsma, 1994). The end of the fracture opened into the ceiling of a large room. The top of a debris cone was discovered approximately 20 feet below the opening in the ceiling at a depth of 205 feet. Exploration revealed passages exiting both ends of the room.

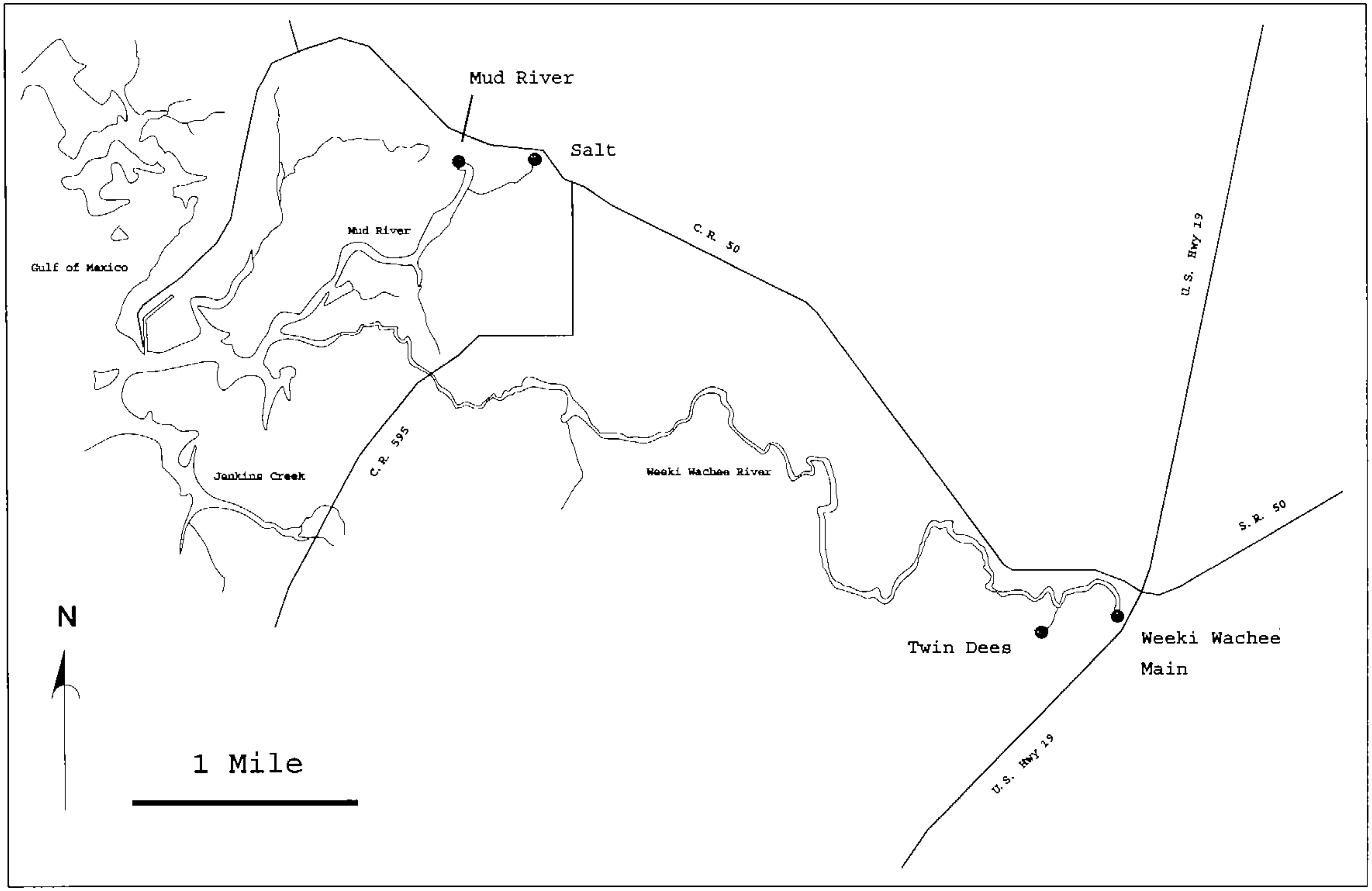


Figure 17. The Weeki Wachee Spring Conplex and Vicinity.

According to Exley (1985) the conduits appeared to convey water away from the fracture leading to Weeki Wachee Spring. One of the passages seemed to be flowing very strongly. This led Exley (1985) to conclude that more water was flowing through the large room than was exiting through the fracture to Weeki Wachee Spring. Exley (1985) was unable to locate an inflowing conduit.

Twin Dees

Twin Dees, also known as Little Spring, is located approximately 3000 feet southwest of the main spring and about 300 feet north of a 20 acre lake. The spring pool is 25 feet in diameter and water enters the pool through a vertical shaft that is just wide enough for a diver to enter the cave system 50 feet below. Another shaft is present in the pool but is apparently plugged. Water discharging from the spring flows through a marsh for approximately 0.2 mile to the Weeki Wachee River. The spring always discharges fresh water and its water quality does not change significantly over a tidal cycle (Rosenau et al., 1977).

An extensive cave system is accessible through Twin Dees Spring (Figure 18). Since June of 1995, an intensive effort to explore and map the cave system has been undertaken by Karst Underwater Research (KUR); an organization of research divers. Currently, KUR has surveyed 2,500 feet from the entrance to depths of 300 feet and has discovered large chambers and wide, extensive passageways. A large tunnel at the end of the survey indicates that the system could be much more extensive.

Salt

Salt Spring is located approximately four miles northwest of the Weeki Wachee Main Spring at the head of Salt Creek. The spring pool is 40 feet in diameter and three feet deep near the vent. Divers report that the spring vent is six feet in diameter, 170 feet deep, and consists of many passageways below 60 feet. The spring discharges brackish water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Mud River

Mud River Spring is located at the head of Mud River, about 400 feet south of State Hwy 50, 1.3 miles east of Bayport and 3000 feet west of the intersection of State Hwys 50 and 595 (Rosenau *et al.*, 1977). The head pool of Mud River is about 400 feet in diameter with a 200 foot-wide run flowing from the east side. Roseneau *et al.* report that the spring is near the southwest side of the pool about 15 feet east of a dock. However, the dock no longer exists. The spring basin is elongate in a north-south direction and slopes irregularly down on the north, east, and south sides. The west side is essentially vertical to a depth of 185 feet (Sinclair, 1977). The bottom is obscured by a brown flaky material, probably algal, that gives the river and the spring the name "Mud." The spring discharges brackish

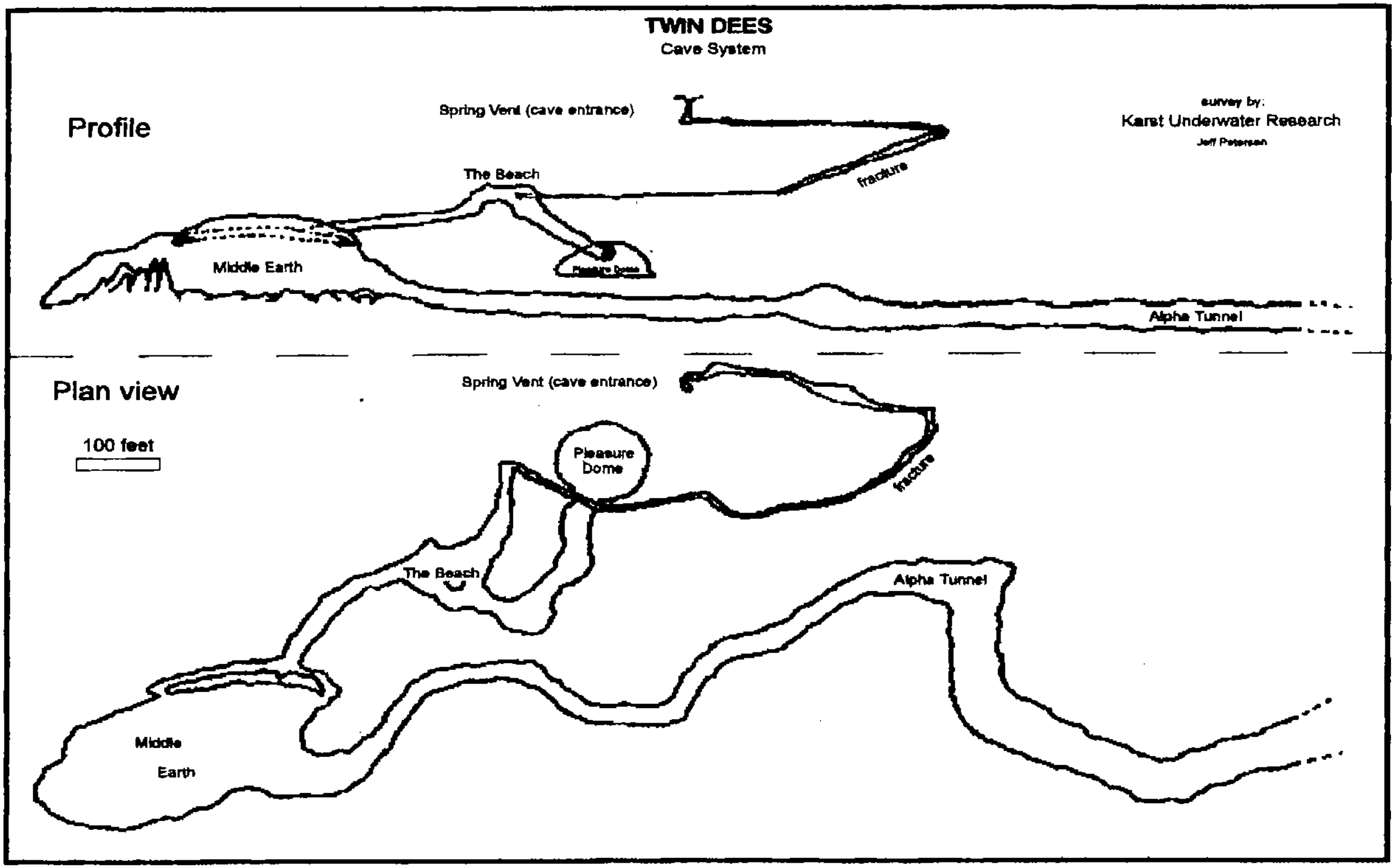


Figure 18. The Twin Dees Cavern System.

water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Discharge

The average discharge of the springs in the Weeki Wachee Spring complex included in this investigation is 254 cfs. Table 4 contains discharge information for the springs.

Table 4. Discharge Information for Springs in the Weeki Wachee Complex.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN
Weeki Wachee Main	165.0*	364	1917-1974
Twin Dees	11.0	2	1972-1975
Salt	33.0	34	1988-1989
Mud River	45.0	5	1988-1989

*Does not include the discharge of Twin Dees.

ARIPEKA SPRINGS COMPLEX

The Aripeka Springs complex is composed of numerous small springs clustered in a one square-mile area in southwestern Hernando County (Figure 19). Springs in the complex include: Aripeka #1 and #2, Boat, Magnolia, Bobhill, Gator, and numerous, small unnamed springs. Most of the springs are located in and around Hammock Creek, a small tidal creek that extends one mile from its upper reaches to the Gulf of Mexico. Springs around Hammock Creek that were selected for comprehensive water-quality analysis included Aripeka #1 and #2 and Boat. Additional springs that were repeatedly sampled included Magnolia Spring, located at the head of a tributary, approximately one quarter mile upstream from Aripeka #2, and Bobhill Spring, located approximately one mile east of the upper reaches of Hammock Creek.

Individual Spring Characteristics

Aripeka #1

Aripeka #1 is located near the eastern shore of the northern-most extent of the north prong of Hammock Creek in a mud-floored elliptical depression approximately 10 feet in diameter and four feet deep at low tide. A small boil is visible at low tide. The spring discharges fresh water during low tide and its water quality changes significantly over a tidal cycle.

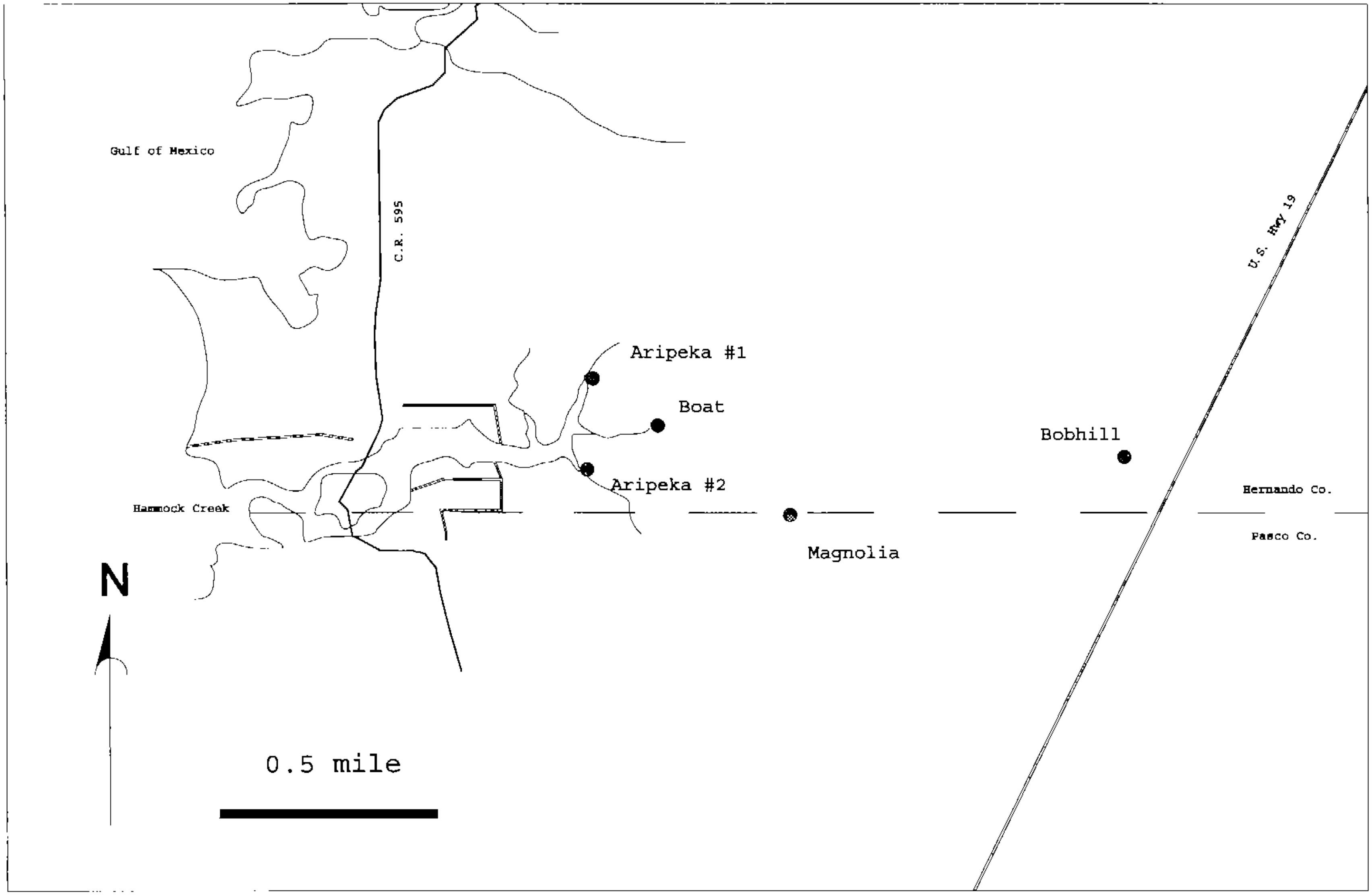


Figure 19. The Aripeka Spring Complex and Vicinity.

Aripeka #2

Aripeka #2 is located in a small embayment on the northern shore of the southernmost prong of Hammock Creek in a mud-floored circular depression approximately 10 feet in diameter and four feet deep at low tide. A small boil is visible at low tide. The spring discharges fresh water during low tide and its water quality changes significantly over a tidal cycle.

Boat

Boat Spring is located approximately 0.7 miles northeast of the town of Aripeka at the head of Hammock Creek. According to Rosenau *et al.* (1977), Boat Spring consists of five spring vents in cavernous limestone in the north half of a pool that is 40 feet long and 20 feet wide. The spring level is partly controlled by the stage of Hammock Creek. The spring discharges fresh water during low tide and its water quality changes significantly over a tidal cycle (Yobbi, 1992).

Magnolia

Magnolia Spring is located at the end of a small tributary of Hammock Creek, just south of the Pasco-Hernando County line approximately 0.5 miles east of the town of Aripeka. The spring vent is at the center of a 30 by 60 foot pool at a depth of approximately six feet. The spring probably always discharges fresh water, regardless of tidal stage, and its water quality does not appear to change significantly over a tidal cycle (Yobbi, 1992).

Bobhill

Bobhill Spring is located 500 feet west of U.S. 19 in a trailer park, seven miles south of Weeki Wachee Springs. According to Rosenau et al. (1977), the spring flows from a single vent, 10 feet in diameter, in the sand-covered limestone bottom of a 100-by-200 foot oval pool with concrete walls and perimeter walk. The vent is 15 feet below the surface. The spring discharges west to the Gulf of Mexico through Bayou Creek and Bayou Lake.

Although Rosenau *et al.* (1977) report a prominent, continuous boil on the surface of the pool, AGWQMP staff have never observed it. In addition, AGWQMP staff report that the spring run was completely dry during the dry-season months of 1994. The spring is well inland of the other springs and, therefore, always discharges fresh water.

Discharge

The average discharge of the springs in the Aripeka Spring complex included in this investigation is probably less than 10 cfs. Although this discharge is very low compared to the other spring complexes, there is probably considerably more water discharging from unknown spring vents, through sediments in the bottom of Hammock Creek, and in the Gulf of Mexico near the mouth of Hammock Creek. Table 5 contains discharge information for the springs.

Table 5. Discharge Information for Springs in the Aripeka Complex.

SPRING NAME	AVERAGE DISCHARGE (CFS)	NUMBER OF MEASUREMENTS	YEARS MEASUREMENTS TAKEN
Aripeka #1	Unknown (<5?)	0	N/A
Aripeka #2	Unknown (<5?)	0	N/A
Boat	1.25	7	1988-1989
Magnolia	0.69	7	1988-1989
Bobhill	2.56	5	1988-1989

STUDY DESIGN, METHODS, AND DATA COLLECTION

The study design and methods of investigation were formulated in January of 1994 by members of the AGWQMP section and Dr. Sam B. Upchurch of ERM-South. The complexity of the problem dictated that the investigation employ a wide variety of geological and geochemical analysis techniques to reach meaningful conclusions. The following is a discussion of these techniques, their implementation, and results.

DELINEATION OF THE STUDY AREA

The study area is divided into four ground-water basins (recharge areas) that supply water to the spring complexes (Figure 20). The ground-water basins were delineated using the September 1994 potentiometric map of the Upper Floridan aquifer (Metz, 1995). Basin boundaries were approximated by drawing flow lines from potentiometric highs to the coastal discharge region, forming flow divides between the spring complexes. The ground-water basins begin at potentiometric highs in southeast Hernando County, central Pasco County, and northern Polk County, and from areas of probable recharge along Lake Tsala Apopka (Rutledge, 1978) in the northeast corner of the study area.

The ground-water basins for the Chassahowitzka, Weeki Wachee, and Aripeka spring complexes cover approximate areas of 190, 390, and 60 square miles, respectively, and are all within the delineated study area. Based on the methodology described above for delineation of the ground-water basins, the Homosassa Springs ground-water basin is by far the largest and extends well outside the study area. The Homosassa basin encompasses approximately 960 square miles, and begins at the Green Swamp potentiometric high in northern Polk County; nearly 70 miles to the southeast.

The disproportionate size of the Homosassa Springs ground-water basin may be due to limitations of the available potentiometric data from which the basin delineation was made. Interactions between the Floridan aquifer and the Withlacoochee River, a major hydrologic feature in the study area, may not be well represented on the potentiometric map. Previous studies of the hydrology of the Withlacoochee River basin (Anderson and Laughlin, 1982; Kimery and Anderson, 1987) indicate there is significant connection and interchange of water between the river and the Floridan aquifer.

During periods of high ground-water levels, ground-water discharge most likely occurs along the entire length of the Withlacoochee River in the study area, which would intercept shallow ground-water flow from a major portion of the Homosassa Springs basin outside the study area. Conversely, sections of the Withlacoochee River have been shown to act as recharge sources for the Floridan aquifer (Kimery and Anderson, 1987). The implications of the Withlacoochee River as a ground-water flow divide, and the recharge potential of the Tsala Apopka system, are only vaguely apparent from the potentiometric map, but are important factors in considering the extent of the effective ground-water

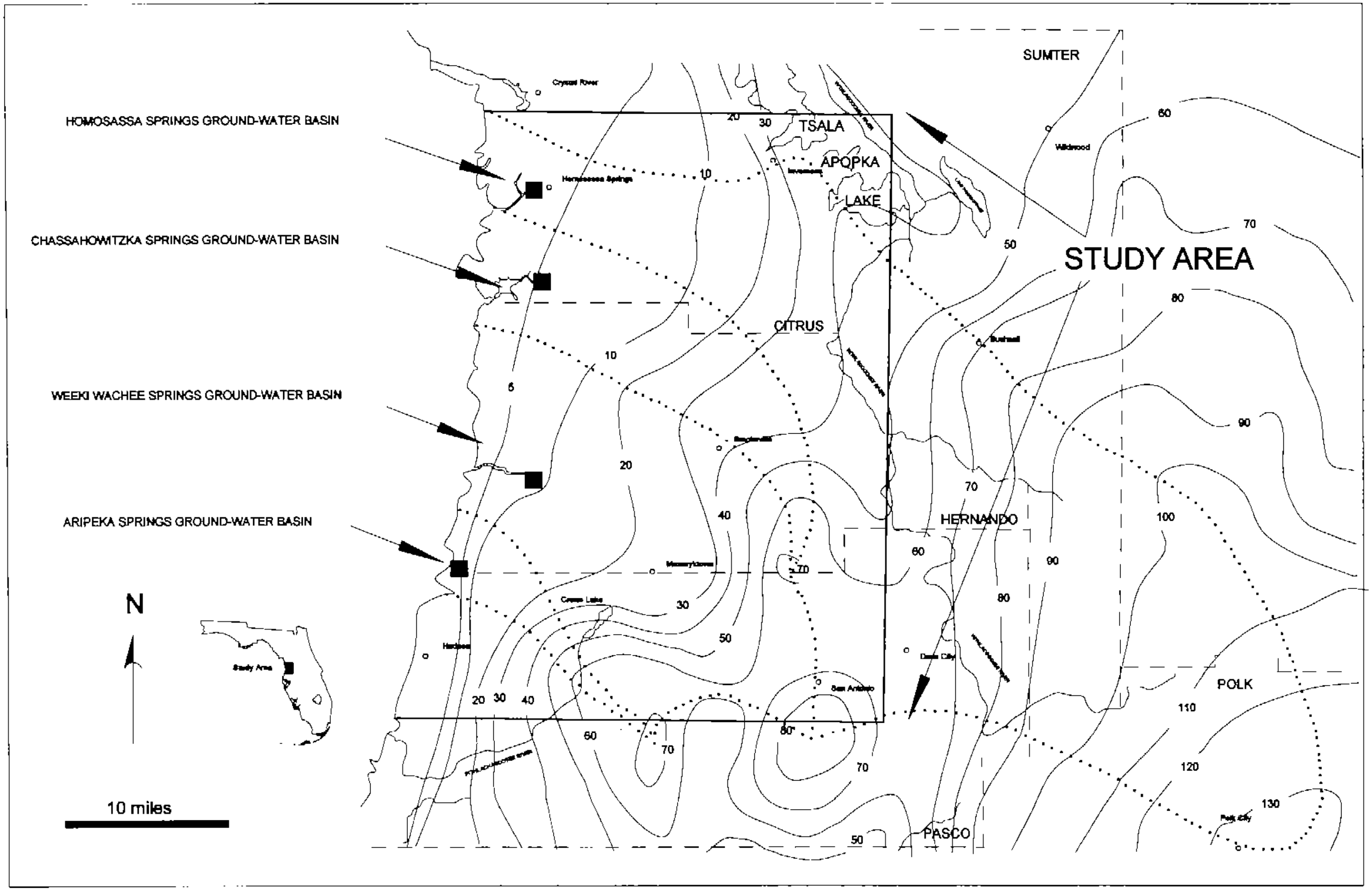


Figure 20. Extent of the Recharge Areas for the Major Spring Complexes in the Study Area and the September 1994 Potentiometric Surface of the Floridan Aquifer (Metz, 1995).

basin for the Homosassa Spring complex. Finally, the travel time of water in the Floridan aquifer from the Green Swamp to the coast is long (hundreds to thousands of years). Therefore, it is unlikely that water from the distal portions of the ground-water basin has any impact on modern spring discharge. For these reasons, and others previously stated, the Homosassa Springs ground-water basin is restricted to the area within the boundary of the study area, which consists of an area of approximately 375 square miles.

Recharge to the Floridan aquifer occurs over most of the basin areas, except (1) in the immediate region of coastal discharge and (2) where relatively impermeable deposits overlie the aquifer. In these areas, recharge water may enter the aquifer after flowing laterally for short distances to areas where confining beds are thin or breached by sinkholes. Discharge occurs mainly in the western coastal margins of the ground-water basins, and along the Withlacoochee River to the northeast of the restricted Homosassa Springs ground-water basin.

STUDY-AREA WIDE MONITOR-WELL NETWORK

The most important tool in determining the source of nutrients in the springs was the water-quality data obtained from the monitor-well network. The network was composed of existing, dedicated monitor wells and wells used for domestic and public supply. Private wells were carefully screened to insure that samples could be collected prior to the point where water entered a treatment device. Figure 21 is a map showing the locations of the 121 wells that remained in the network. Well specifications are listed in Appendix I.

Samples were obtained from 130 wells that were initially included in the network. The samples were analyzed for an extensive suite of chemical analytes. Based on an analysis of the water-quality data, nine wells were eliminated. Three wells had low pH values (< 6.2), which, indicated the wells were probably open only to the surficial aquifer. Three wells were open to the transition zone (chloride concentration > two standard deviations from the population mean). Two wells had calcium to sodium ratios that indicated the sample was subjected to a water softener before it was collected, and one well was located directly adjacent to a well with similar water quality.

To insure that the interval monitored by the well network was the upper-most flow zone of the Floridan aquifer, depth below land surface of the 121 remaining wells was carefully evaluated. Of the 121 wells, total depth was known for 89 percent and cased depth was known for 83 percent. All but two wells had total depths that ranged from 31 feet above to 320 feet below sea level. This was considered to be a relatively discrete, hydraulically connected, and well mixed interval of the upper Floridan aquifer. Two wells were outside of this range with total depths of 470 and 562 feet. However, these wells were not eliminated because the mean concentrations of their analytes were not more than two standard deviations from the population means.

Although total depth was not known for 13 of the 121 wells, none of these were eliminated because the mean concentrations of their analytes did not exceed two standard deviations from the population means.

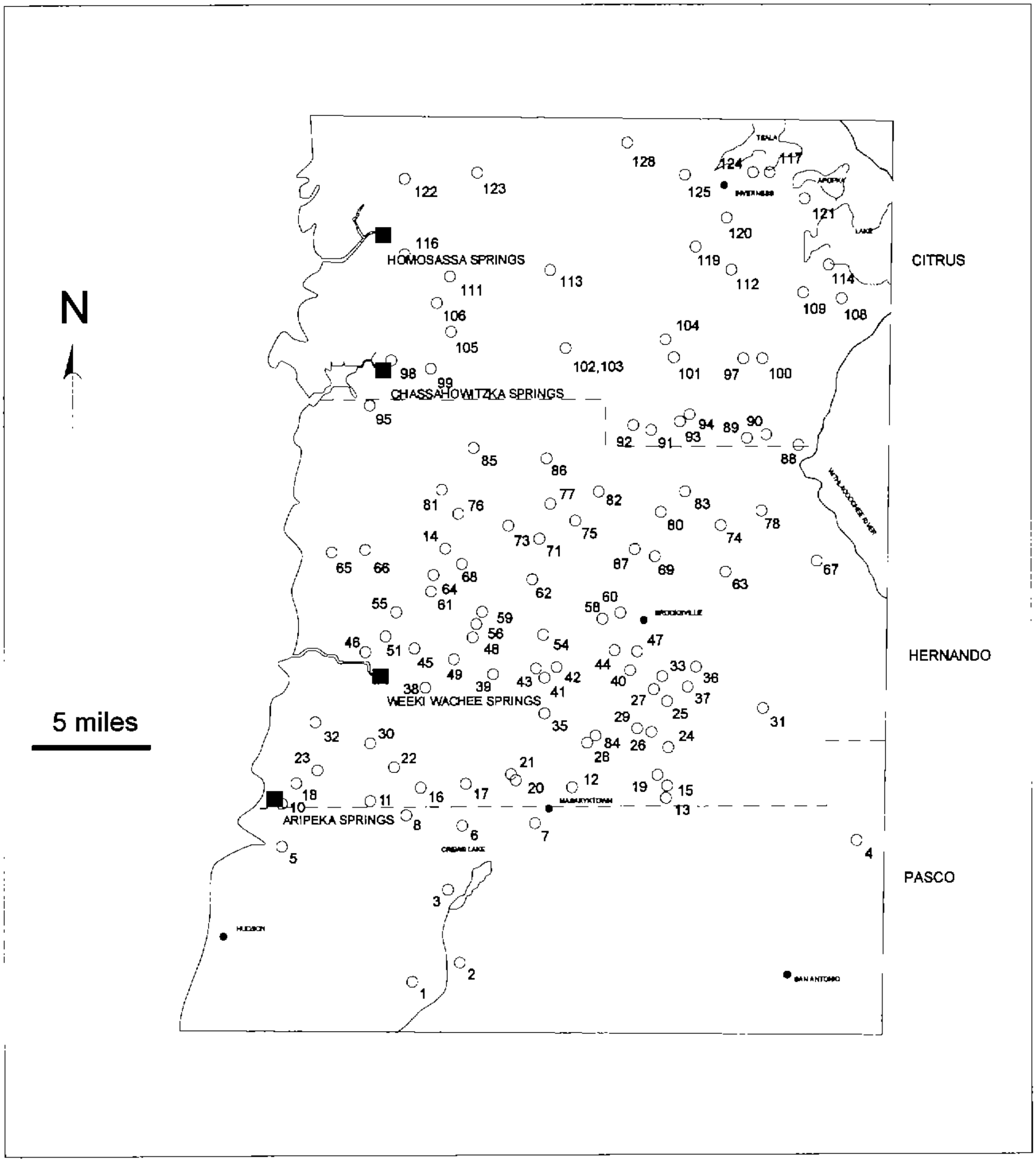


Figure 21. Location of Wells Sampled in the Study Area.

WATER-QUALITY SAMPLING OF MONITOR WELLS AND SPRINGS

Water-quality sampling of springs and monitor wells by the AGWQMP was the most time consuming and labor intensive aspect of the study. All water-quality data obtained from the analysis of monitor well and spring samples are included in Appendices II and III respectively. Methods used are current, U.S. Environmental Protection Agency (U.S. E.P.A.) -approved standard methods, where available.

Analytes

The analytes selected for analysis from spring and well samples are listed in Table 6. In addition to the traditional list of analytes, two isotopic analytes, nitrogen and uranium, were measured for selected samples. Tritium is also addressed in this report, but wells in the network were not sampled for it. This was because sufficient work on characterization of tritium activities in ground water in and near the study area had been done previously (Swancar and Hutchinson, 1992; Jones and Upchurch, 1994). Because of the high cost of analysis, the number of samples analyzed for isotopic composition was limited. Samples were selected to cover the range of land uses and water-quality variability in the study area.

Table 6. - Chemical Analytes Used in the Study.

pH	Potassium	Ammonia Nitrogen
Temperature	Bicarbonate	Orthophosphate
Total Dissolved Solids	Sulfate	Total Phosphorus
Specific Conductance	Chloride	Total Organic Carbon
Calcium	Fluoride	Iron
Magnesium	Nitrate Nitrogen	$^{234}U/^{238}U$*
Sodium	Nitrate/Nitrite Nitrogen	$^{15}N/^{14}N$*

*Analyzed on a subset of samples (see text).

Monitor-Well Network

All network wells were sampled for the non-isotopic analytes listed in Table 6. Twenty-three wells were also sampled for isotopes of nitrogen and 18 wells were sampled for isotopes of uranium.

Springs Network

Thirty springs in the study area were sampled from two to thirteen times between October of 1993 and April of 1997 for the analytes listed in Table 6. Sixteen of the springs have been sampled quarterly beginning at times varying from late 1993 to late 1994 and will continue to be sampled indefinitely for the analytes listed in Table 6. In addition to the conventional parameters, seven of the springs were sampled for isotopes of nitrogen and nine were sampled for isotopes of uranium.

CHARACTERIZATION OF THE FLOW SYSTEM

The presence of sinkholes, internal drainage, and springs in the study area indicate that a well-developed, underground flow system exists in the Floridan aquifer. To characterize the system in terms of its extent, the location of major flow zones, and rate of movement of ground water through the system, a number of different investigations were performed. These are discussed below.

Sinkhole Reconnaissance and Fracture Trace Analysis

To delineate the areas of high recharge, karst features were mapped in the study area. This was done using the District's Arc Info-based Geographic Information System (GIS). Significant karst features were delineated by selecting the topography layer and isolating closed contours that enclosed areas in excess of 20 acres. Locations and shapes of the features are plotted in Figure 22. From the figure it is apparent that a large number of areally extensive sinkholes, some covering up to several square miles, are located in the study area. Sinkholes exist predominantly in the Brooksville Ridge Physiographic Province, although a number of very large sinkholes are located in the Coastal Lowlands Province in Hernando County. Although sinkholes are present across all of the study area, Plio-Pleistocene marine deposition has buried (and masked) many karst features in the Coastal Swamps and the majority of the Coastal Lowlands Provinces.

Fracture traces are the surface expressions of subsurface fractures. Fracture traces can be composed of aligned hydrologic features such as lakes and rivers, sinkholes and springs, and linear vegetative and soil tonal patterns. The identification of fracture traces is important because the underlying fractures tend to control the development of karst features. In addition, fractures can be the primary paths of ground-water flow in a karst area. To facilitate the identification of fracture traces, black and white aerial photographs from the 1950's and 60's were used in conjunction with USGS topographic maps and the map of closed depression features discussed in the previous paragraph. In Figure 22, fracture traces identified by the authors are superimposed on the closed depression features to show how the fractures often control sinkhole development in an area.

Tracer Testing

A tracer test was conducted in April of 1996 between the Weeki Wachee Main Spring and one of the Diepolder sinkholes, located approximately 2.5 miles northeast of

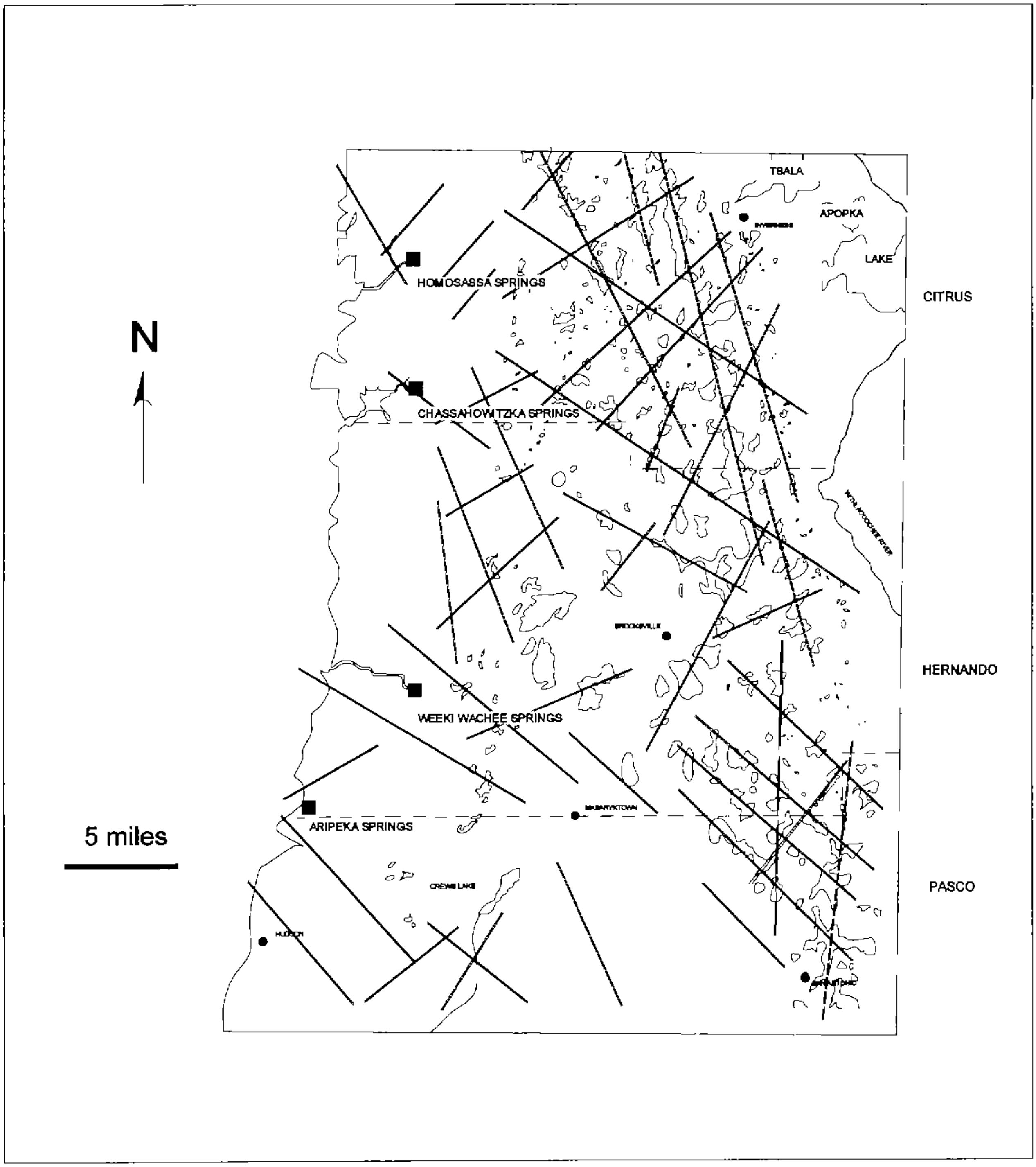


Figure 22. Closed Depression features Greater Than 20 Acres in Area and Selected Fracture Traces in the Study Area.

the spring, to determine ground-water velocity in the vicinity of the spring complex. The Diepolder sinks consist of two sinkholes that are open along fractures that descend to depths of nearly 200 feet into the Ocala Limestone. At the base of Diepolder #1, the fracture opens to a large passage that divers have explored for over 3000 feet in the direction of Weeki Wachee Spring (personal communication Dustin Clesi, cave diver, 1996).

On April 1st, 1996, AGWQMP staff, along with a team of divers led by Dustin Clesi, pumped several hundred gallons of water containing 50 pounds of dissolved Blankophor BBH, a colorless optical brightener, through a 250 foot hose that extended into the horizontal passage of Diepolder #1 at the base of the fracture. Also on April 1st, an American Sigma automatic sampler was placed a short distance down stream of the Weeki Wachee Main Spring and set to collect samples every three hours. The samples were checked for the presence of the tracer at the SWFWMD laboratory using a fluorometer. As an additional indicator for the presence of the tracer, cotton balls capable of absorbing the tracer were placed at the main spring and also at Twin Dees Spring. The cotton balls were checked for the presence of the tracer every three days using a hand-held ultra-violet light. Unfortunately, the automatic sampler malfunctioned and did not begin collecting samples until April 3rd. Collection of samples ceased on May 13th. Placing of the cotton balls began on April 3rd and ceased on May 13.

The results of the test were disappointing as the tracer was not detected in any of the samples or cotton balls. There are several possible explanations for the negative results. First, an underground connection between Diepolder Sink and Weeki Wachee Main and Twin Dees Springs does not exist. Second, all of the tracer came through between the time of injection on April 1st and the collection of the first samples on April 3rd. Third, the tracer was injected at concentrations that were too low. By the time the tracer reached the spring, it's concentration was diluted to a level that could not be detected. Finally, the tracer reached the spring after the test was terminated on May 13th.

GROUND-WATER CHEMISTRY: STUDY AREA

Data obtained from ground-water samples collected from the monitor-well network were analyzed through the use of hydrochemical facies techniques and by contouring the concentrations of major analytes. In this section, a conceptual ground-water quality model was developed by using the above techniques to correlate the geology, hydrogeology, and land use of the study area with the distribution and occurrence of the major analytes.

CONCEPTUAL MODEL

The occurrence and distribution of the major analytes in the study area are affected by a number of geologic, hydrologic, atmospheric, and anthropogenic factors. These include 1) the thickness of Hawthorn Group clays in the Brooksville Ridge, 2) major sinkhole features, 3) the fresh-water/salt-water transition zone along the coast, 4) Lake Tsala Apopka, 5) the chemistry of rainfall, 6) the presence of extensive agricultural and urban development, and 7) the presence of large limestone quarries northwest of Brooksville. These features are depicted in Figure 4 (land use), Figure 7 (thickness of the confining units), Figure 11 (position of the 250 mg/l chloride isoconcentration line), Figure 22 (closed depression features), and Figure 23 (location of quarries and areas in the Brooksville Ridge where the Hawthorn Clays are thin to absent). The relationship of the features to ground-water quality is explained in the following paragraphs.

The Brooksville Ridge in the Vicinity of the Town of Brooksville

A combination of geologic and anthropogenic factors has resulted in many of the analytes having their highest or lowest concentrations centered around Brooksville and the quarry area shown on Figure 23. The geologic factor responsible for this is the absence of significant Hawthorn clays in the Brooksville Ridge from just south of Brooksville to just north of the Citrus/Hernando County line. Because the clays are thin or missing, rainfall is able to percolate directly into the aquifer. Wells in this area have the lowest pH and temperature in the study area, which reflects the lower pH and temperature of recharge.

Anthropogenic factors that influence ground-water quality in this area include the town of Brooksville and large limestone quarries northwest of Brooksville. The highest calcium and bicarbonate concentrations are centered on the western side of the area, where the Hawthorn clays are minimal in extent and thickness and direct rainfall recharge is occurring. A possible explanation for these elevated concentrations may be related to the presence of limestone quarries. The quarries are large excavations into the Suwannee Limestone that cover many square miles. The limestone is excavated and crushed for use as road base and in cement manufacture. Since the mines drain internally, some of the crushed limestone dissolves and the dissolution products enter the Floridan aquifer. In addition, transport of the material by wind distributes the finer-grained particulates where their dissolution products would eventually be flushed into sinkholes by rainfall. Acidic

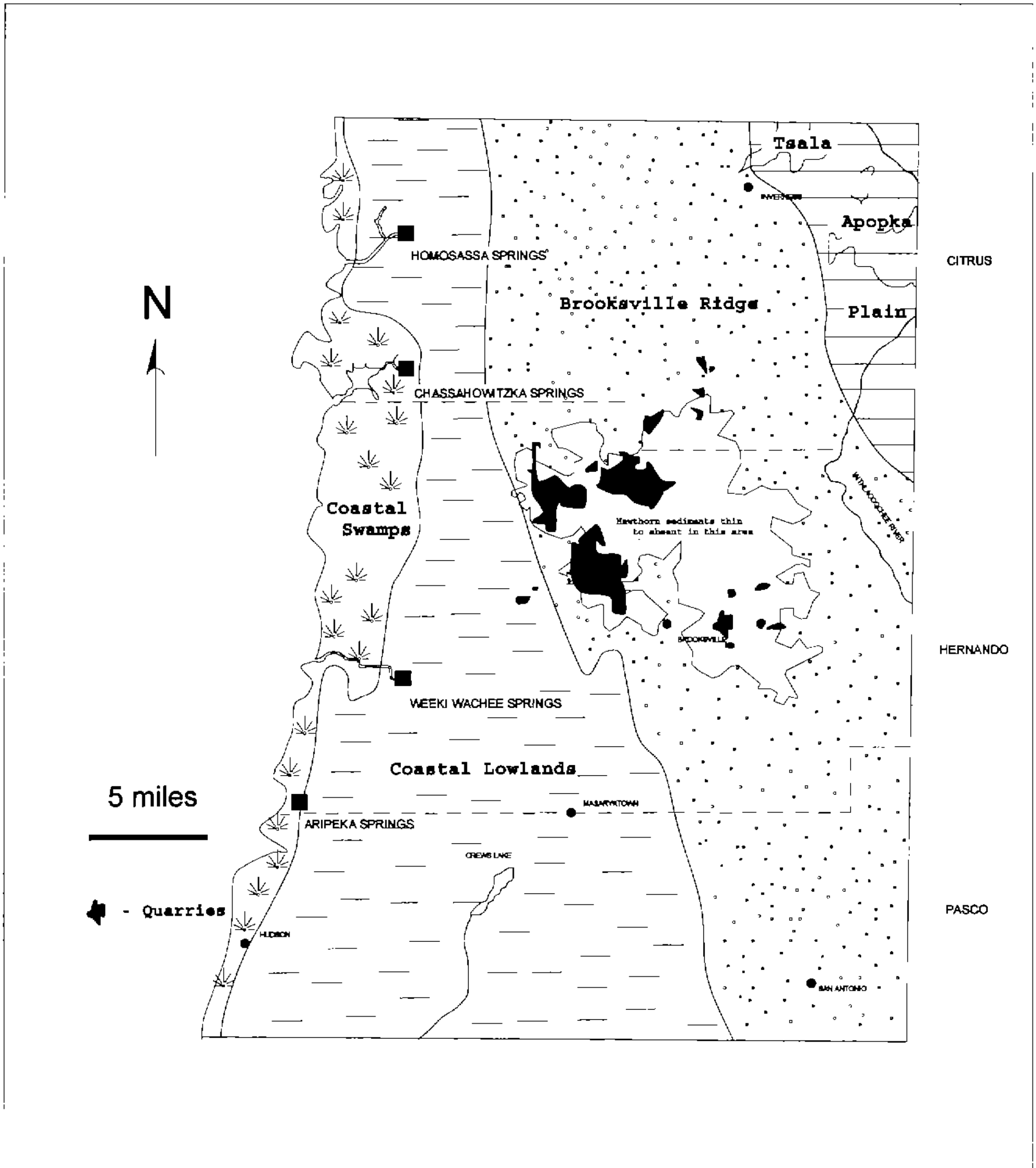


Figure 23. Location of Quarries and Areas in the Brooksville Ridge where Hawthorn Clays are Thin to Absent.

rain water readily dissolves the crushed limestone which increases the calcium and bicarbonate concentrations in the Floridan aquifer and raises the pH. If so much limestone is dissolving in Floridan aquifer water, the pH should not be as low as the data indicate. However, without the buffering action of the limestone from the quarries, the pH might be even lower due to direct recharge of low pH rainfall (statewide average rainfall pH = approximately 4.8; Upchurch, 1993).

The town of Brooksville may play a role in elevating the concentrations of some of the major ions. Wells within two miles of Brooksville, in a southwesterly direction, show elevated concentrations of chloride and sulfate. A possible explanation is as follows. Because of the proximity of Florida to the Gulf of Mexico and the Atlantic Ocean, rainfall is typically enriched in sodium, chloride, sulfate and other analytes. When rain falls and evaporates in the Brooksville area, these minerals are left behind and concentrated on artificial surfaces. The minerals are dissolved in storm water during subsequent rainfall events and much of this storm water drains to a series of large sinkholes to the southwest of town where it enters the Floridan aquifer.

Fresh-Water/Salt-Water Transition Zone

The concentrations of the major ions and nutrients (with the exception of nitrate) are elevated along the coast of the study area. The major ions are elevated because high-TDS ground water located seaward of the transition zone is mixing with low-TDS ground water that has moved westward from the recharge areas further inland. The nutrients are elevated because organic-rich, surface water from the extensive coastal forests and swamps is locally recharging and mixing with the aquifer water along the coast.

Lake Tsala Apopka

The concentrations of all the major ions and nutrients in ground water are elevated in the vicinity of Lake Tsala Apopka. Water in Lake Tsala Apopka is slightly enriched in the major ions as a result of evaporative concentration. It is also enriched in nutrients because of the decay of organic matter in the water column, organic material in lake sediments, and possibly because of nutrient loading from fertilizers and human and animal waste. Because the lake is essentially a large karst feature, large volumes of water recharge into the Floridan aquifer during the dry season, which, raises the concentrations of analytes in the surrounding ground water (Jones and Upchurch, 1994).

HYDROCHEMICAL FACIES

Hydrochemical facies analysis (Upchurch, 1993) is an excellent way to place a series of water-quality analyses into a spatial context. The analysis depends on pattern recognition techniques. Using the PLOTCHEM software, individual samples are plotted on Stiff diagrams (Stiff, 1951), which show the relative proportions, in milliequivalents per liter, of major ions in a sample. The size of the Stiff diagram is proportional to the total dissolved solids content of the sample, and the shape conveys a rapid impression of the water type, or dominant ions in the sample. All samples are plotted on a Piper diagram (Piper, 1944), which relates the variations in proportions, but not concentrations, between samples.

Chemical data from 118 of the wells in the study area monitor-well network were used to construct a Stiff diagram for each sample. A Piper diagram was also constructed. Figure 24 displays three Stiff diagrams that are representative of the three principal water-quality types delineated from the well samples. Figure 24 also displays the Piper diagram.

It is apparent in Figure 24 that the wells plot roughly in a straight line across the center of the piper diagram. This pattern, described by Hanshaw and Back (1979), is typical of ground water in unconfined coastal carbonate aquifers. From the graph it is apparent that the samples can be divided into three groups. Group A samples, which plot in the far left portion of the diagram, are open to the portion of the aquifer that is inland of the transition zone. Group A wells contain water that is dominated by calcium and bicarbonate. The majority of wells are clustered in this group. Group C samples, which plot in the far right portion of the diagram, are open to the portion of the aquifer within the transition zone. The wells from which group C samples were obtained are located seaward of group A wells and contain water that is dominated by sodium and chloride. Only five wells are included in this group. Group B samples, which plot in a cluster between group A and group C samples, are transitional between the two groups. The group B samples are dominated by calcium/bicarbonate but have higher concentrations of sodium and chloride than the group A samples. Eight wells produced group B samples and are included in this group.

MAJOR ANALYTES

In this report the major analytes were considered to be pH, bicarbonate, calcium, chloride, sulfate, and TDS. pH is included as an analyte because it is intimately associated with bicarbonate and calcium and it controls chemical interaction with rock materials. TDS is also included because it is a measure of the total concentration of all the major and minor constituents. Other major ions, such as sodium, magnesium, potassium, and fluoride, occur in small but significant concentrations. Contour maps of these ions were not included because their utility was considered to be limited in characterizing ground-water quality in the study area. However, data for these parameters are included in Appendix II.

In Figures 25 through 35, the concentration in milligrams per liter (mg/l), unless otherwise noted, of each major constituent is plotted next to the well from which it was sampled. The SURFER graphics package was used to machine contour the data. The plot files were edited to produce hydrogeologically reasonable maps. No changes were

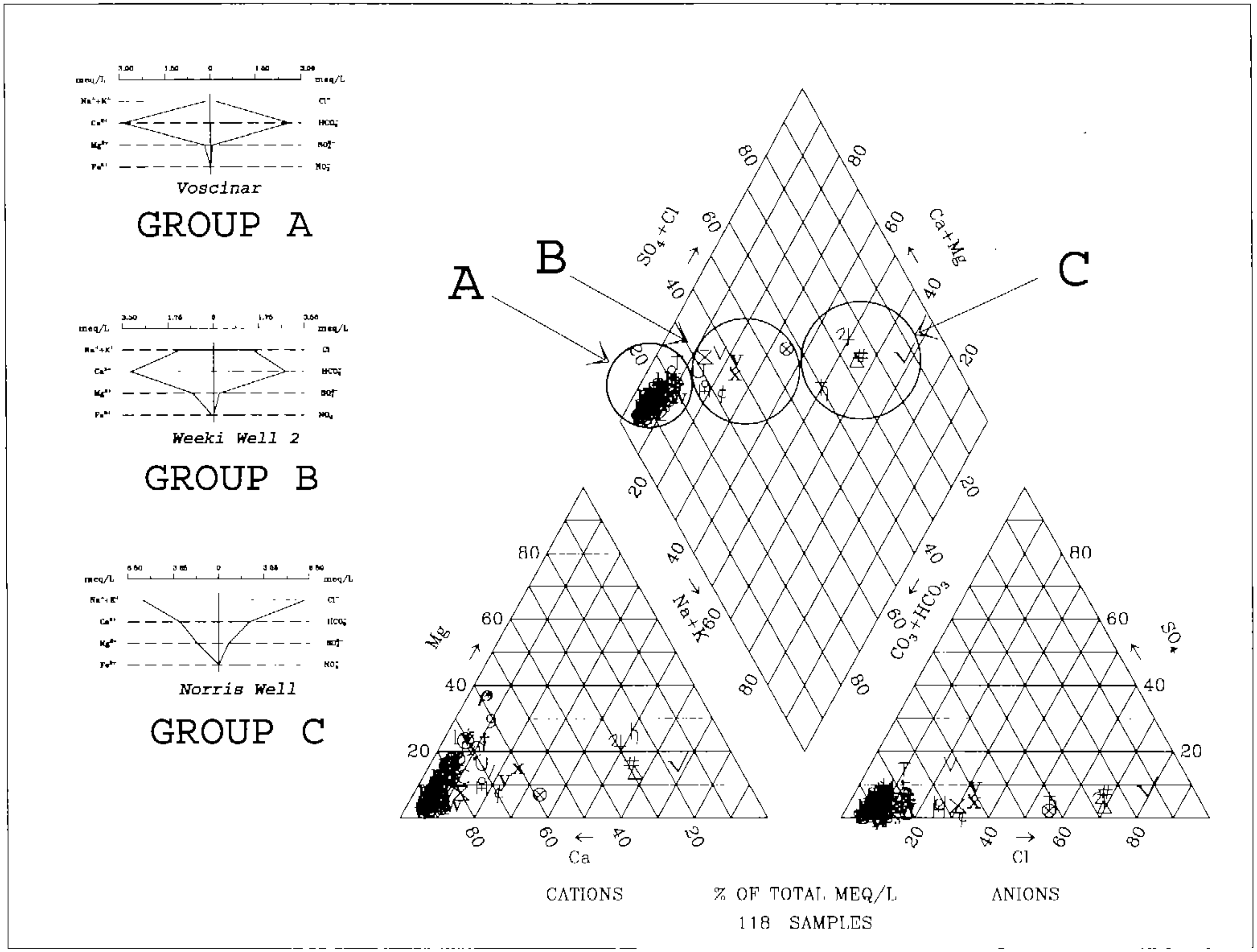


Figure 24. Characterization of Floridan Aquifer Waters from Well Samples Using Piper and Stiff Diagrams.

made to the contour patterns, only unsupported lines and inappropriate contours were changed. The maps, therefore, reflect an independent, quantitative interpretation of the data. To assist the reader's understanding of the concentration contour maps, it should be remembered that a negative sign in front of a concentration indicates the concentration is below the laboratory detection limit.

Bicarbonate, Calcium, and pH

As rainfall passes through the soil layer it becomes increasingly acidic (low pH) as a result of its reaction with carbon dioxide (CO_2) to form carbonic acid (H_2CO_3) and by addition of natural organic acids (humic acid, etc.). Carbonic acid reacts with limestone ($CaCO_3$) to produce dissolved calcium (Ca^{2+}) and bicarbonate (HCO_3^-). As limestone is consumed by carbonic acid, pH increases because carbonic acid is consumed and calcium and bicarbonate are produced. Figures 25, 26, and 27 show the distribution of bicarbonate, calcium, and pH, respectively, in study area ground water.

In a system that is unaffected by human activities, the concentrations of calcium and bicarbonate ions and the pH of ground water in the study area would be important indicators of chemical maturity (extent of chemical equilibrium with the aquifer rock materials). Water that has been in contact with limestone for a relatively short length of time would have low concentrations of these ions and a relatively low pH while water that has been in the flow system for a long period of time would have higher concentrations and a higher pH. However, according to the conceptual model, the presence of the limestone quarries in the study area has resulted in a situation that is just the opposite. Recharge of surface water that has been in contact with fine-grained particles of calcite has caused the most recently recharged water to have the highest calcium and bicarbonate concentrations and a higher pH than expected for water recently recharged from rainfall.

Chloride

Chloride is a chemically conservative[3] element, so it is usually used as a tracer of physical water flow. Rainfall typically contains less than 10 mg/l chloride (Upchurch, 1993). Figure 28 shows the distribution of chloride in the study area. Most of the area has chloride concentrations similar to rainfall, which suggests recently recharged water in a shallow flow system. Areas where concentrations exceed 10 mg/l are either within the transition zone or are in areas where evaporative concentration of rainfall is occurring.

---

[3] A conservative analyte does not react with rock, water, or organic components of the aquifer system. Conservative analytes are changed in concentration only by dilution, evaporation, dispersion, or transpiration. Chloride is the most abundant conservative analyte in water.

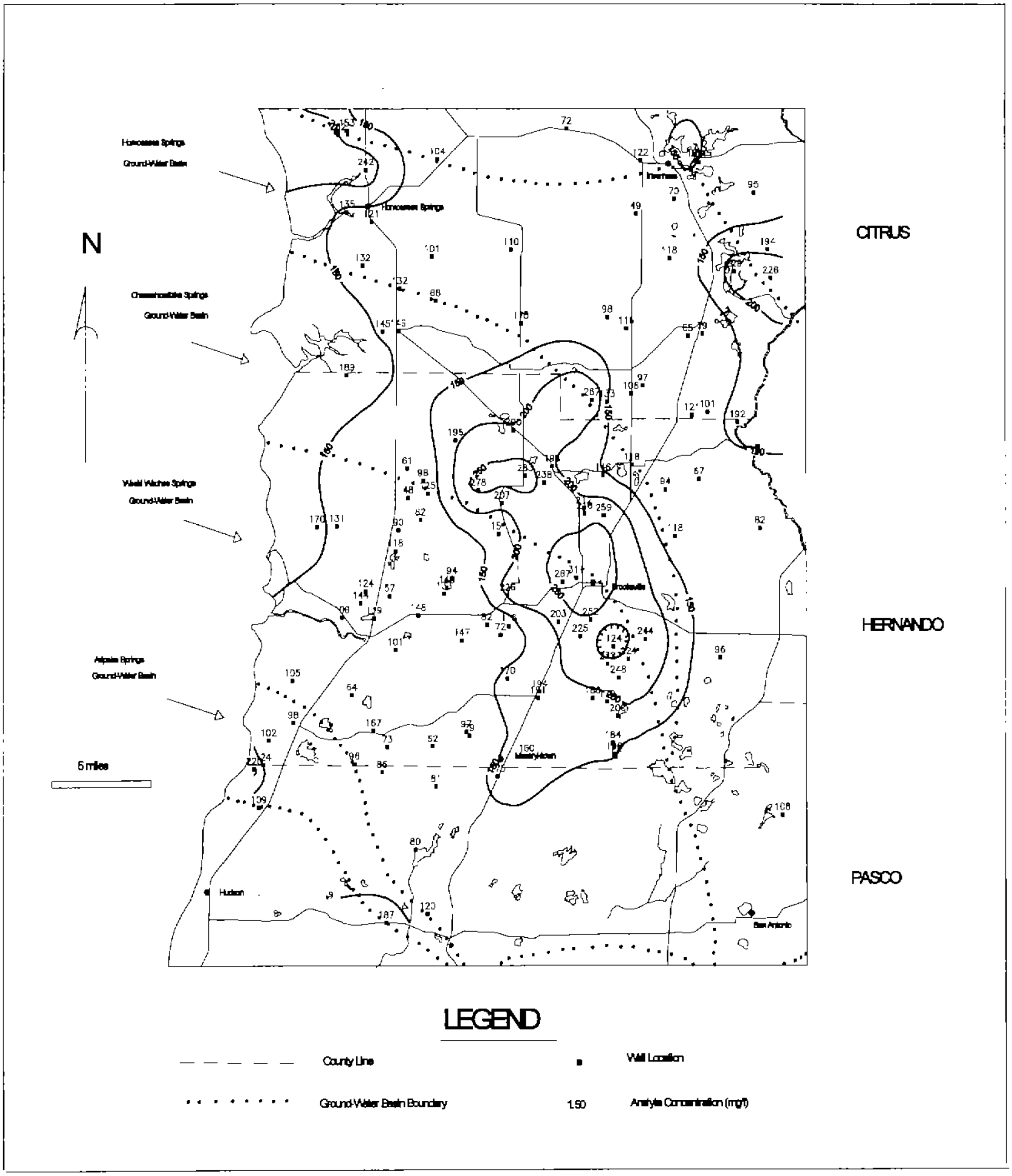


Figure 25. Bicarbonate Concentrations in Floridan Aquifer Ground Water.

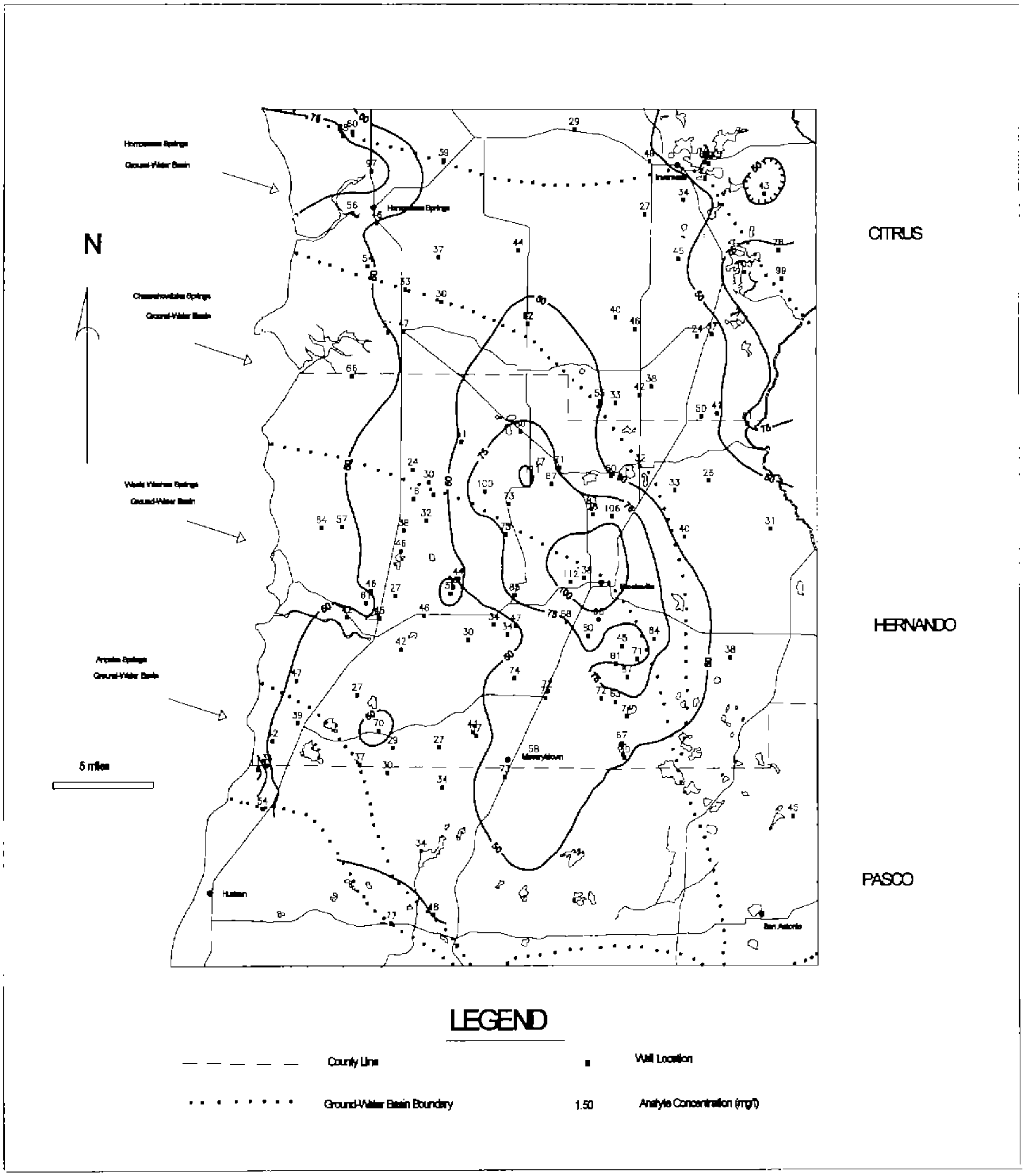


Figure 26. Calcium Concentrations in Floridan Aquifer Ground Water.

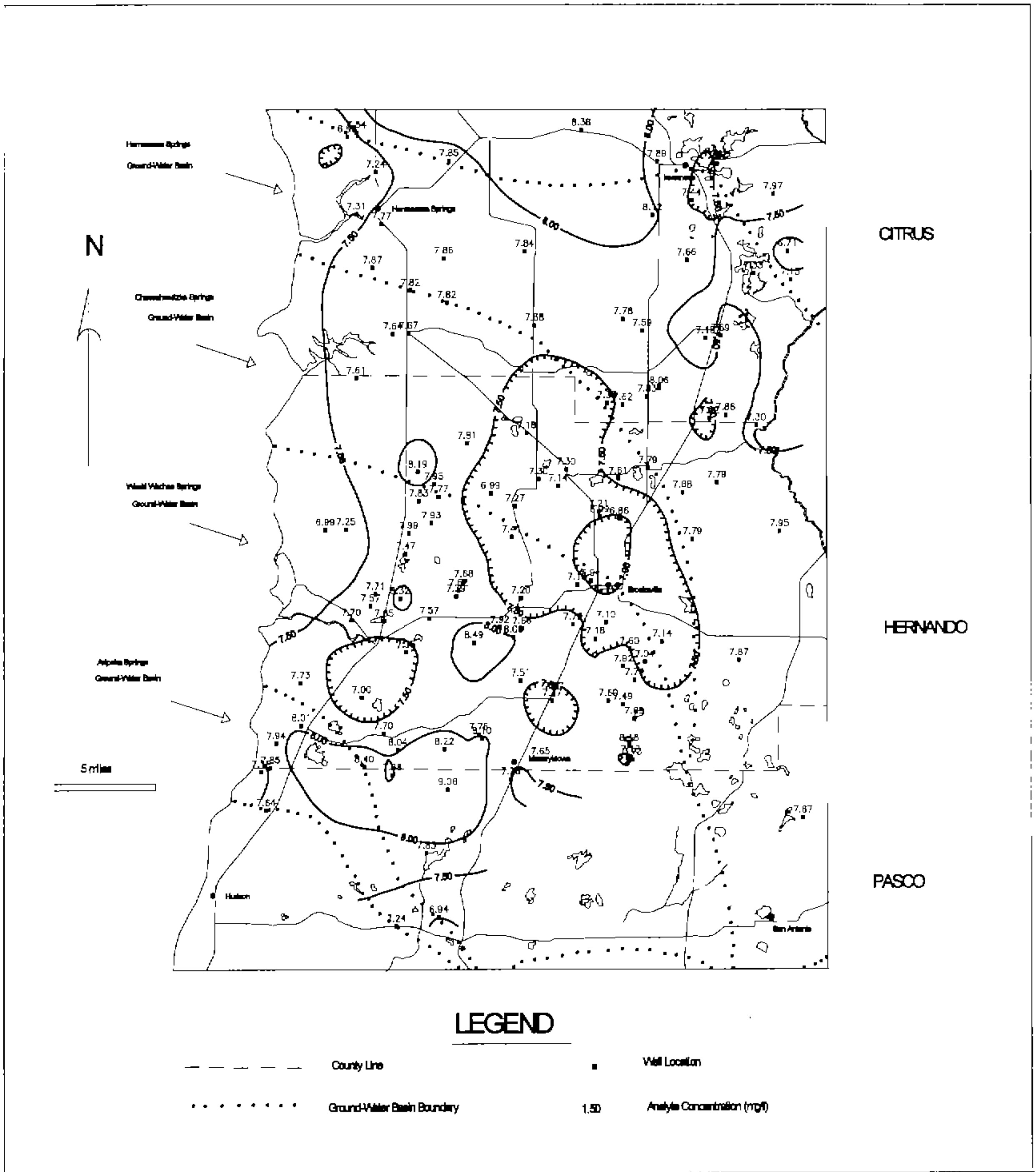


Figure 27. pH in Floridan Aquifer Ground Water.

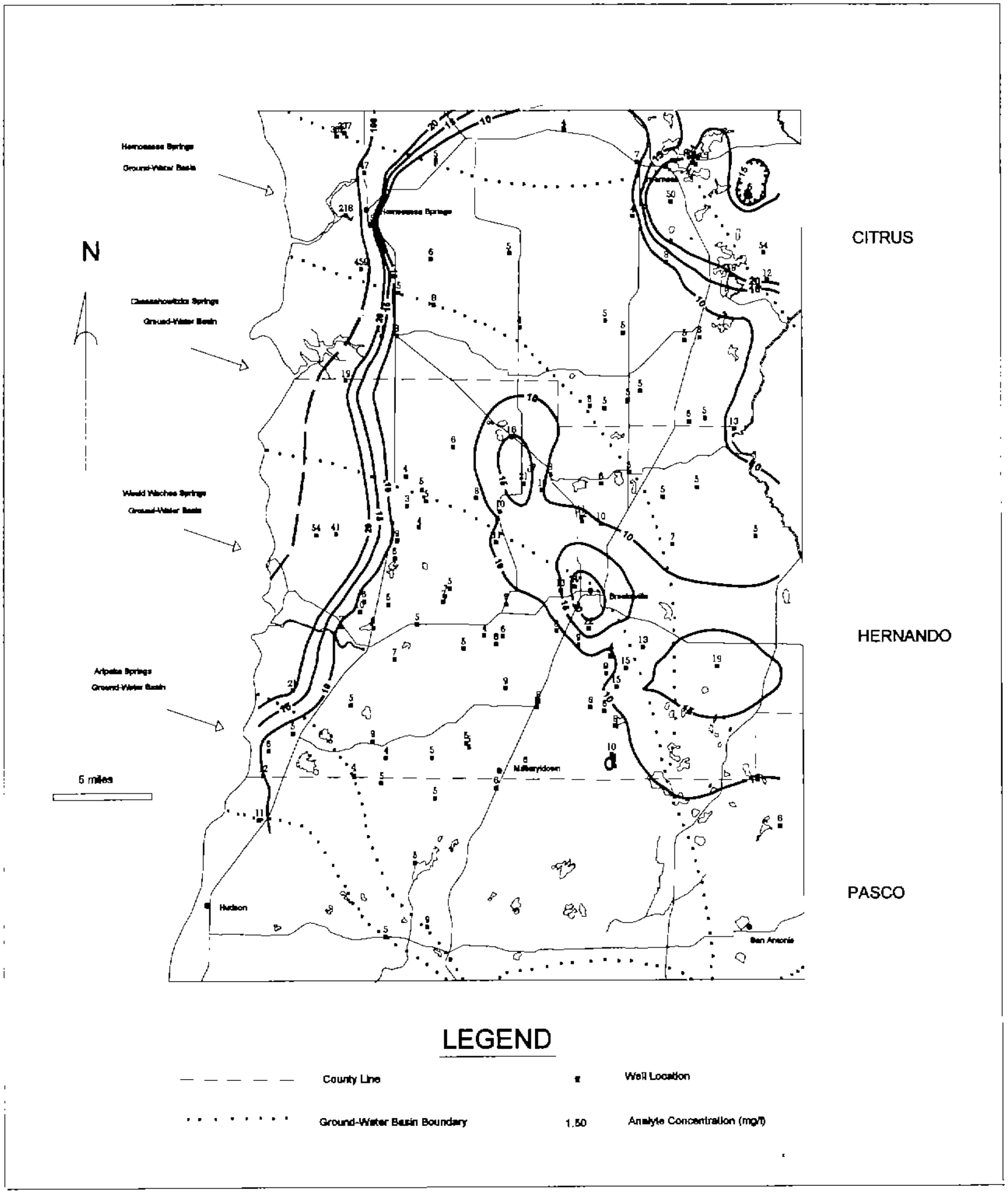


Figure 28. Chloride Concentrations in Floridan Aquifer Ground Water.

Sulfate

Sulfate (SO_4^{2-}) is formed by oxidation of pyrite (FeS_2), a common mineral in marine sediments; oxidation of organics; and dissolution of gypsum ($CaSO_4 \cdot 2H_2O$) or anhydrite ($CaSO_4$). Upchurch (1993) provides examples of these reactions. Pyrite is widespread in Florida rocks, and it is especially abundant in the clays of the Hawthorn Group. Oxidation of organics is also universally important. There is minimal gypsum and/or anhydrite in near-surface sediments, but the base of the upper Floridan aquifer is characterized by these minerals. Sulfate is also abundant in sea water. With the exception of the transition zone, shallow flow-system waters typically contain minor concentrations of sulfate. Deep-flow systems that come in contact with the base of the aquifer may contain significant sulfate, especially near the inner margin of the transition zone (Upchurch, 1993). Therefore, the distribution and concentrations of sulfate can be used to deduce the depth and extent of flow systems and interactions of ground water and host sediments.

Figure 29 shows the distribution of sulfate in study-area ground water. Sulfate concentrations in most of the study area are low enough to indicate that ground water is not reaching the gypsum at the base of the upper Floridan aquifer. Therefore, the flow system that is monitored by the well network is shallow; residence time of ground water in the system is short; and upwelling from the deeper flow system is not occurring (at least not in areas inland of the transition zone).

Sulfate concentrations are elevated in several regions of the study area. The highest concentrations occur along the coast because of the proximity of wells to the transition zone and possibly as a result of water upwelling from a deeper flow system. Concentrations are slightly elevated in an area on the western flank of the Brooksville Ridge near the town of Brooksville and in the vicinity of Lake Tsala Apopka. According to the conceptual model, this may be the result of evaporative concentration of rainfall and decomposition of organics.

Total Dissolved Solids

The distribution of total dissolved solids (TDS) in the study area is shown in Figure 30. Although TDS is a measure of all the chemical constituents dissolved in ground water, in west-central Florida it is most influenced by the concentrations of the major ions: calcium, bicarbonate, magnesium, sodium, sulfate and chloride (Appendix II). The highest TDS concentrations occur along the coast near the transition zone, in the Brooksville Ridge in Hernando County, and in the Lake Tsala Apopka vicinity. The lowest occur on the western and eastern flanks of the Brooksville Ridge and in the central portion of Citrus County.

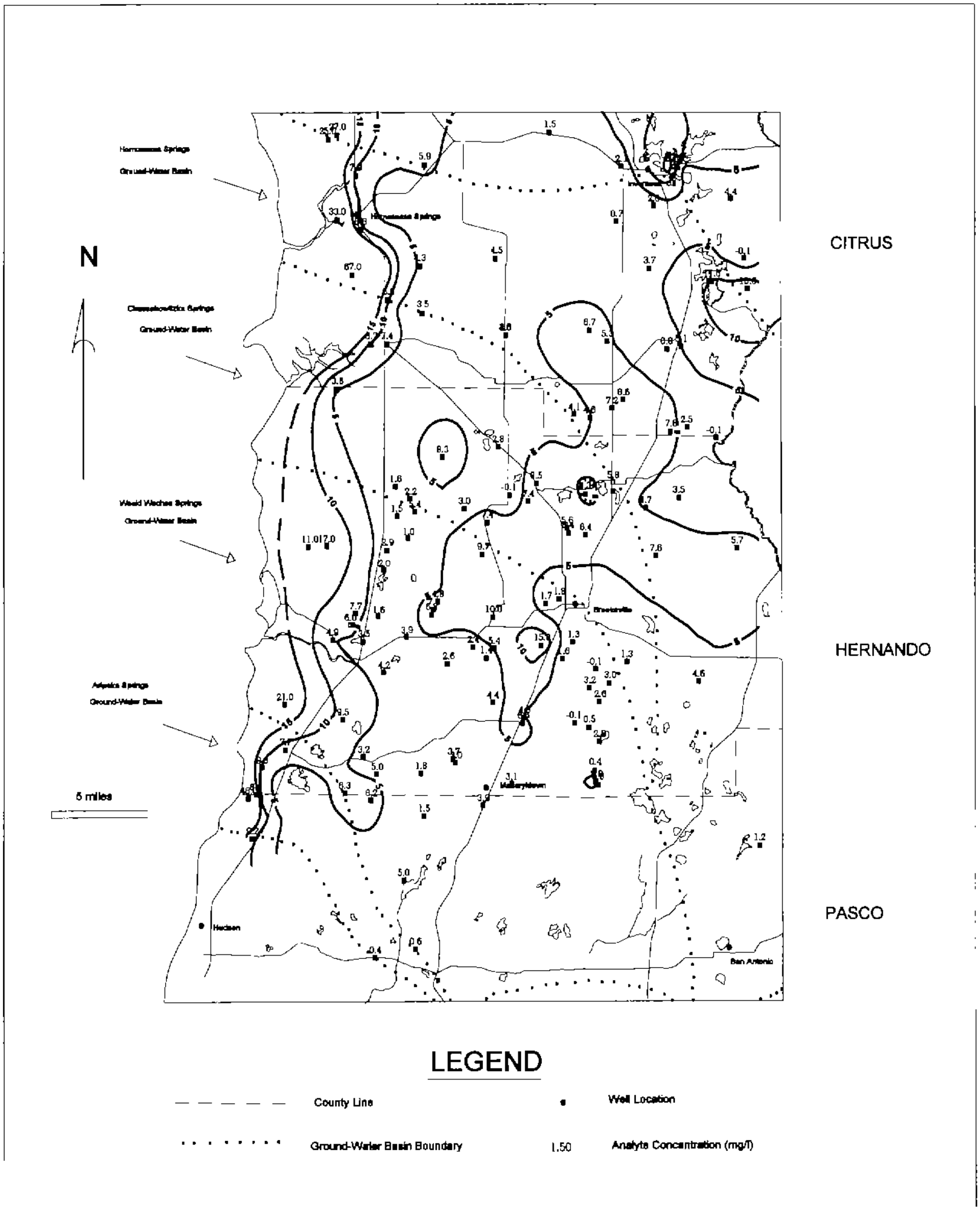


Figure 29. Sulfate Concentrations in Floridan Aquifer Ground Water.

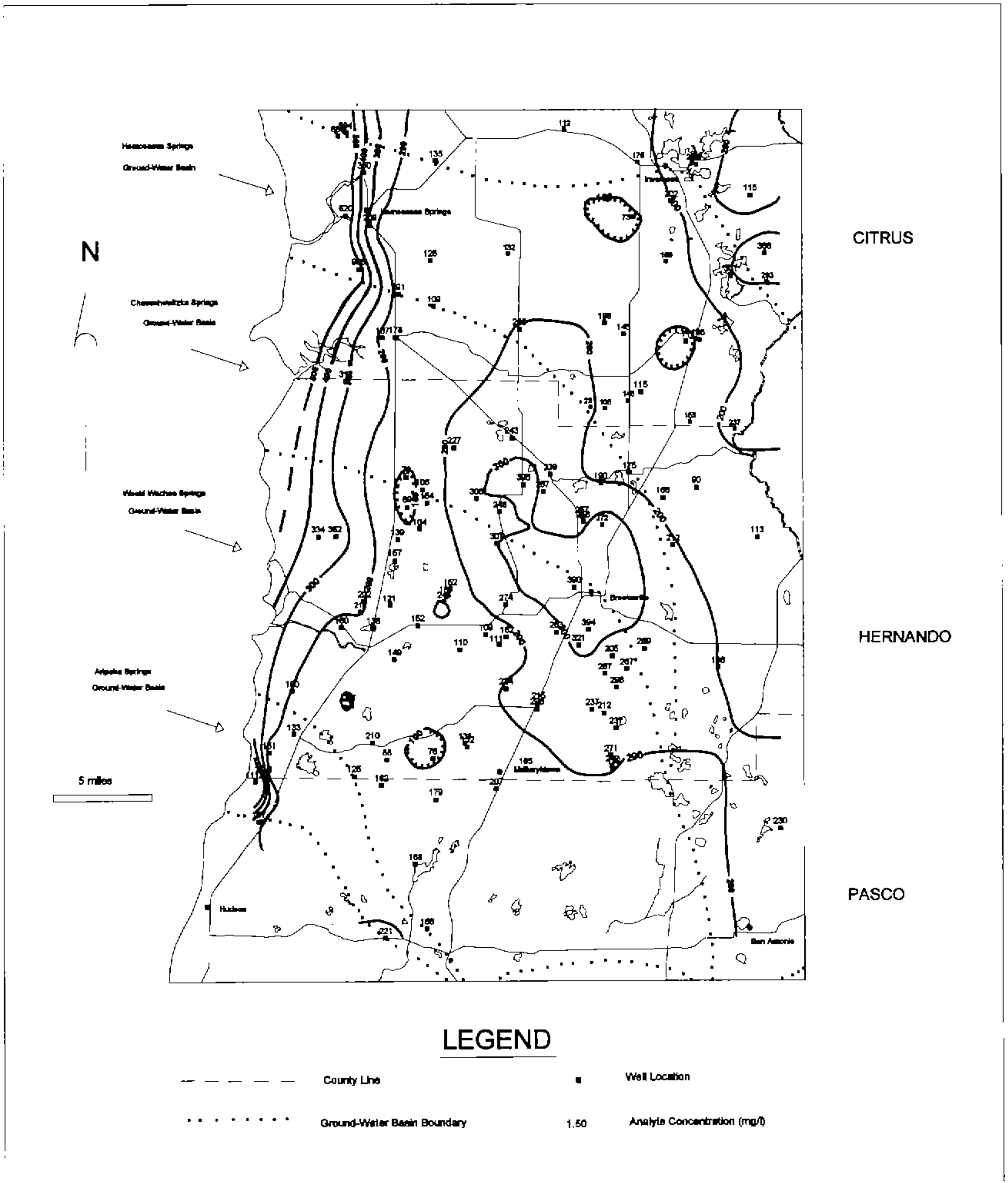


Figure 30. TDS Concentrations in Floridan Aquifer Ground Water.

NITROGEN GEOCHEMISTRY

To understand the loading of nitrogen compounds to ground water, their transformations and movements through the ground-water system, and their ultimate discharge in the coastal springs, it is first necessary to discuss a few basic principals of nitrogen aqueous geochemistry. These principals are discussed in the following section, which contains excerpts from Upchurch (1993) and Bicki *et al.* (1984).

Nitrate (NO_3^-), which is one of the nitrogen species that has been targeted as a source of nitrogen in the coastal springs systems, is one member of a sequence of related nitrogen compounds that also includes nitrogen gas (N_2), nitrogen dioxide gas (NO_2) and other oxides (collectively, NO_X), ammonia and ammonium (NH_3, NH_4^+), nitrite (NO_2^-), and a number of other inorganic and organic compounds. The gaseous phases exist in the atmosphere and in soil atmospheres, but are not of importance in the saturated zones of aquifers. Ammonia gas (NH_3), for example, is likely to escape into the atmosphere. Ammonia is usually present in ground water as the ammonium ion (NH_4^+) because of prevalent pH and reduction-oxidation potentials. The complex, organic compounds can occur as soluble organic molecules and as particulates. Concentrations of ammonium and dissolved, organic-nitrogen compounds, including amino acids and proteins, are reported as Total Kjeldahl Nitrogen (TKN) in samples from aqueous systems and soils. Organic nitrogen is determined by subtracting ammonium/ammonia concentrations from TKN concentrations.

Organic nitrogen, ammonium, nitrite, and nitrate are the compounds considered important in ground-water systems. These compounds are related through a sequence of microbially mediated, reduction and/or oxidation reactions as indicated below

$$\begin{array}{c} \textit{Organic Nitrogen} \rightarrow NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-. \\ \textit{Oxidation} \rightarrow \\ \leftarrow \textit{Reduction} \end{array} \qquad \textbf{(1)}$$

The reduction/oxidation reactions indicated in the above reaction series can be driven by inorganic processes, but the primary mechanisms for the reactions are microbial. If the environment is chemically oxidizing, nitrate will be the final product. In these aerobic environments (>0.3 mg/l dissolved O_2) chemically reduced nitrogen is almost immediately oxidized to nitrite and then to nitrate. These oxidation reactions are known as nitrification reactions. In a reducing environment, the organic nitrogen and/or ammonium will persist. Partially oxidizing conditions may also exist in which the nitrogen compounds only progress part way through the sequence. Where dissolved oxygen concentrations are low, nitrate and nitrite are reduced to nitrogen gas by denitrification bacteria. It is the energy yield of these reduction-oxidation reactions which controls nitrogen behavior and hence its state and concentration in a given aquifer or water body.

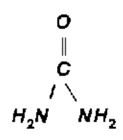
The largest reservoir of nitrogen is the atmosphere, which is 78.93 percent nitrogen, mostly as N_2 gas. NH_3 and NO_3^- occur naturally in the atmosphere as a result of releases by terrestrial plants (Stallard and Edmond, 1981). Atmospheric nitrogen is also converted to NO_X by lightning. Modern precipitation contains NO_x concentrations that are increased over natural levels as a result of combustion of fossil and modern organic fuels. The oxides of nitrogen are then converted by oxidation and hydrolysis reactions to nitric acid (HNO_3), which dissociates to H^+ and NO_3^-. Consequently, precipitation is a source of nitrate, and possibly ammonium, derived from both natural and anthropogenic causes. Nitrate in precipitation in Florida ranges from below detection limits to over 10.0 mg/l, and the statewide mean in precipitation is approximately 1.0 mg/l (Upchurch, 1993). Ammonium ion ranges from below detection limits to over 17.0 mg/l (Upchurch, 1993) and the mean is 0.2 mg/l.

Clearly, conversion of nitrogen compounds in the atmosphere followed by precipitation introduces nitrogen to the ground-water system. Modern rainfall, however, cannot be used as an argument for high nitrogen in ground water discharging from the springs. This is apparently because of the uptake of nitrogen by plants. The low nitrogen-species concentrations in rainfall and sporadic loading through rainfall events supplies nitrogen to the plant cover, and there is apparently little excess nitrogen to pass into the ground-water system. However, direct recharge of storm runoff through sinkholes, drainage wells, or other sources may introduce some of this nitrogen to the aquifer systems.

Certain microbes can fix nitrogen gas in soils. These microbes, in conjunction with plants such as the legumes, directly convert nitrogen compounds into tissues and nitrogenous by-products. Plants require nitrate as a major nutrient, and they are responsible for removal of much of the nitrate that is taken from soils and ground water. Average nitrogen content of living organisms is 16 percent. These living tissues contain amino acids and other nitrogen compounds that can be released back into the environment upon death or waste elimination.

Animal wastes and decaying plant tissues release ammonia and ammonium, nitrite, nitrate, urea[4], and a number of nitrogenous organic molecules. Soil and aquifer microbes metabolize these according to the reduction-oxidation potential of the soils and aquifers. Under reducing conditions, microbes convert these compounds to ammonium, and other reduced-nitrogen species. Under oxidizing conditions, they are converted to nitrate, usually with an intermediate nitrite step.

---

[4] Urea is a principal nitrogen product in urine. It has the structural formula 

. Urea is an excretion product of the liver.

Therefore, in reducing environments, such as water-saturated, reducing soils and aquifers, ammonium may persist and become a part of the ground-water system. Under these circumstances, ammonium can travel considerable distances before sorption, microbe metabolism, dilution, or dispersion reduce concentrations to below detection limits. Ammonium tends to weakly sorb onto clays and soil particles, so some soil and aquifer materials mitigate ammonium migration. Septic-tank systems, land-application waste-treatment systems, and feed-lot wastes can, under circumstances of overloading or failure of sorption systems, cause widespread ammonium contamination.

Oxidizing conditions are necessary for microbes to produce the complex reactions required to make the nitrogen useable for plants. These aerobic microbes convert the ammonium and complex, organic-nitrogen molecules to nitrite and then nitrate. Ammonium and organic-nitrogen compound concentrations are low in most aquifers because oxidizing conditions are widespread near the land surface, where these nitrogen compounds are generated and quickly utilized by plants. Oxidizing conditions occur in oxygenated soils, vadose environments and shallow, oxygenated portions of aquifers.

If nitrate is available in small amounts near the land surface, plants will utilize it. There are also microbes that denitrify soils by conversion of nitrate to nitrogen gas. If nitrate production from ammonium and more complex nitrogen compounds is not completed within the root zone, if the nitrate is unavailable to plants and denitrifying microbes, or if nitrate is produced in quantities too great for biological agents to fix, nitrate migrates with the ground water. Unless conditions for denitrification exist, nitrate will not undergo further transformations once in the ground water (Preul and Schroepfer, 1968; Bouma, 1975; Hall, 1975). As a result, nitrate can travel long distances because the only mechanism that will reduce its concentration is diffusion, dilution, and dispersion into surrounding waters of lower nitrate content (Walker *et al.*, 1973a, b; Hook *et al.* 1978).

Ideal, land-based, waste-disposal practices include sufficient vadose zone and biomass to convert nitrogen compounds to nitrate and then to utilize the nitrate. Unfortunately, high water tables, plugging of soils by particulate matter, under-design of treatment facilities, crowding of waste-disposal facilities or animals on too small a tract of land, and many other factors tend to lead to failures of natural nitrogen-removal mechanisms. Under such circumstances, nitrate, ammonium, and other nitrogen compounds may enter the ground-water system and travel long distances.

Swamps and organic horizons in soils can also contribute natural ammonium and/or nitrate to aquifers. Under most circumstances, however, decay of the organics is sufficiently slow that the nitrogen compounds are utilized within the wetland and adjacent aquifers. High nitrate and ammonium concentrations in aquifers are more likely to be caused by inadequate soil and aquifer conditions and contamination by human or animal wastes or fertilizers.

For microbial decomposition of nitrogenous compounds to occur, there must be a source of organic carbon, and other nutrients. The role of nitrogen-utilizing microbes in deep aquifers has not been adequately evaluated. It appears that microbial transformations analogous to sulfate reduction may occur. Availability of organic carbon and nitrogen compounds is limited in deeper portions of the Floridan aquifer system, so nitrogen-utilizing microbes are probably ineffective in the same way as are sulfate-reducing microbes. Our present concepts suggest that the majority of nitrogen fixation occurs in shallow, oxidizing aquifers and soils.

The presence of nitrate, and the other nitrogenous compounds in ground water, is not considered to be a result of interaction of aquifer system water with surrounding rock materials. Nitrate in ground water is a result of specific land uses. If the land use is widespread, a body of nitrate-enriched water that is large enough to be contoured may result. Otherwise, detection of nitrate is an isolated phenomenon.

The only nitrogen compound for which there is a standard or guidance criterion in ground water in Florida is nitrate, which is subject to a Primary Drinking Water Standard (Florida Department of Environmental Regulation (FDER), 1989a). The limit under the Primary standard is 10.0 mg/l as N, or 44.0 mg/l as NO_3^-. There is a health advisory for nitrate at 1.0 mg/l as N (4.4 mg/l as NO_3^-), as well. The major cause of concern is methemoglobinemia, an excess of methemoglobin[5], which causes oxygen deprivation. This condition is especially hazardous in infants and young children, where it produces a condition known as "blue baby syndrome" (Hersh, 1968; Hem, 1986). There are no standards for ammonium or other nitrogenous decay products in ground water (FDER, 1989a).

Ammonium

Ammonium (NH_4^+) in ground water can be derived from 1) animal waste products, 2) decay of complex organic molecules, and 3) application of inorganic fertilizers. It can only persist in reducing environments and/or in the immediate vicinity of a source.

The distribution of ammonium in study area ground water is shown in Figure 31. Ammonium concentrations are below the detection limit (0.01 mg/l) throughout most of the study area. Concentrations are slightly elevated along the coast, along the Brooksville Ridge in Hernando County, and in the vicinity of Lake Tsala Apopka. Elevated coastal concentrations are a result of local recharge from the extensive coastal swamps and forests that are rich in organic material. The two highest concentrations in the study area are located about five miles northwest of Brooksville and three miles southeast of

---

[5] Methemoglobin (ferrihemoglobin) is the equivalent of hemoglobin with the exception that the iron is oxidized to the ferric state. Methemoglobin is, therefore, incapable of carrying oxygen in the circulatory system.

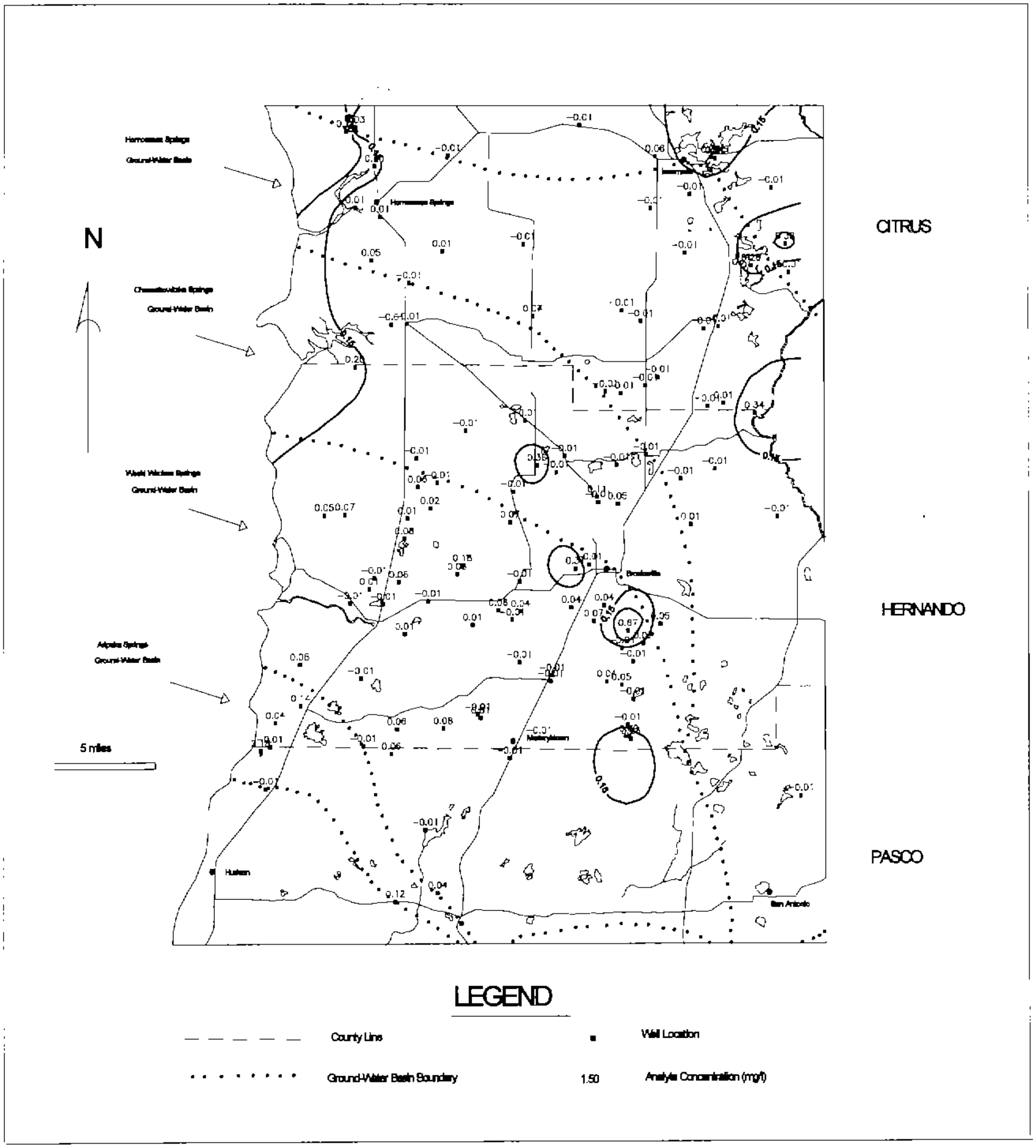


Figure 31. Ammonium Concentrations in Floridan Aquifer Ground Water.

Brooksville. Both wells are located almost on the shore of large, water-filled sinkhole features. The sinkholes collect large amounts of organic-rich surface water and funnel it underground where the organics are converted to ammonia. Elevated concentrations near Brooksville may result from transport of the town's storm water to sinkholes, from septic tanks, or from a combination of the two. Finally, elevated concentrations in the vicinity of Lake Tsala Apopka result from recharge of the Floridan aquifer with organic-rich water from the lake and possibly from local waste disposal.

The presence of low concentrations of ammonium and relatively high concentrations of nitrate in the Floridan aquifer is a strong indication that ground water in the upper portion of the Floridan aquifer in the study area is flowing in a shallow, well oxygenated flow system, which allows rapid conversion of ammonium to nitrate.

Nitrite

Nitrite (NO_2^-) is less stable in ground water than either nitrate or ammonium. It is primarily a step in the oxidation of ammonium and other nitrogen compounds to nitrate. Nitrite is determined by subtracting nitrate-nitrogen concentrations from nitrate+nitrite-nitrogen concentrations. Nitrite can usually only persist near a source.

Nitrite concentrations are below the detection limit in all but two samples. Because concentrations in these wells are only slightly above the detection limit, nitrite concentrations were not plotted or contoured. Similar to the low ammonium concentrations, the low nitrite concentrations are indicative of a shallow, well oxygenated flow system that allows rapid conversion of nitrite to nitrate.

Nitrate

Figure 32 shows the distribution of nitrate in the study area. From the figure it is apparent that ground water in the study area is widely enriched in nitrate.[6] Table 7 is a breakdown of nitrate concentrations in wells in the study area. The table indicates that the majority of wells have concentrations that are significantly elevated above background levels (0.01 mg/l).

Nitrate concentrations are elevated in a north-south trending zone that covers most of the western half of the study area. Concentrations are also elevated through most of eastern Hernando County and in the vicinity of Lake Tsala Apopka. The highest nitrate

---

[6] To establish a background concentration for nitrate in the Floridan aquifer, the AGWQMP has sampled over 300 wells throughout the 16 counties within the SWFWMD. The median concentration is < 0.01 mg/l (Upchurch, 1993).

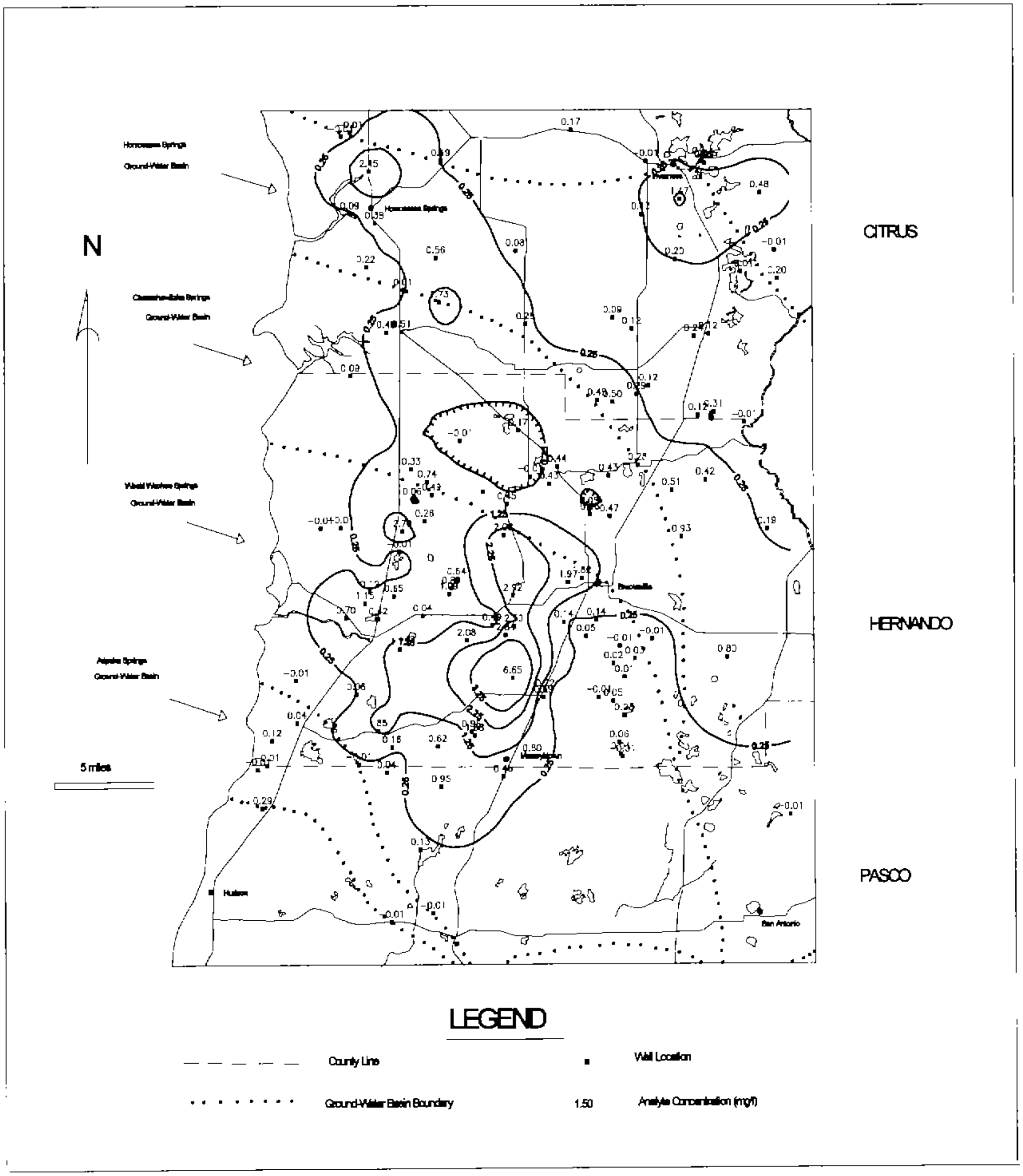


Figure 32. Nitrate Concentrations in Floridan Aquifer Ground Water.

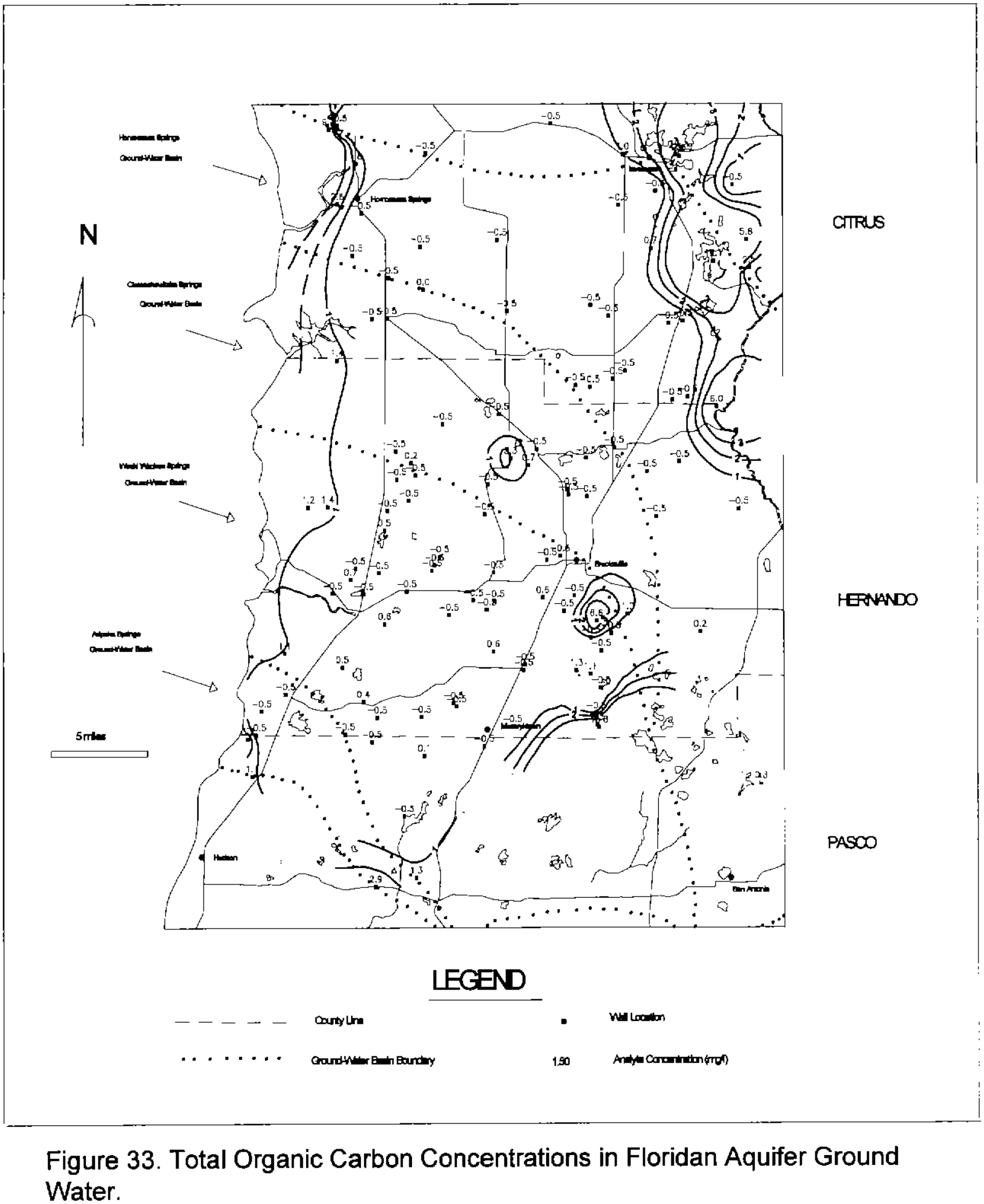


Figure 33. Total Organic Carbon Concentrations in Floridan Aquifer Ground Water.

orthophosphate is present in the limestone aquifers of the intermediate or Floridan aquifers, local recharge is often indicated (Upchurch and Lawrence, 1984). Organic phosphorus compounds are destroyed by the microbial reactions discussed previously. Orthophosphate is strongly sorbed onto ferric hydroxides in soils and aquifers and quantitatively precipitated in alkaline waters, so it should also not travel far from its source. Orthophosphate concentrations were so low that they were not plotted and contoured.

Total phosphorus concentrations (Figure 34) are elevated in isolated wells in the vicinity of the Lake Tsala Apopka and Withlacoochee River wetlands, probably from local recharge of phosphorus-rich surface water. Phosphorus compounds are also elevated in three isolated wells in the center of the study area.

Iron

The sources of iron in ground water in the study area include 1) oxidation of pyrite (FeS_2), 2) oxidation of organic compounds, and 3) dissolution of iron oxide minerals. Iron has two valence states, Fe^{2+} and Fe^{3+}. Fe^{2+} is generally the stable form of iron in chemically-reducing ground water. In oxidizing ground water, bacteria induce colloidal ferric hydroxide ($Fe(OH)_3$) to precipitate. These iron colloids and the associated bacteria cause clogging of well screens and aquifer pore throats. They also cause color and turbidity to violate the Secondary Drinking Water Standard. Ferric hydroxide is the reddish to yellowish scale or stain that is so commonly found where iron-rich waters are utilized.

Iron concentrations (Figure 35) are elevated along the coast as a result of the higher iron content in sea water that is mixing with ground water. Concentrations are also elevated in the Lake Tsala Apopka area and the two wells located northwest and southeast of Brooksville (see the ammonium and TOC sections) that are located close to very large, water-filled sinkholes.

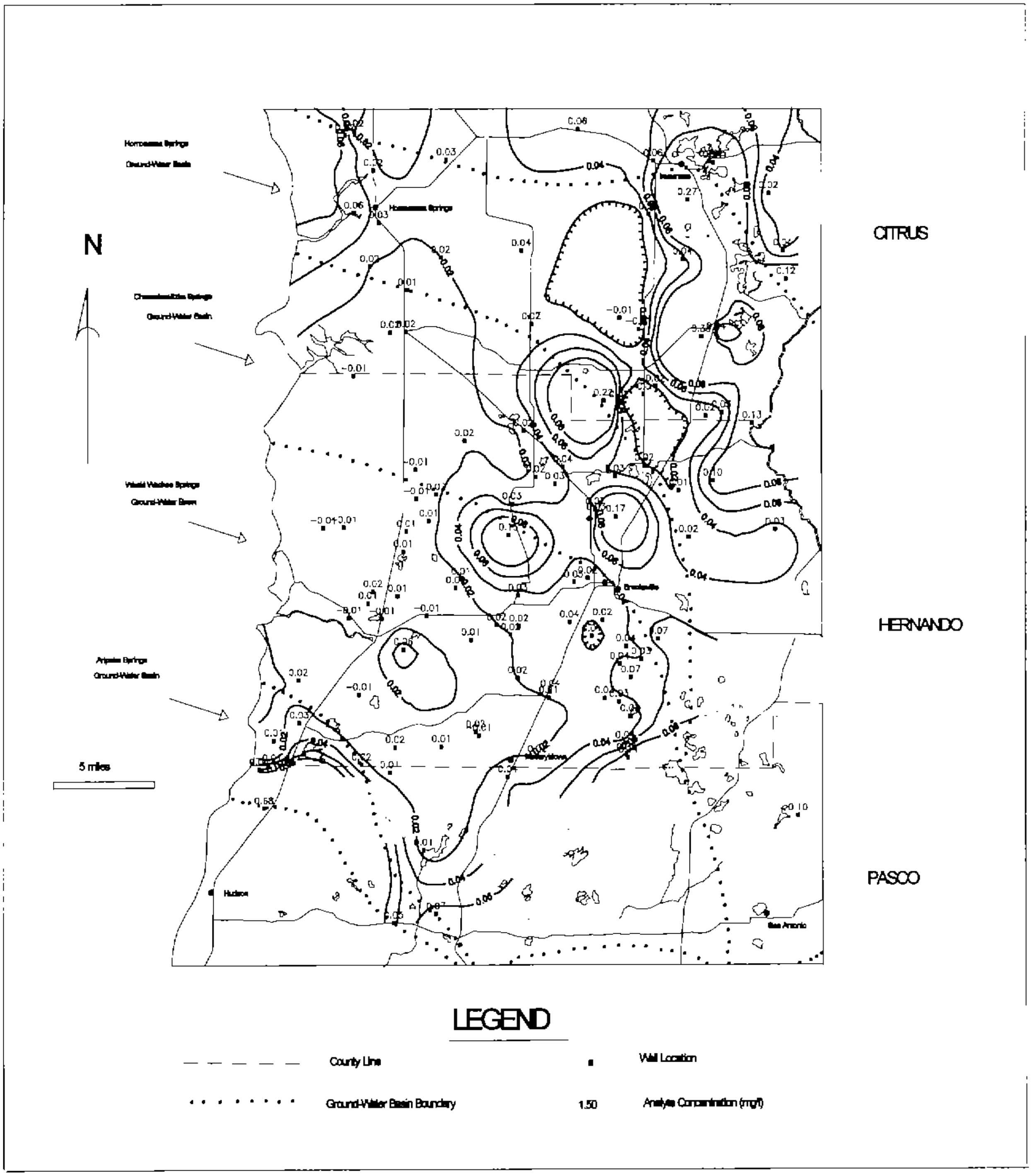


Figure 34. Total Phosphorus Concentrations in Floridan Aquifer Ground Water.

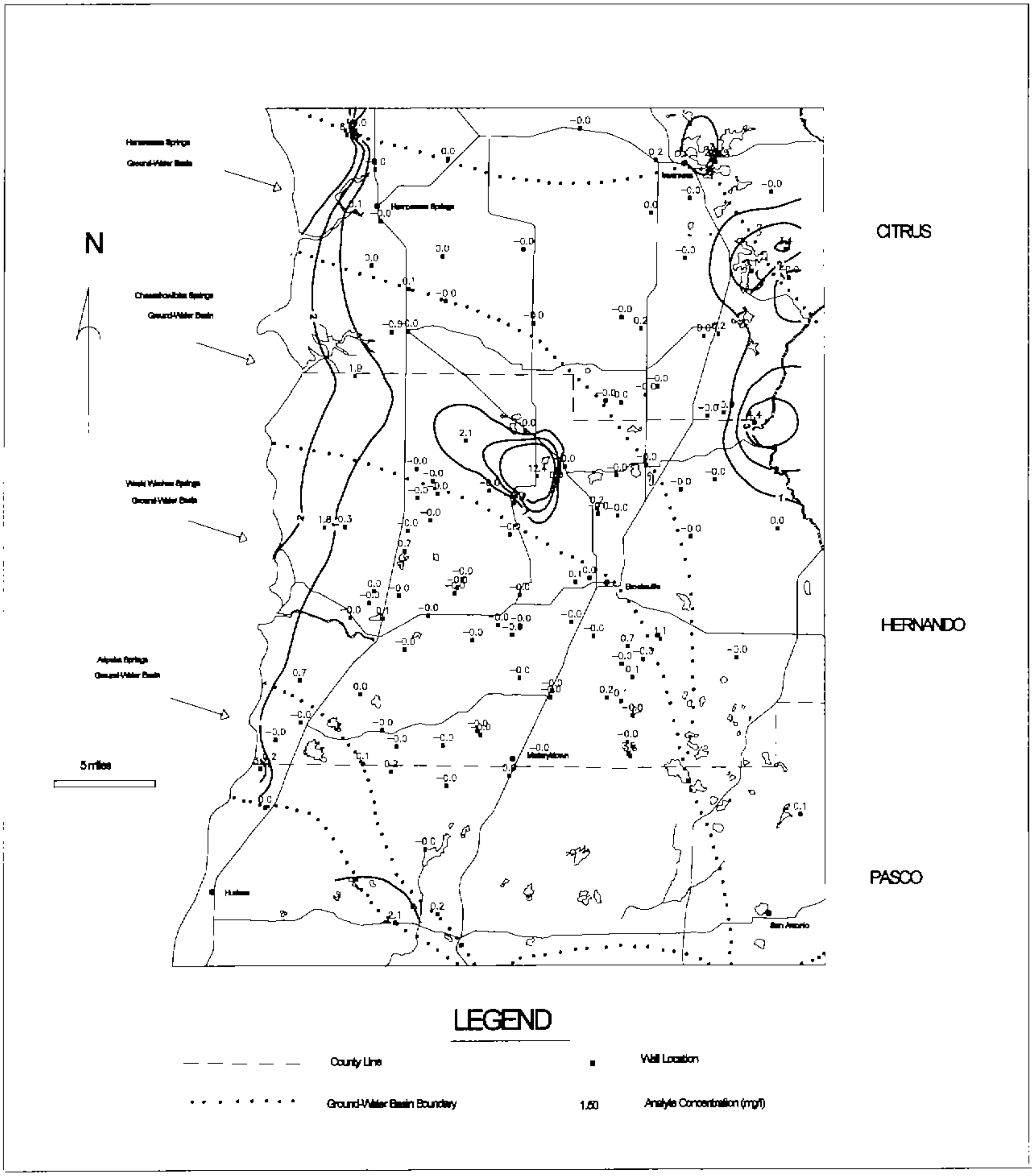


Figure 35. Iron Concentrations in Floridan Aquifer Ground Water.

GROUND-WATER CHEMISTRY: SPRING COMPLEXES

The following is an analysis of the chemical quality of water discharging from the individual springs that comprise the four spring complexes. A total of 30 springs in the study area were sampled from two to thirteen times between October of 1993 and April of 1997. Although there are many more springs in the study area, the springs chosen for sampling were considered to be representative of the water quality in a given area. Tables 8 through 11 show the means of the concentrations of a number of chemical analytes for each of the sampled springs, the number of times each spring was sampled, and the hydrochemical facies group of water from each spring. A complete list of the chemical data for all the samples for each spring is included in Appendix III

Fourteen springs, sampled between two and six times, were irregularly sampled during the study because they are low-discharge springs that have water quality similar to a larger, nearby spring in most cases. The remaining 16 springs were sampled quarterly as soon as they were located and classified. These springs were sampled through the end of the data collection phase of the project (April, 1997) and will continue to be sampled indefinitely on a less-frequent basis once the project is completed. Nine springs were sampled once for uranium isotopes. Seven springs were sampled for nitrogen isotopes; four were sampled once and three were sampled twice.

HYDROCHEMICAL FACIES

The hydrochemical facies technique is used here to provide a preliminary appraisal of the chemistry of the springs. The means of chemical analytes in samples collected from the 30 springs during the sampling events were used to construct a Stiff diagram for each spring. For a comparison of the chemistry of the individual springs, the 30 analyses were plotted on a Piper diagram. Examination of the Piper diagram (Figure 36) reveals three distinct groups of samples. Figure 36 also displays three Stiff diagrams that are representative of the different water-quality groups delineated from the spring samples.

Group A includes Weeki Wachee Main, Twin Dees, Aripeka #1, and Bobhill. The location of the group A springs in the center-left area of the Piper Diagram indicates that these springs are dominated by calcium-bicarbonate-type water. Calcium-bicarbonate-type water results from simple dissolution of limestone in the shallow Floridan aquifer flow system. The group A springs are located furthest inland of all the springs in the study area and, therefore, they are not tidally influenced (water quality does not change in response to tidal fluctuations). In addition, chloride concentrations are low because they are not affected by mixing with sea water.

The group B and C springs are located close enough to the coast for water quality changes to occur in response to tidal fluctuations. Because the water discharging from the

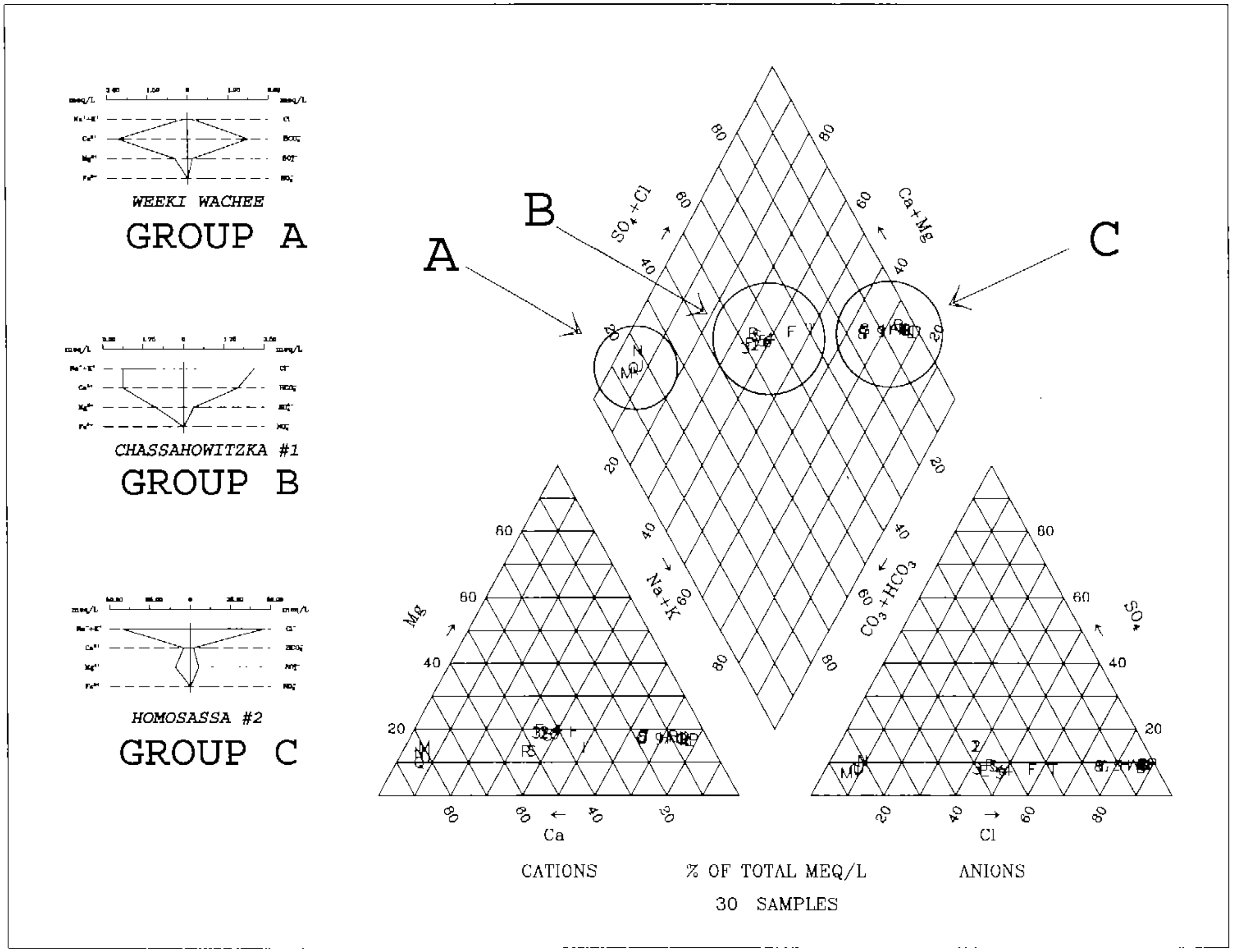


Figure 36. Characterization of Water Discharging from Springs in the Study Area Using Piper and Stiff Diagrams.

springs is freshest at low tide, every attempt was made to consistently collect samples at low tide. This proved very difficult because the lag between low tide at Cedar Key, the nearest tide station in the Gulf of Mexico, and the corresponding low water level in the Floridan aquifer in the study area can be highly variable for each spring. The most effective method of determining when to collect a sample in a spring was to begin taking conductivity measurements approximately one half hour before the calculated dead low tide while the measurements were dropping. When the conductivity began to rise, the sample was collected.

The location of the group B springs in the center of the Piper Diagram indicates that the water quality of these springs, at low tide, is transitional between the calcium-bicarbonate dominated water of the group A springs and the sodium-chloride dominated water of the group C springs. If samples were collected from the group B springs at high tide, the concentration of the major ions, especially sodium and chloride, would be higher, but not necessarily high enough to place them into group C. The group B springs include Abdoney, Aripeka #2, Belcher, Beteejay, Boat, Chassahowitzka #1, Magnolia, McClain, Pumphouse, Trotter #1, and Trotter Main.

The location of the group C springs in the center-right area of the Piper Diagram indicates that these springs are dominated by sodium-chloride type water that results from minimal mixing of fresh water from the recharge area with sea water from the Gulf. The group C springs, include Baird, Blue Run, Crab Creek, Chassahowitzka Main, Hall's River Head, Hidden River Head, Hidden River #2, Homosassa Main (#1, #2, and #3), Homosassa River #1, Mud River, Potter Creek, Ruth, and Salt.

MAJOR ANALYTES, NITROGEN SPECIES, ADDITIONAL NUTRIENTS, AND IRON

As explained previously, the major analytes were considered to be pH, bicarbonate, calcium, chloride, sulfate, and TDS. pH was included because it is intimately associated with bicarbonate and calcium. TDS was included because it is a measure of the concentration of all the major and minor analytes. In analyzing the water quality of the springs, magnesium, sodium, and potassium were also included with the major analytes. This is because the concentration of these parameters is low in ground water and much higher in sea water. Therefore, these parameters are very useful when identifying springs with a significant sea-water influence. Nitrate is the only nitrogen species included in this discussion because the concentrations of nitrite and ammonium in the springs were almost always near or below the detection limit. Total organic carbon was the only additional nutrient included because phosphorus concentrations were always near or below the detection limit. Finally, iron was included because it occurs in significant concentrations in some of the springs.

Figures 14,16,17, and 19 depict the locations of the individual springs in each of the four complexes. Tables 8 through 11 contain the means of the concentrations of each major analyte (mg/l unless otherwise noted) for each spring in the complex. The springs are separated into groups in the tables according to the hydrochemical facies classification discussed previously (group A, B, or C). This is to insure that springs not influenced by the transition zone are not compared to those that are.

Homosassa Springs Complex

Figure 14 is a location map of springs in the Homosassa complex and Table 8 contains the means of the analyte concentrations for the springs. The table shows that there are no group A springs (calcium/bicarbonate dominated water), six group B springs (significant sodium/chloride influence), and seven group C springs (sodium/chloride dominated water).

All of the group B springs in the Homosassa complex are located along the southeast fork of the Homosassa River. It is apparent from the table that, at low tide, the means of the concentrations of all the analytes are well within the Florida Department of Environmental Protection's (FDEP) Drinking Water Standards.

The group C springs in the Homosassa complex include the three vents that compose the Homosassa Main Spring, a nearby spring in the Homosassa River, the two Hidden River Springs, and Hall's River Head Spring. These springs discharge non-potable water at low tide because they exceed the FDEP Drinking Water Standards for chloride, sodium, and TDS. Iron values for Homosassa Main Spring #2 are considerably higher than those of any other spring in the complex and may indicate mixing with organic-rich water from the coastal swamps.

Total phosphorus concentrations for all springs in the complex were not included in the table because concentrations were all at or slightly above the detection limit of 0.01 mg/l. Since orthophosphate tends to precipitate as a calcium phosphate mineral (carbonate-hydroxylapatite) in an alkaline environment, the low concentrations indicate minimal orthophosphate and organic phosphorus and suggests that significant sources of phosphorus, such as organic-rich surface water or animal wastes, are not in close proximity to the springs.

TOC concentrations were at or slightly above the detection limit of 0.5 mg/l for all springs in the complex with the exception of Trotter Main, Pumphouse, and McClain. As discussed previously (p. 30) these springs probably receive recharge from a spring-fed stream that alternates between surface and underground flow for approximately one half mile before finally sinking again just before reaching the springs on the southeast fork of the Homosassa River. The stream flows above ground long enough to accumulate organic material that ultimately is measurable at some of the springs on the southeast fork.

Table 8. Analyte Concentration Means at Low Tide for Springs in the Homosassa Complex (mg/l unless otherwise noted).

Hydrochemical Facies Group	Spring Name	Times Sampled 10/93 - 04/97	Field pH (std. units)	Field Cond. (umhos)	*Dis Ca	HCO_3	Dis Mg	Dis Na	Dis F	Dis Cl	Dis K	Dis SO_4	Dis NO_3 as N	TOC	Dis Fe^{+3}	TDS
A	None															
B	Belcher	3	7.80	455	39	109	10	36	0.10	51	1.2	27	0.44	<0.50	<0.030	245
	Trotter #1	3	7.79	462	39	110	9.7	36	0.11	52	1.2	27	0.44	<0.50	<0.030	246
	Trotter Main	13	7.70	429	40	112	9.8	33	0.10	54	1.1	14	0.42	0.74	<0.037	246
	Abdoney	3	7.75	489	37	107	11	41	0.11	75	1.4	15	0.46	<0.50	<0.030	263
	Pumphouse	13	7.66	506	44	119	11	4 3	0.10	76	1.4	14	0.39	1.01	<0.033	283
	McClain	3	7.66	548	45	118	12	48	0.10	78	1.4	16	0.36	1.10	0.032	292
C	Homosassa Main #3	11	7.69	1,339	42	105	26	176	0.12	310	6.4	50	0.44	0.58	0.035	696
	Hidden River Head	11	7.76	1,449	48	123	29	196	0.11	342	7.2	54	0.66	0.51	<0.034	726
	Hidden River #2	12	7.74	2,162	55	121	42	316	0.11	546	11	83	0.53	0.60	0.039	1,112
	Homosassa Main #1	11	7.59	3,245	62	108	62	481	0.12	863	18	126	0.43	0.57	0.073	1,697
	Homosassa River #1	2	7.27	4,160	72	118	84	646	0.13	1,335	24	171	0.39	?	<0.030	2,131
	Homosassa Main #2	11	7.53	5,694	79	110	110	917	0.14	1,594	33	235	0.42	0.58	0.137	3,094
	Hall's River Head	3	7.72	7,297	86	115	145	1,165	0.15	1,994	43	280	0.32	<0.50	0.035	4,030

* Dis = Dissolved

Average nitrate concentrations for all springs in the Homosassa complex range from 0.32 mg/l (Hall's River Head Spring) to 0.66 mg/l (Hidden River Head Spring). The mean of the nitrate concentrations for the springs in the Homosassa complex is 0.44 mg/l, which, is slightly above the mean nitrate concentration of all the sampled springs in the study area (0.41 mg/l). Ammonium and nitrite concentrations are not listed in the table because they are all near or below their detection limits. However, ammonium is detected in the springs of the Homosassa complex from time to time. While ammonium concentrations range over two orders of magnitude in some springs (i.e., Homosassa River #1 ranges from <0.01 to 0.14 mg/l), there is no pattern to the ammonium concentrations with time. This suggests minor nearby nitrogen sources that are sporadically contributing to the spring discharge. Because ammonium and nitrite concentrations in the springs are low and nitrate concentrations are high, ammonium in ground water appears to have been oxidized to nitrate before reaching the springs. The fact that this process occurs rapidly in shallow karst flow systems indicates the major contributors of nitrogen in the recharge area are not within the immediate vicinity (several thousand feet) of the springs. Local sources that may be responsible for the occasional ammonium detections include 1) natural contributions from decay of organics in nearby swamps and spring sediments or local animal wastes and 2) local contributions from septic tanks, fertilizers, or other human sources. However, nitrogen isotopes (see below) do not indicate a significant animal waste contribution.

Chassahowitzka Spring Complex

Figure 16 is a location map of springs in the Chassahowitzka complex and Table 9 contains the means of the analyte concentrations for the springs. The table shows there are no group A springs (calcium/bicarbonate dominated water), two group B springs (significant sodium/chloride influence), and six group C springs (sodium/chloride dominated water).

At low tide the means of the concentrations of all the analytes for the group B springs are well within the FDEP Drinking Water Standards. None of the group C springs in the Chassahowitzka complex discharge potable water at low tide as they exceed the FDEP Drinking Water Standards for chloride, sodium, and TDS. Iron values for Potter Creek Spring are considerably higher than those of any other spring in the complex and nearly exceed the FDEP Drinking Water Standard of 0.3 mg/l. These elevated iron values may indicate mixing with organic- rich water from the coastal swamps.

Total phosphorus concentrations for all springs in the complex were not included in the table because they were all at or slightly above the detection limit of 0.01 mg/l. Since orthophosphate tends to precipitate in an alkaline environment, the low concentrations indicate minimal orthophosphate and organic phosphorus and suggest that significant sources of phosphorus, such as organic-rich surface water or animal wastes, are not in close proximity to the springs.

Table 9. Analyte Concentration Means at Low Tide for Springs in the Chassahowitzka Complex (mg/l unless otherwise noted)

Hydrochemical Facies Group	Spring Name	Times Sampled 10/93 - 04/97	Field pH (std. units)	Field Cond. (umhos)	*Dis Ca	HCO_3	Dis Mg	Dis Na	Dis F	Dis Cl	Dis K	Dis SO_4	Dis NO3 as N	TOC	Dis Fe^{+2}	TDS
A	None															
B	Beteejay	9	7.34	671	61	167	16	53	0.15	89	1.8	20	0.27	3.70	0.037	385
	Chassahowitzka #1	11	7.58	770	53	145	17	74	0.14	138	2.7	25	0.47	<0.5	0.036	411
C	Chassahowitzka Main	11	7.56	1,730	58	141	33	229	0.14	434	8.4	67	0.42	0.62	0.040	929
	Ruth	6	7.48	2,977	67	146	58	439	0.14	819	16	122	0.44	1.79	0.048	1,744
	Crab Creek	5	7.51	5,294	85	149	106	842	0.16	1,571	32	227	0.46	0.54	0.055	2,888
	Blue Run	9	7.32	7,747	113	166	156	1,263	0.17	2,334	48	340	0.26	334	0.110	4,333
	Potter Creek	2	7.26	9,770	125	153	191	1,638	0.14	2,990	60	427	0.33	2.99	0.290	5,649
	Baird	4	7.45	11,423	130	154	229	2,003	0.17	3,631	70	512	0.21	0.65	0.064	6,600

* Dis = Dissolved

TOC concentrations are significantly elevated above the detection limit of 0.5 mg/l for most of the springs in the complex. This is probably because the springs with the highest TOC, Beteejay, Blue Run, Ruth, and Potter Creek, are located further west into the coastal swamps portion of the recharge area than the low-TOC springs. A portion of the water discharging from the high TOC springs is surface water that accumulates organics in the swamps, infiltrates locally into the Floridan aquifer, then discharges from the springs.

Average nitrate concentrations for the springs in the Chassahowitzka complex range from 0.21 mg/l (Baird Spring) to 0.47 mg/l (Chassahowitzka #1). The mean of the nitrate concentrations for the springs in the Chassahowitzka complex is 0.36 mg/l, which is below the mean nitrate concentration of all the sampled springs in the study area (0.41 mg/l). In addition, this is the lowest nitrate mean of the four spring complexes. Ammonium and nitrite concentrations are not listed in the table because they were all near or below their detection limits. Because ammonium and nitrite concentrations in the springs are low and nitrate concentrations are high, ammonium in ground water appears to have been oxidized to nitrate before reaching the springs. The fact that this process occurs rapidly in shallow karst flow systems indicates the major contributors of nitrogen in the recharge area are not within the immediate vicinity (several thousand feet) of the springs.

Weeki Wachee Spring Complex

Figure 17 is a location map of springs in the Weeki Wachee complex and Table 10 contains the means of the analyte concentrations for the springs. The table shows that there are two group A springs (calcium/bicarbonate dominated water), no group B springs (significant sodium/chloride influence), and two group C springs (sodium/chloride dominated water).

The water quality of the two group A springs in the Weeki Wachee complex does not change in response to tidal fluctuations. The spring water has a very low TDS content and only contains significant quantities of bicarbonate and calcium. All constituents are well below the FDEP Drinking Water Standards.

Salt Spring and Mud River Spring do not discharge potable water at low tide as they exceed the FDEP Drinking Water Standard for chloride, sodium, sulfate, and TDS. The concentrations of the analytes that are indicative of sea water are much higher in Mud River Spring than any other spring included in the study. According to Yobbi (1992), the discharge of Mud River Spring is composed of approximately 50 percent sea water. The discharge of Baird Spring, the next highest in terms of sea water dominance, is composed of only 18 percent sea water. The iron concentration of Mud River Spring is considerably higher than those of any other spring in the complex and may indicate mixing with organic-rich water from the coastal swamps.

Table 10. Analyte Concentration Means at Low Tide for Springs in the Weeki Wachee Complex (mg/l unless otherwise noted)

Hydrochemical Facies Group	Spring Name	Times Sampled 10/93 -04/97	Field pH (std. units)	Field Cond. (umhos)	*Dis Ca	HCO_3	Dis Mg	Dis Na	Dis F	Dis Cl	Dis K	Dis SO_4	Dis NO3 as N	TOC	Dis Fe^{+2}	TDS
A	Weeki Wachee Main	12	7.64	302	51	136	5.8	3.8	0.1	5.9	0.23	8.2	0.53	0.53	0.032	177
	Twin Dees	4	7.64	303	55	139	5.2	3.6	0.09	9.1	0.25	14	0.36	0.58	0.041	177
B	None															
C	Salt	11	7.57	6,805	92	126	134	1,097	0.15	1,994	41	282	0.43	0.66	0.065	3690
	Mud River	3	7.34	33,667	300	123	757	6.605	0.42	11,232	233	1,605	0.17	0.86	0.193	21,612

*Dis = Dissolved

Total phosphorus concentrations for all springs in the complex were not included in the table because they were all at or slightly above the detection limit of 0.01 mg/l. Since orthophosphate tends to precipitate in an alkaline environment, the low concentrations indicate minimal orthophosphate and organic phosphorus and suggest that significant sources of phosphorus, such as organic-rich surface water or animal wastes, are not in close proximity to the springs.

TOC concentrations are only slightly elevated above the detection limit of 0.5 mg/l for the springs in the complex. This is because the springs are not significantly recharged by nearby sources of organic-rich surface water.

Average nitrate concentrations for all springs in the Weeki Wachee complex range from 0.17 mg/l (Mud River) to 0.53 mg/l (Weeki Wachee Main). The mean of the nitrate concentrations for the springs in the Weeki Wachee complex is 0.37 mg/l, which, is below the mean nitrate concentration of all the sampled springs in the study area (0.41 mg/l). Ammonium and nitrite concentrations are not listed in the table because they were all near or below their detection limits. Because ammonium and nitrite concentrations in the springs are low and nitrate concentrations are high, ammonium in ground water appears to have been oxidized to nitrate before reaching the springs. The fact that this process occurs rapidly in shallow karst flow systems indicates the major contributors of nitrogen in the recharge area are not within the immediate vicinity (several thousand feet) of the springs.

Aripeka Springs Complex

Figure 19 is a location map of springs in the Aripeka complex and Table 11 contains the means of the analyte concentrations for the springs. The table shows that there are two group A springs (calcium/bicarbonate dominated water), three group B springs (significant sodium/chloride influence), and no group C springs (sodium/chloride dominated water).

The water quality of Bobhill Spring does not change in response to tidal fluctuations. The water discharging from Bobhill at all times and from Aripeka #1 at low tide has a low TDS content and only contains significant quantities of bicarbonate and calcium. All constituents for both springs are well below the FDEP Drinking Water Standards.

Although at low tide, Aripeka #1 and #2 are group A and B springs, respectively, their proximity to the Gulf causes them to become group C springs as the transition zone migrates inland with the rising tide. This transition is extremely rapid. As an example, the field conductivity readings in the Aripeka #2 spring vent have been observed to change from 535 umos to 5,820 umos within 10 minutes.

At low tide the means of the concentrations of many of the constituents, especially

Table 11. Analyte Concentration Means at Low Tide for Springs in the Aripeka Complex (mg/l unless otherwise noted)

Hydrochemical Facies Group	Spring Name	Times Sampled 10/93 -04/97	Field pH (std. units)	Field Cond. (umhos)	*Dis Ca	HCO_3	Dis Mg	Dis Na	Dis F	Dis Cl	Dis K	Dis SO_4	Dis NO3 as N	TOC	Dis Fe^{+t}	TDS
A	Bobhill	12	7.58	269	46	114	3.3	3.8	0.06	6.3	0.36	8.1	0.62	0.75	0.044	158
	Aripeka #1	3	7.74	415	42	108	4.0	4.2	0.06	6.9	0.25	8.2	0.49	0.56	0.030	201
B	Aripeka #2	4	7.74	450	42	102	6.5	31	0.07	58	1.18	16	0.51	<0.50	0.030	229
	Magnolia	12	7.78	447	43	105	6.9	34	0.06	62	1.23	16	0.38	0.53	0.032	243
	Boat	10	7.59	720	49	119	12	77	0.07	150	3.02	25	0.35	0.67	0.040	390
C	None															

*Dis = Dissolved

chloride and sodium, for the Group B springs are considerably higher than those of the Group A springs. However, the means of all the constituents are well within the FDEP Drinking Water Standards.

Total phosphorus concentrations for all springs in the complex were not included in the table because they were all at or slightly above the detection limit of 0.01 mg/l. Since orthophosphate tends to precipitate in an alkaline environment, the low concentrations indicate minimal orthophosphate and organic phosphorus and suggest that significant sources of phosphorus, such as organic-rich surface water or animal wastes, are not in close proximity to the springs.

TOC concentrations are only slightly elevated above the detection limit of 0.5 mg/l for the springs in the complex. This is probably because the springs are not recharged by nearby sources of organic-rich surface water.

Average nitrate concentrations for all springs in the Aripeka complex range from 0.35 mg/l (Boat Spring) to 0.62 mg/l (Bobhill Spring). Bobhill Spring has the highest nitrate concentration of all the springs included in the study. The mean of the nitrate concentrations for the springs in the Aripeka complex is 0.47 mg/l, which is above the mean nitrate concentration of all the sampled springs in the study area (0.41 mg/l). Similar to the other spring complexes, ammonium and nitrite concentrations for the Aripeka Springs are not listed in the table because they were all near or below their detection limits. Because ammonium and nitrite concentrations in the springs are low and nitrate concentrations are high, ammonium in ground water appears to have been oxidized to nitrate before reaching the springs. The fact that this process occurs rapidly in shallow karst flow systems indicates the major contributors of nitrogen in the recharge area are not within the immediate vicinity (several thousand feet) of the springs. Minor local sources are suggested by the periodic detection of ammonium in the springs of this complex.

GROUND-WATER CHEMISTRY: ISOTOPIC CONTENT

URANIUM

The naturally occurring concentrations of uranium and the activity ratio of ^{234}U to ^{238}U in well and spring-water samples has been successfully utilized by J.K. Osmond and J.B. Cowart (*i.e.*, Osmond and Cowart, 1976; Cowart , 1978) of Florida State University to trace ground-water flow systems, determine relative ages of ground-water masses, and determine provenance of water masses. Cowart's analysis of the uranium isotopic content of ground-water samples collected for a study of Lithia and Buckhorn Springs (Jones and Upchurch, 1993) and Rainbow Springs (Jones *et al.*, 1996) was instrumental in determining the source areas of those springs. The following three paragraphs, modified from Cowart and Osmond (1992), explain the chemical basis for the technique.

Ground water in the deep, slow-moving portions of the Floridan aquifer flow system is characterized by low concentrations of uranium (< 0.1 µg/l) associated with relatively high $^{234}U/^{238}U$ activity ratios (appreciably greater than the equilibrium ratio of 1.0). The reasons for these characteristics are: (1) the solubility of U^{4+}, the ionic state prevalent in deep, chemically reducing waters, is quite low, and the mobilization of the decay product ^{234}U by alpha-recoil processes is favored by the intimate water/rock relationship in aquifers, and (2) the effect on the $^{234}U/^{238}U$ activity ratio is more apparent when the leaching component (involving both ^{238}U and ^{234}U) is low.

Rapidly recharging waters in a shallow, karst flow system, which is characteristic of the study area, tend to have a character that is distinctly different from deeper Floridan aquifer systems. These shallow waters exhibit higher concentrations of uranium with much lower $^{234}U/^{238}U$ activity ratios (sometimes with less than the equilibrium value of 1). This results from: 1) the oxidizing nature of rapidly recharging water which mobilizes uranium as a complex of the U^{6+} ion (uranyl, UO_2^{+2}), 2) the resulting high leach component of uranium which completely masks the recoil component of ^{234}U, and 3), assuming that the leaching process has just begun on a time scale "short" relative to the half-life of ^{234}U (250,000 years) the uranium leached from host-rock surfaces is depleted in ^{234}U because of previous recoil mobilization.

Because uranium is most soluble in oxidizing environments where it forms uranyl (UO_2^{+2}) ions, uranium concentration can be used to roughly determine age and history of ground water in Florida. Low concentrations (<0.1 µg/L) are typically associated with reducing conditions and deep, slow-moving waters. High concentrations (>0.1 µg/L) are found in oxidizing waters that are typically shallow and relatively young (recently recharged). The ratio of ^{234}U to ^{238}U is also sensitive to ground-water age. Alpha recoil (Osmond and Cowart, 1976) forces ^{234}U into ground water relative to ^{238}U. Thus, older waters tend to have higher $^{234}U/^{238}U$ than do younger waters.

Eighteen wells were sampled for uranium isotopes. The analysis of the samples was completed by Dr. James Cowart at Florida State University. Cowart was also contracted to determine relationships between the ground-water and spring samples, if possible. The distributions of $^{234}U/^{238}U$ activity ratio and uranium concentration data for the wells are shown in Figure 37.

Seventeen of the eighteen wells sampled for uranium isotopes have the low activity ratio (<1.0), high concentration signature (> 0.1) indicative of rapid recharge and flow in a shallow, short system. Well #48 near Brooksville has an activity ratio (1.2) that is slightly out of this range.

Nine springs in the study area were sampled for uranium isotopes. The $^{234}U/^{238}U$ activity ratio and uranium concentration data for the sampled springs and the locations of the sampled springs are shown in Figure 37. Similar to the wells, all springs sampled for uranium isotopes have the low activity ratio (<1.0) high concentration signature (> 0.1) characteristic of ground water that has recharged rapidly and traveled a relatively short distance (more than several thousand feet) in a shallow flow system.

In studying the results of the uranium analyses of the well and spring samples, Cowart (1995) was unable to find distinct, large-scale relationships between geographic location of the wells and isotopic ratio and uranium concentration. However, Cowart was able to group wells with similar concentrations and activity ratios into a northern and southern cluster.

Samples in the northern cluster have an average uranium concentration of 0.55 ug/l and an average activity ratio of 0.875. The northern cluster contains all of the wells and springs in Citrus County, and most, but not all, of the wells located southeast of Chassahowitzka Springs area as far south as Brooksville. Beteejay Spring, part of the Chassahowitzka Springs complex, is anomalous in that it has a distinctly higher uranium concentration and lower activity ratio than the other wells and springs in the vicinity.

Samples in the southern cluster have an average uranium concentration of 1.2 ug/l and an average activity ratio of about 0.75. The southern cluster contains Weeki Wachee, Aripeka #2, and Bobhill Springs and several but not all of the wells to the east of these springs. At present there is no apparent explanation for the higher uranium concentrations in the southern cluster. However, the explanation may be related to possible differences in the uranium content of the Hawthorn Group sediments in the northern and southern portions of the Brooksville Ridge in the study area.

NITROGEN

Although many proven sources of nitrate, including septic-tank effluent, treated sewage effluent, commercial and residential landscape fertilizers, land spreading of

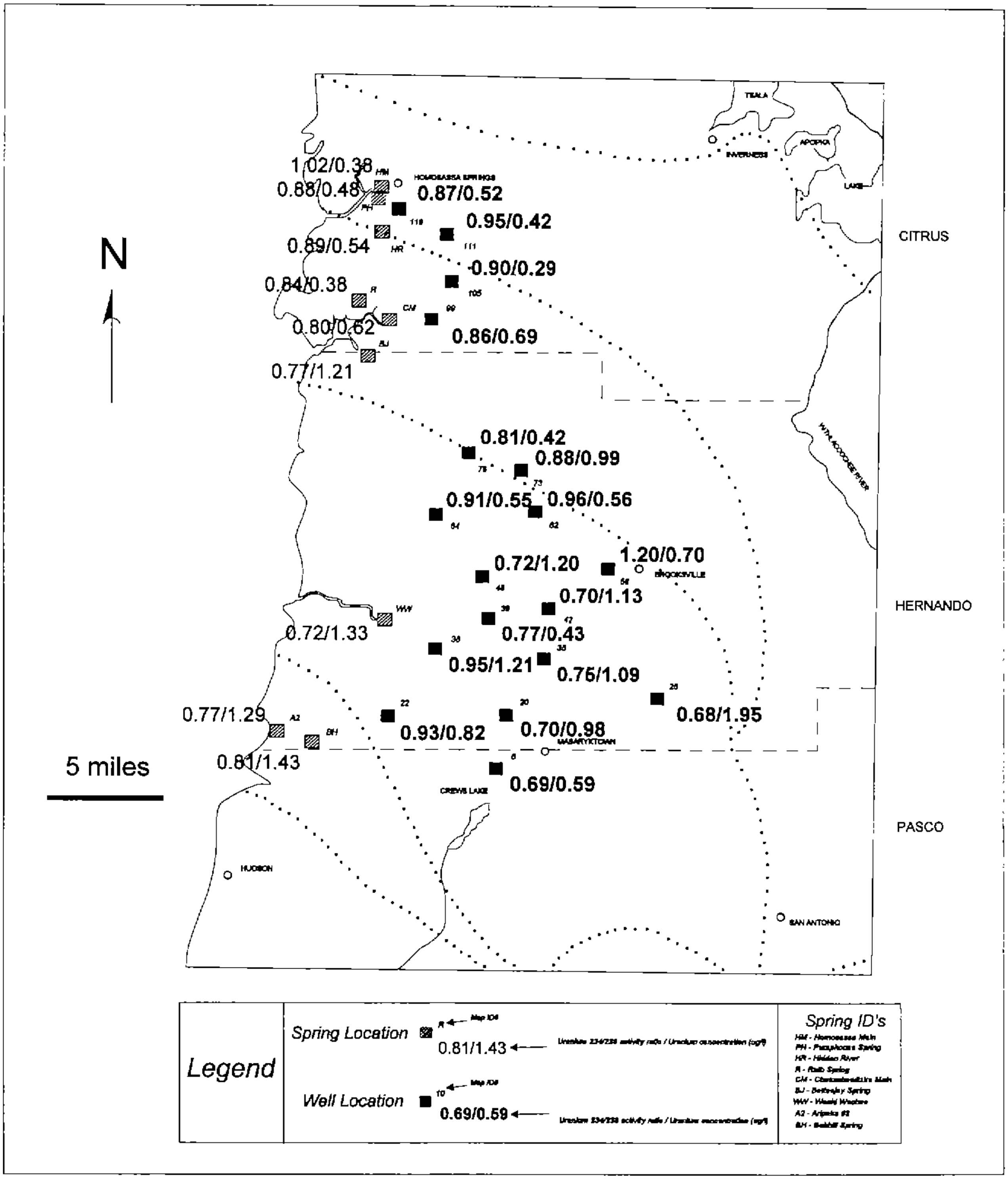


Figure 37. Uranium Isotopic Ratios and Concentrations in Wells and Springs in the Study Area.

septage and sewage sludge, and agricultural fertilizers are present in the study area, it is difficult to determine the relative contributions of these sources to nitrate in study area ground water. The isotopic ratio of $^{15}N/^{14}N$ (expressed as $\delta^{15}N$) can provide a direct indication of the importance of certain nitrate sources. It is especially useful for characterization of animal waste (organic) sources as opposed to inorganic sources. The ratio of nitrogen isotopes in dissolved nitrate is expressed in parts per thousand (ppt) and is calculated using the following equation:

$$\delta^{15} N = 1000 \frac{\left(\frac{\alpha_{^{15}N}}{\alpha_{^{14}N}}\right)_{sample} - \left(\frac{\alpha_{^{15}N}}{\alpha_{^{14}N}}\right)_{air}}{\left(\frac{\alpha_{^{15}N}}{\alpha_{^{14}N}}\right)_{air}}$$

Where

α = the activity of the specified isotope

Three $\delta^{15}N$ ranges have been defined for nitrate from different sources (Wolterink *et al.,*1979). The $\delta^{15}N$ values for nitrate from unfertilized, cultivated fields (nitrate resulting from the oxidation of part of the organic nitrogen in the soil from crop plowing) range from +2 to +8 ppt (Kreitler, 1975). In the warm, humid environment of west-central Florida, only a minimal amount of nitrate should leach from undisturbed soils (Andrews, 1994). Isotopic ratios in water affected by animal waste (organic nitrogen) sources, such as septic tanks, feedlots, and barnyards, range from +10 to +20 ppt. However, these sources cannot be distinguished from each other. Nitrate leached from synthetic, ammonium nitrate fertilizers composed of inorganic nitrogen (the type most likely to be used on row crops, citrus, and landscaping) have associated $\delta^{15}N$ ratios of -8 to +6.2 ppt, with 90% of the samples ranging from -3 to +2 ppt (Kreitler, 1975; Kreitler and Jones, 1975).

Twenty three wells in the study area were sampled for nitrogen isotopes. These wells had the highest nitrate concentrations of the 121 wells sampled in the study area. Figure 36 shows the spatial distribution of $\delta^{15}N$. Ratios range from 0.6 to 9.3 with an anomalously high value of 30.1 ppt. Ratios that fall between the +2 to +8 range could be attributable to natural oxidation of organic material in soil (Kreitler, 1975). However, this is unlikely because the nitrate concentrations in the wells that were sampled for isotopes appear to be too high to have originated from natural sources. Seventy seven percent of the ratios are below 6.2 ppt, indicating that inorganic fertilizers are the most significant source of nitrate in the study area. However, because 90 percent of the samples dominated by inorganic nitrogen fertilizers should range from -3 to +2 ppt, those between +2 ppt and 6.2 ppt may be influenced by organic nitrogen from animal

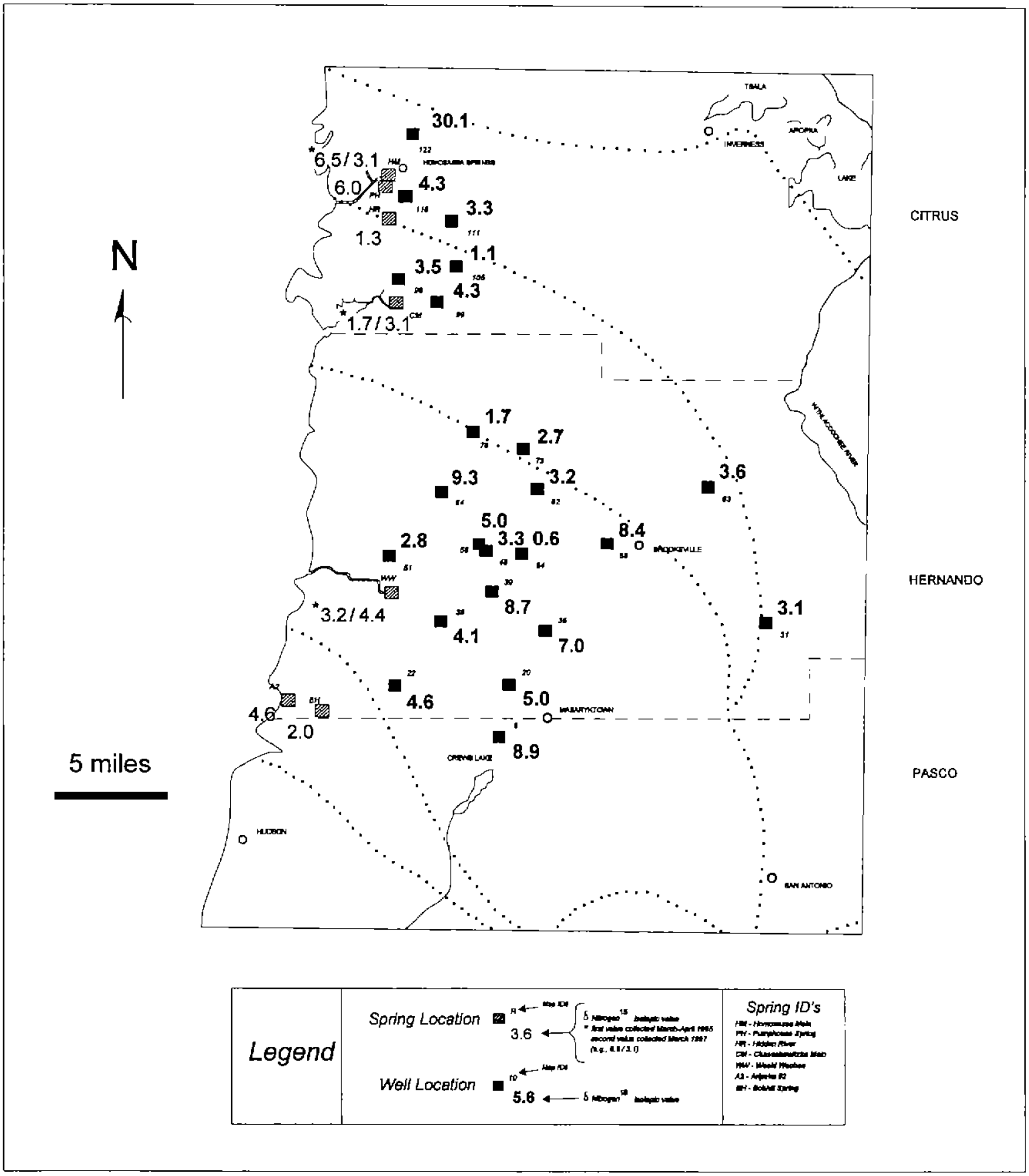


Figure 38. $\delta^{15}N$ Isotopic Ratios in Wells and Springs in the Study Area.

waste. Twenty three percent of the ratios are between 6.2 ppt and 9.3 ppt. These ratios probably indicate a mixing of inorganic fertilizer nitrogen and animal waste nitrogen, with animal waste nitrogen being the dominant component. Only the anomalously high ratio of 30.1 ppt exceeds 10 ppt, the lower end of the animal waste range (Wolterink, 1979).

Wells where $\delta^{15}N$ ratios indicate organic animal waste include well #6 located in Pasco County south of the Hernando/Pasco county line and several miles west of U.S. 41 (ratio = 8.9 ppt), well #64 near U.S. 19 north of Weeki Wachee Springs (ratio = 9.3 ppt), and well #39 located between Brooksville and Weeki Wachee Springs (ratio = 8.7 ppt). These wells are in rural areas of oak and pine scrub where a scattering of widely-spaced single family homes are served by septic tanks. No other significant source of organic nitrogen was observed. Since the density of septic tanks is low, this could be an indication of localized contamination of the well by the septic tank on the property. A further indication that these wells are possibly affected by their associated septic tanks is that a number of wells in very similar surroundings have very low ratios.

Well #58, located just west of Brooksville, has a nitrogen isotopic ratio of 8.4 ppt. This area encompasses numerous, closely spaced septic tanks that have existed for many years. The relatively high ratio may be indicative of septic tank effluent down gradient from the town. Well #35, located between Brooksville and Masaryktown a few miles west of U.S. 41 (ratio = 7.0 ppt), is in a rural area where numerous chicken farms and extensive cattle pasture surround a few single family homes. This well has the highest nitrate concentration of all the wells in the network. The ratio may be indicative of a mixture of organic nitrogen from the chicken farms and cattle and inorganic nitrogen from fertilized pastures.

The dominant nitrogen source of the remaining 18 wells ($\delta^{15}N$ ratios below 5.0 ppt), is probably inorganic nitrogen fertilizer. In rural , agricultural areas such as the vicinities of wells #31 and #63 (ratios = 3.1 ppt and 3.6 ppt, respectively), where pastures and/or row crops have been fertilized for long periods of time, this is reasonable. However, the situation in the developed coastal areas of southern Hernando and southern Citrus Counties is more problematic. Wells in these areas, wells #22 and #38 in southern Hernando and wells #98, #99,#105, #111, and #116 in southern Citrus County, have low $\delta^{15}N$ ratios, which, indicate an inorganic source. The historical land cover prior to the construction of the subdivisions in the mid 1960's was oak and pine scrub, which would not have been a significant source of inorganic nitrogen. Therefore, the only possible source of inorganic nitrogen in the subdivisions that could produce the low ratios is residential and golf course turf/landscape fertilizer.

Seven springs in the study area were sampled for nitrogen isotopes in March and April of 1995. Three of these springs, Homosassa Main #3, Chassahowitzka Main, and Weeki Wachee Main, were resampled for nitrogen isotopes in March of 1997. Figure 35 shows the spatial distribution of $\delta^{15}N$ in springs. Ratios for the springs range from 1.3 ppt

(Hidden River Head) to 6.5 ppt (Homosassa Main). The $\delta^{15}N$ ratios in the springs are all indicative of inorganic fertilizer sources along with smaller, less significant, components of animal waste.

TRITIUM

Tritium (^3H) is an isotope of hydrogen that is formed by cosmic-ray activation of nitrogen and by atmospheric testing of nuclear weapons. Determining the tritium content of aquifer water helps to determine whether the aquifer is being recharged locally or from a more distant source. Because of the dramatic increase in tritium in 1952 as a result of the onset of atmospheric testing of hydrogen bombs, tritium provides a useful marker for relatively young water in the hydrologic cycle. Before 1952, the tritium content of meteoric water ranged from 1 to 10 tritium units[7] (TU) (Kaufman and Libby, 1954). Water recharged in Florida prior to 1952 should have a tritium concentration of less than 2 TU (Yobbi, 1992).

Atmospheric, nuclear-weapons testing has raised tritium activities as much as two orders of magnitude. While tritium began to be introduced to the hydrologic cycle in the mid-1940's, the major build-up of tritium began with increased atmospheric testing in the 1950's. This resulted in rainfall concentrations of tritium reaching 1,188 TU at Ocala, Florida, in 1963 (Yobbi, 1992). With the advent of the Nuclear Test-Ban Treaty in 1963, tritium levels have decreased, and in 1988 they averaged about 5 TU. Tritium has a half life of 12.4 years, so decay and cessation of atmospheric testing have resulted in a decline of tritium in precipitation to activities similar to pre-1950 background. Thus, any ground waters that contain tritium above background levels can be assumed to have been recharged in the period from 1950 to 1975. Ground waters with tritium activities less than 10 TU can be assumed to have been recharged before 1952 or within the last 20 years.

Wells and springs in the study area were not sampled for tritium because a number of investigations have characterized the tritium concentrations of ground water in areas near or within the study area.

Studies in the northern portion of the SWFWMD (Faulkner, 1970; Swancar and Hutchinson, 1992; Jones and Upchurch, 1994) determined that ground water in the shallow portion of the Floridan aquifer has entered the aquifer very recently. Faulkner (1970) investigated the tritium content of ground water in the Rainbow Springs study area and found tritium activities in wells and springs as high as 174 TU at the same time (1966-68) that rainfall contained activities as high as 158 TU. Activities in Rainbow and Silver Springs ranged from 38 to 85 TU and 25 to 150 TU, respectively. This indicates that a

---

[7] A Tritium Unit (TU) is 1 atom of ^3H in every 10^{18} hydrogen atoms. One TU is approximately 3.2 µµCi per milliliter of water (3.2 picoCuries per liter).

large percentage of the water discharging from Rainbow and Silver Springs in 1966-68 could not have been in the flow system for more than 16 years.

Swancar and Hutchinson (1992) used tritium to show that Floridan aquifer waters in the northern half of the District are relatively young, with activities of 8 to over 10 TU common. They also concluded that recent recharge water has relatively low tritium concentrations (on the order of 10 TU) because of 1) relatively long periods required for recharge and 2) mixing with older waters in the Floridan aquifer. Their data for wells in the ground-water basins of the springs described in this report strongly implicate rapid recharge and flow toward the coastal springs.

Jones and Upchurch (1994), in a study of the King's Bay Spring System and recharge area immediately north of the study area, used tritium to show that ground water in the Floridan aquifer entered the aquifer sometime between 1952 and the present.

NITROGEN LOADING OF THE GROUND-WATER SYSTEM

It is estimated that approximately 360 tons of nitrate is dissolved in the combined yearly discharge (approximately 900 cfs) from the springs in the four complexes that were investigated as part of this study. Nitrate in the water of these springs enters the Floridan aquifer system within the boundaries of the recharge areas of the spring complexes (Figure 20). A number of sources that have the potential to contribute nitrate to ground water exist in the recharge areas. These include: 1) naturally occurring nitrate from organic decay, 2) nitrate in rainfall, 3) fertilization of golf course turf, 4) fertilization of residential turf/landscape, 5) sewage-system effluent disposal, 6) land disposal of sewage sludge, 7) effluent from septic tanks servicing residential and commercial development, 8) land disposal of septage sludge, 9) row crop fertilization, 10) citrus fertilization, 11) pasture fertilization, 12) poultry, 13) dairies, and 14) cattle.

The following section is a discussion and, where possible, a quantification of the contribution of nitrate from each of these sources to the recharge areas of each of the spring complexes. It is important for the reader to remember that discussions of land use and land-use acreage in this section refer to the situation that existed in the study area in 1990 as depicted in Figure 4.

NATURALLY OCCURRING ORGANIC DECAY

Nitrogen can be released into the environment through the microbial decomposition of surface biomass, which is largely plant material. However, the actual amount of nitrate contributed to ground water by this process is generally small as microbes and plants in the soil layer utilize and recycle the nitrogen as soon as it is made available. This observation is verified by the fact that nitrate concentrations in Floridan aquifer ground water average less than 0.01 mg/l in undeveloped and unaffected portions of the study area where the only sources of nitrogen are organic decay and rainfall.

RAINFALL

The average nitrogen concentration in rainfall in the study area was determined using data from a study of the chemical characteristics of rainfall in Florida (Irwin and Kirkland, 1980). Nine rainfall samples collected from a station in northwestern Citrus County contained an average of approximately 1.0 mg/l total nitrogen. Using this figure, for the average rainfall year (56 inches), the calculated rainfall load of nitrogen for the four ground-water basins in the study area is approximately 3,820 tons/yr. When broken out by ground-water basin the loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	1,219
Chassahowitzka	772
Weeki Wachee	1,585
Aripeka	244
Total	3,820

This quantity of nitrogen, though large, may have little effect on ground water because it is made available in small quantities to plant communities that utilize the nitrogen over the course of a year. It is also probable that a large portion is lost to mineralization, adsorption, other biological uptake, fixation, or volatilization. The assumption that rainfall is not a major contributor of nitrogen to ground water is supported by the fact that monitor wells in undeveloped portions of the study area usually have very low (<0.01mg/l) concentrations of nitrogen species. If rainfall was a significant source of nitrogen, ground water would probably have uniformly elevated nitrogen-species concentrations across the entire study area.

GOLF COURSES

There are 24 golf courses in the study area (Figure 39) covering approximately 2,040 acres. Nineteen of these courses lie within the ground-water basins for the four springs. One golf course is located north of the Homosassa ground-water basin, and four are located south of the Aripeka ground-water basin. These five golf courses are not included in the nitrogen loading calculations.

Determining the amount of nitrogen applied to golf courses as fertilizer is highly problematic. However, a study commissioned by the Sarasota Bay National Estuary Program (1992) estimated that 28 tons N/yr is applied to a golf course with 15 acres of tees and greens and 200 acres of fairways. Therefore, the golf courses in the study area may be receiving 188 tons N/yr. When broken out by ground-water basin, the approximate loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	22
Chassahowitzka	33
Weeki Wachee	111
Aripeka	22
Total	188

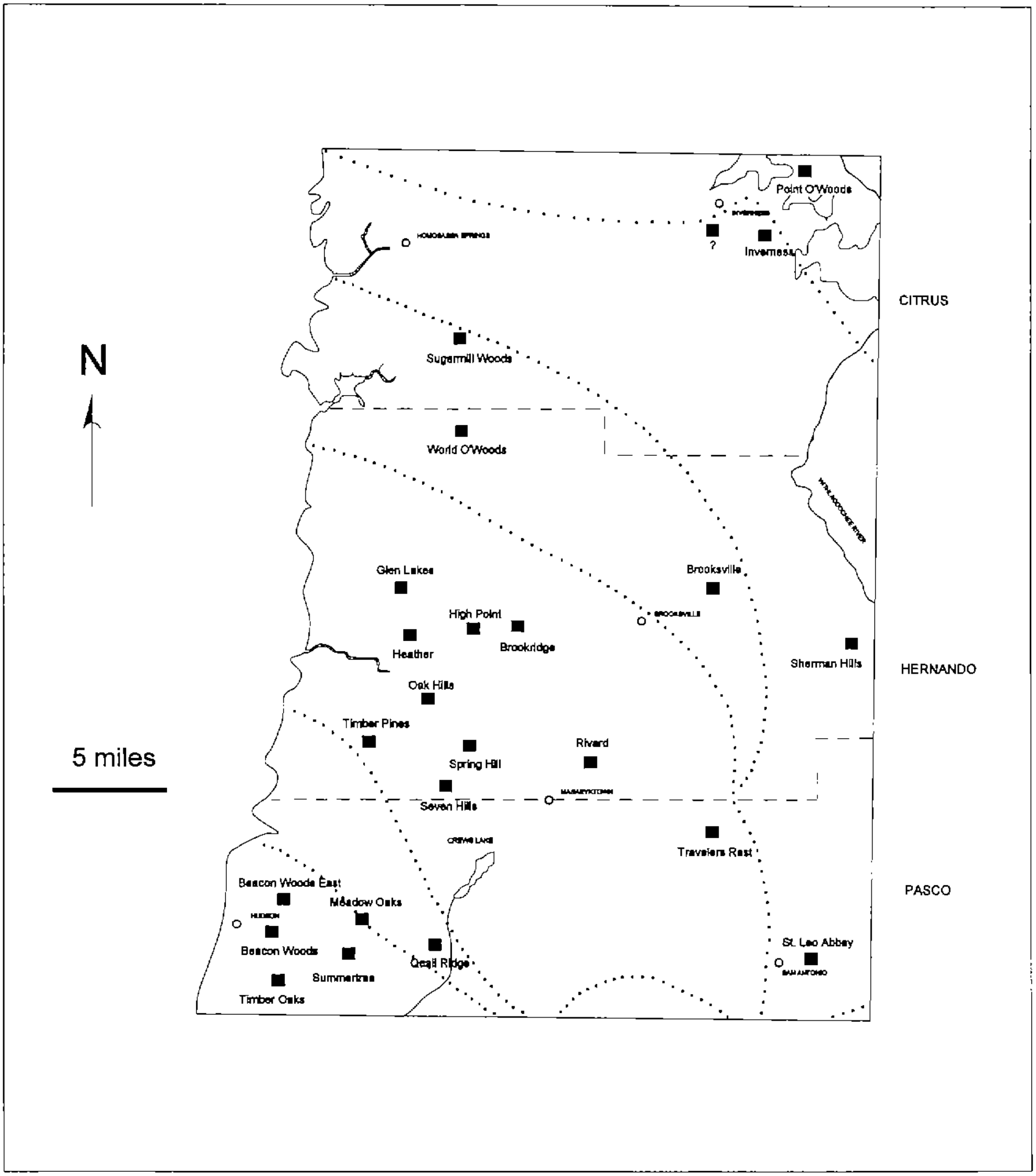


Figure 39. Golf Courses in the Study Area.

This amount is especially significant for Weeki Wachee Springs because most of the golf courses in the Weeki Wachee Springs ground-water basin are near the spring complex.

TURF/LANDSCAPE FERTILIZATION

Accurately quantifying the nitrogen contribution from the fertilization of landscaping in the study area is problematic. In previous investigations of nitrogen loading in spring complexes in the SWFWMD conducted by the authors (Jones and Upchurch, 1994; Jones, Upchurch, and Champion, 1996), nitrogen loading from landscape fertilization was determined using a complicated series of assumptions that included: 1) the amount of turf associated with low, medium, and high density residential development acreage obtained from aerial photography, 2) the percentage of turf that is actually fertilized, and 3) the amount of fertilizer that is actually used.

For this report, the authors developed a new method that estimates loading using the Florida Department of Agriculture and Consumer Services (FDACS) annual summary of the consumption of fertilizer materials and mixtures in Florida counties.[8] The Fertilizer statistics obtained from this report (FDACS, 1993) indicate that the most common non-farm fertilizers are the multi-nutrient fertilizer, 16-4-8, and a ureaform fertilizer, 38-0-0. These fertilizers, commonly applied to turfgrass, landscaping, ornamental and greenhouse crops, are often used together to maintain quality turf throughout the year (Tisdale et al., 1985; McCarty et al., 1993) .

A number of steps are involved in the new method. First, GIS county-wide land use maps developed from aerial photography flown in 1990 were used to determine the acreage of residential development in each of the four ground-water basins. Next, several assumptions were made in determining the amount of nitrogen present in the fertilizer tonnages reported in FDACS (1993). These include: 1) tonnages reported in the nonfarm category were assumed to be applied to residential and golf course turf/landscaping, 2) the nitrogen content of unknown fertilizer grades was 11 percent and 28 percent for multi-nutrient and single-nutrient fertilizers, respectively, and 3) the nitrogen derived from fertilizer was evenly distributed throughout the acreage of the residential and golf course land uses.

To remove the golf course fertilization component from the estimate, the nitrogen loading from fertilization of golf course turf (calculated using the method explained in the previous section) was subtracted from the estimate.

Using the above method, the following estimates of nitrogen loading from fertilization of residential turf/landscaping were calculated for the four ground-water basins:

---

[8]The nitrogen loading estimate for turf/landscape fertilization calculated using the new method is approximately 33 percent lower than the estimate calculated using the old method. The new method is used in this report because it uses fewer assumptions and more verifiable data.

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	171
Chassahowitzka	52
Weeki Wachee	213
Aripeka	64
Total	500

A study of nitrate sources in a sewered housing development in Long Island, New York (Flipse *et al.*, 1984) estimated that at least 60 percent of the nitrogen applied as fertilizer to turf leached below the root zone and eventually reached ground water. If the results of the Long Island study can be applied to the study area, at least 300 tons of nitrogen fertilizers could reach ground water. This number may be conservative given the sandy soils of the area, the higher rainfall compared to Long Island, and the difference in growing season and climate. To determine the accuracy of these figures, it is recommended that a program of long-term monitoring of ground-water quality in the vicinity of several recently-constructed, sewered subdivisions in the area begin in the near future.

Compared to other nitrogen sources in the vicinity of the coastal springs, 500 tons N/yr from turf/landscaping fertilization is significant. This is especially true for the Weeki Wachee Springs ground-water basin because most of the 213 tons of nitrogen applied in the basin is used in high-density subdivisions that are near the spring.

Storm-water runoff from residential areas is high in nitrogen (U.S. EPA, 1983). This indicates that excess nitrogen applied to landscaping is leached from the land surface by rainfall and carried away by storm water. Since storm water in the study area may eventually reach the Floridan aquifer, it is important to determine the amount of nitrogen contributed by storm water from turf/landscape fertilization and how much of that nitrogen reaches ground water. Although it is not possible to quantify the contribution to ground water, it is possible to quantify the amount of nitrogen contributed to storm water from residential areas. This figure is 30 tons N/yr (calculated on page 126), which is six percent of the 500 tons of nitrogen that may be applied to residential areas as fertilizer. This amount of nitrogen is relatively insignificant.

SEWAGE TREATMENT PLANTS

There are approximately 98 active wastewater treatment facilities in the four ground-water basins in the study area (Figure 40). These facilities have a total permitted capacity of 12.0 million gallons per day (mgd), and the average volume of waste water processed by these facilities during 1995 was 6.9 mgd. Tables 12-15 contain the name, map index number, volume of effluent treated in 1995, and effluent disposal method for each facility. The facilities range from small package plants for businesses with permitted capacities of < 2,500 gallons per day (gpd) to large regional plants serving residential areas with permitted capacities of 2 mgd.

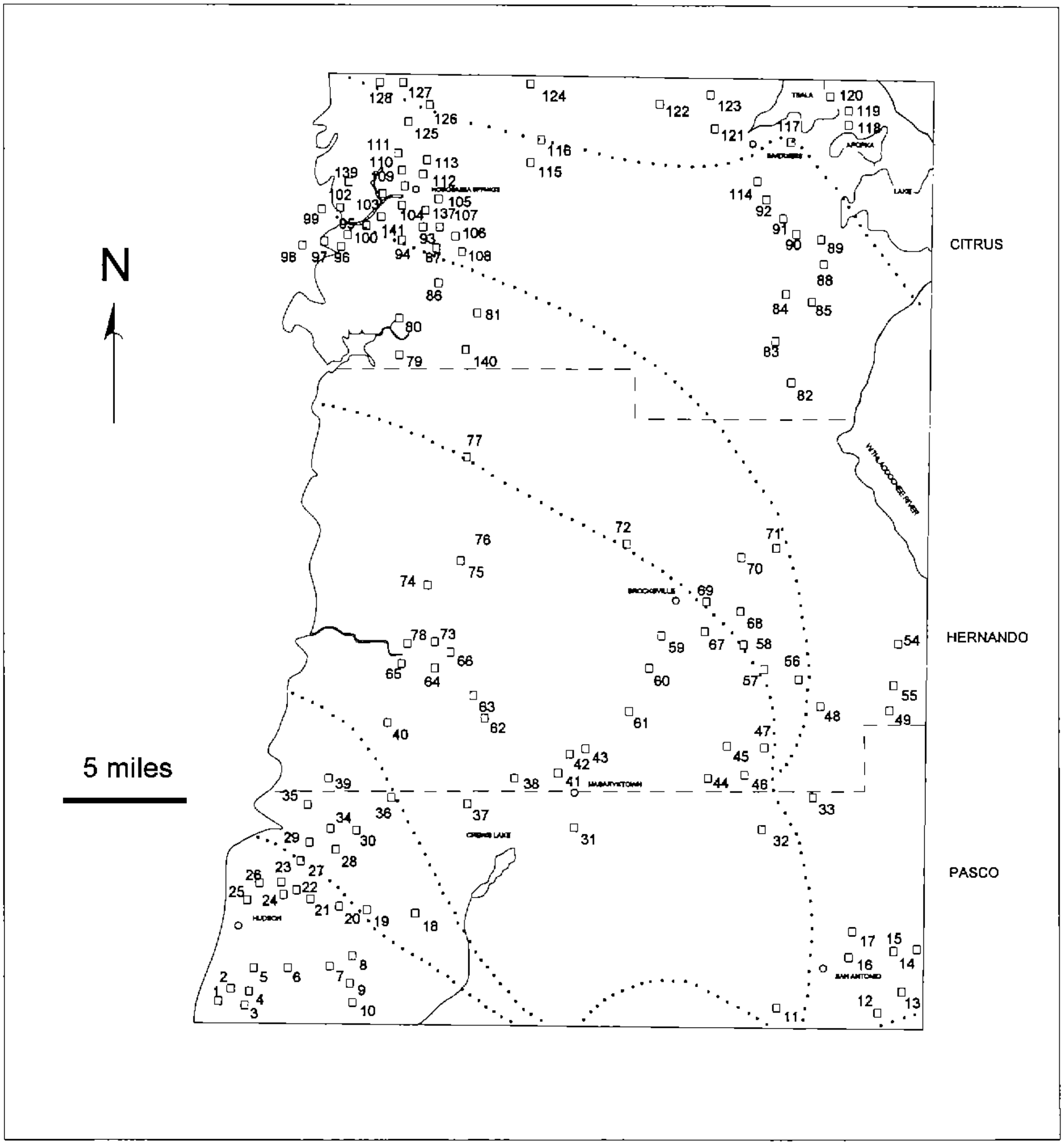


Figure 40. Wastewater Treatment Facilities in the Study Area.

Table 12. Wastewater-Treatment Facilities in the Homosassa Springs Ground-Water Basin.

FACILITY	MAP INDEX	WASTEWATER TREATED IN 1995 (GALLONS)	EFFLUENT DISPOSAL METHOD
BELLA VILLA M.P.	110	4,407,000	SPRAY FLD
CITRUS HILL RV PARK	12	2,952,000	PER PND
EVANRIDGE MHP	87	3,208,000	PERC PND
FISHERMANS COVE	14	882,000	PERC PND
FLORAL CITY ELEM.	85	1,094,000	PERC PND
FLORAL OAKS APTS.	84	1,034,000	PERC PND
FPL NUCLEAR TRAINING	106	370,100	PERC PND
HILL AND DALE WWTP	48	17,117,000	PERC PND
HOMOSASSA SQUARE	93	2,843,800	PERC PND
HOMOSASSA IND. PARK	111	1,453,750	PERC PND/SPY FLD
HOMOSASSA REGIONAL WWTP	112	3,045,000	PERC PND
HOMOSASSA ELEM.	100	608,000	PERC PND
HOMOSASSA SPGS WILDLIFE PRK	103	1,000,000	SPRAY FLD
LAKESIDE OAKS MHP	13	2,061,800	PERC PND
MANATEE CAMP & MARINA	141	699,000	PERC PND
MEADOWS OF HOMOSASSA	137	5,639,000	PERC PND
MISTY RIVER SEAFOOD REST.	105	853,000	PERC PND
NATURES RESORT CAMPGROUND	102	2,773,000	PERC PND
OAK MANOR MHP	49	441,220	PERC PND
RIDGE MANOR WEST	55	33,864,000	PERC PND
RIVER HAVEN VILLAGE	99	20,971,000	PERC PND
RIVERSIDE INN	94	5,548,000	PERC PND/DRN FLD
RIVERVIEW MOBILE ESTATES	95	2,010,000	PERC PND
SAINT LEO WWTP	16	13,290,000	SPRAY FLD
SAN ANTONIO ELEM.	17	1,310,000	PERC PND
SPRING GARDENS WWTP	108	14,867,000	PERC PND
SPRINGS PLAZA WWTP	109	2,917,000	SPRAY FLD
STONERIDGE LANDINGS	82	21,525,400	PERC PND
SUNNY DAYS PLAZA	104	1,423,000	PERC PND
SUNNYSKIES MHP	15	3,623,000	PERC PND

Table 12. Wastewater-Treatment Facilities in the Homosassa Springs Ground-Water Basin (Continued).

FACILITY	MAP INDEX	WASTEWATER TREATED IN 1995 (GALLONS)	EFFLUENT DISPOSAL METHOD
TALL PINES	54	849,000	PERC PND
TARAWOOD	83	315,640	PERC PND
TERRACE PARK	33	2,398,000	PERC PND
WESTWIND VILLAGE	139	4,154,000	PERC PND/SPY FLD
IMPERIAL GARDENS	125	946,000	PERC PND
STONEBROOK MHP	113	5,784,000	PERC PND
FORESTVIEW	138	5,802,000	PERC PND
LECANTO SCHOOL COMPLEX	115	10,361,000	PERC PND
OAK POND	117	1,214,000	PERC PND
ROYAL OAKS	114	2,161,000	PERC PND
CITY OF INVERNESS	92	227,312,000	SPRAY FIELD
MURPHY'S RESTAURANT	91	19,408,500	PERC PND
ENSIGN DOSIS	90	790,700	PERC PND
MOONRISE RESORT	89	3,057,000	PERC PND
SINGING FOREST MHP	88	4,570,800	PERC PND
SPRINGS VILLAGE	107	CLOSED	PERC PND

Table 13. Wastewater-Treatment Facilities in the Chassahowitzka Springs Ground-Water Basin.

FACILITY	MAP INDEX	WASTEWATER TREATED IN 1995 (GALLONS)	EFFLUENT DISPOSAL METHOD
BROOKSVILLE GOLF & COUNTRY CLUB	71	1,750,000	PERC PND
CAMP-N-WATER	97	1,372,000	SPRAY FLD
CENTRAL POWER & LIME	72	671,000	PERC PND
CHASSAHOWITZKA RIVER CAMPGROUND	79	1,084,700	SPRAY FLD
CHASSAHOWITZKA RIVER LODGE	80	1,912,000	PERC PND
CITY OF BROOKSVILLE CROOM ROAD	70	75,857,000	PERC PND
COUNTRYSIDE ESTATES	56	2,506,100	PERC PND
HERNANDO HIGH & ELEM SCHOOL	69	9,545,000	PERC PND
HERNANDO CHRISTEN ACADEMY	58	967,400	PERC PND
HIDDEN VALLEY CAMPGROUND	57	84,900	PERC PND
ISLANDS CONDOMINIUMS	96	5,167,000	PERC PND
SEVILLE WWTP	77	166,000	PERC PND
SUGARMILL WOODS CYPRESS VILLAGE	81	102,936,000	PERC PND/SPY FLD
TURTLE CREEK CAMPGROUND	98	1,779,000	PERC PND
WALDEN WOODS	140	1,520,000	PERC PND
WESLEYAN VILLAGE	68	10,612,500	PERC PND
WHISPERING PINES MHP	86	1,316,000	PERC PND

Table 14. Wastewater-Treatment Facilities in the Weeki Wachee Springs Ground-Water Basin.

FACILITY	MAP INDEX	WASTEWATER TREATED IN 1995 (GALLONS)	EFFLUENT DISPOSAL METHOD
BERKELY MANOR	40	93,316,000	PERC PND
BIG OAKS TRAVEL PARK	31	996,500	PERC PND
BROOKRIDGE	73	110,314,000	PERC PND
BROOKS INDUSTRIES	59	6,650	PERC PND/SPRAY FLD
CAMP E-HOW-KEE	44	166,200	PERC PND
CAMP-A-WYLE	62	4,542,000	PERC PND
CAMPERS HOLIDAY	45	6,697,000	PERC PND
CITY OF BROOKSVILLE SCHOOL ST	67	289,812,000	PERC PND
EVERGREEN MOBILE VILLAGE	60	1,984,600	PERC PND
GLEN SUBREGIONAL WWTP	75	82,815,000	PERC PND/SPRAY FLD
HERNANDO CO. AIRPORT	42	32,453,000	PERC PND
HOLIDAY INN WEEKI WACHEE	64	7,357,000	PERC PND
IMPERIAL ESTATES MHP	61	5,200,500	PERC PND/SPRAY FLD
LAKEWOOD RETREAT	47	541,000	PERC PND
McGIST MHP	66	2,332,000	PERC PND
PASCO CENTER SUBREGIONAL	11	8,872,000	PERC PND/SPRAY FLD
PINE VILLAGE WWTP	76	2,456,000	PERC PND
SHADY HILLS ELEM.	37	913,000	PERC PND
SOUTHWEST FL WATER MANAGEMENT DISTRICT	43	1,030,700	PERC PND
SPARTON ELECTRONICS	78	1,731,000	PERC PND
SPRINGHILL UTILITIES	41	545,696,000	PERC PND/SPRAY FLD
THE MEADOWS MHP	74	645,000	PERC PND
TOPICS RV PARK	38	5,116,000	PERC PND
TRAVELERS REST RV PARK	32	13,403,400	PERC PND
WEEKI WACHEE SPRING	65	4,080,000	PERC PND
WEST HERNANDO WWTP	63	62,601,000	PERC PND
YOUTH CAMP CHURCH	46	824,500	PERC PND

Table 15. Wastewater-Treatment Facilities in the Aripeka Springs Ground-Water Basin.

FACILITY	MAP INDEX	WASTEWATER TREATED IN 1995 (GALLONS)	EFFLUENT DISPOSAL METHOD
BRENTWOOD ESTATES	28	2,197,400	PERC PND
COUNTRY AIRE VILLAGE	34	3,988,000	PERC PND
EASTLAKE LANDINGS	36	4,822,000	PERC PND
HOLIDAY SPRINGS TRAVEL PARK	39	5,198,000	PERC PND
HUDSON WWTP	30	818,437,000	PERC PND/REUSE
SEVEN OAKS TTP	29	4,059,000	PERC PND
SHADY HILLS	18	193,224,000	PERC PND
RIVER RIDGE INTERIM	19	34,122,000	PERC PND/REUSE
A & W MHP	35	4,758,500	PERK POND

The total volume of municipal wastewater entering the treatment plants in 1995 was 2.5 billion gallons. Total nitrogen concentrations in municipal wastewater range from 20 to 85 mg/l (U.S. E.P.A., 1981). An important factor that must be considered in determining an accurate value from this range is the degree to which the nitrogen concentration in raw sewage is diluted by ground-water inflow to buried sewer pipes. Because many areas in Florida have a high water table, ground-water inflow to pipelines is probably significant, which would result in a lower nitrogen concentration of effluent entering the treatment facility. A value of 40 mg/l, the median nitrogen concentration (U.S. E.P.A., 1981) of municipal sewage, was chosen to represent the nitrogen content of wastewater. Using 40 mg/l, the total amount of nitrogen in 2.5 billion gallons of raw wastewater is 505 tons. All of the wastewater treatment plants currently treat to the secondary level. Secondary treatment typically removes approximately 10 to 40 percent of the total nitrogen from domestic wastewater effluent (Ayers and Associates, 1991). Using an average of 25 percent removal, 126 tons is removed from the wastewater and incorporated into the sludge fraction of the waste while 379 tons remain in the effluent fraction.

Quantifying the amount of nitrogen from the treatment and disposal of municipal waste water that bypasses the vegetative and soil uptake mechanisms and reaches ground water was not attempted. However, a discussion of the potential for nitrate to reach ground water from the disposal of both treated effluent and sludge is presented in the following sections.

Effluent

The effluent from treatment facilities in the study area that contains the 379 tons of nitrogen is disposed of in several different ways. Percolation ponds are used at 80 facilities, nine use a combination of percolation ponds and spray fields, seven use spray fields only, one uses a combination of percolation ponds and drain fields, and one uses a combination of percolation ponds and reuse. Since the disposal facilities are near the treatment facilities, the 379 tons of nitrogen in effluent can be broken out by ground-water basin.

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	58
Chassahowitzka	27
Weeki Wachee	160
Aripeka	134
Total	379

Jones and Upchurch (1993) and Jones and Upchurch (1994) documented that some effluent percolation ponds near the study area drain extremely rapidly. This is because many of the ponds have highly porous bottoms composed of clean, fine-grained filter material. Since the geology of the study area is such that low permeability confining units are either not present or are frequently breached by sinkholes, treated effluent can rapidly percolate directly into the Floridan aquifer. A study by Jones and Upchurch (1994) in Citrus County demonstrated this by showing that levels of nitrate exceeding the drinking water standard were detected in numerous wells monitoring large effluent percolation ponds.

The effect of effluent on springs in the Homosassa and Chassahowitzka complexes is probably insignificant because the amount of nitrogen contributed from effluent in their ground-water basins is low. The 160 tons of effluent nitrogen in the Weeki Wachee ground-water basin is high, but the treatment plants are dispersed over a very large area and many are located far from the spring. The nitrogen isotopic ratios in the springs are low and are, therefore, indicative of an inorganic source which is probably fertilizer.

The 134 tons of effluent nitrogen in the Aripeka basin may contribute some nitrogen to springs in the Aripeka complex because the Hudson wastewater treatment plant, which contributes over 76 percent of the 134 tons, is located approximately 3.5 miles from the spring. However, the plant is probably not the dominant source of nitrogen because, similar to Weeki Wachee Springs, the low nitrogen isotopic ratios indicate an inorganic fertilizer source.

Sludge

Sludge generated by the 98 wastewater treatment plants in the study area is disposed of at seven sites in the study area (Figure 41). Sludge spreading sites include privately owned agricultural lands and county-owned disposal facilities. Although both septage and sludge wastes can be disposed of at the same site, they must be spread in separate, designated areas. Sludge waste is brought to the sites by disposal companies that contract with the municipalities or the individual treatment plants.

Land spreading of sludge can contaminate ground water because the waste contains high concentrations of nutrients, trace metals, and organic compounds. If the application rate of sludge exceeds the capacity of the vegetation or soils to utilize or absorb these compounds, they may percolate into ground water.

The Domestic Waste Section of the FDEP is responsible for overseeing sludge disposal. Chapter 62-640 of the Florida Administrative Code states that sludge disposal sites must have an agricultural use plan that details how sludge will be used as part of a planned agricultural operation. According to Chapter 62-640 and FDEP Domestic Waste staff, the amount of sludge that can be applied is based on the type of crop the sludge is

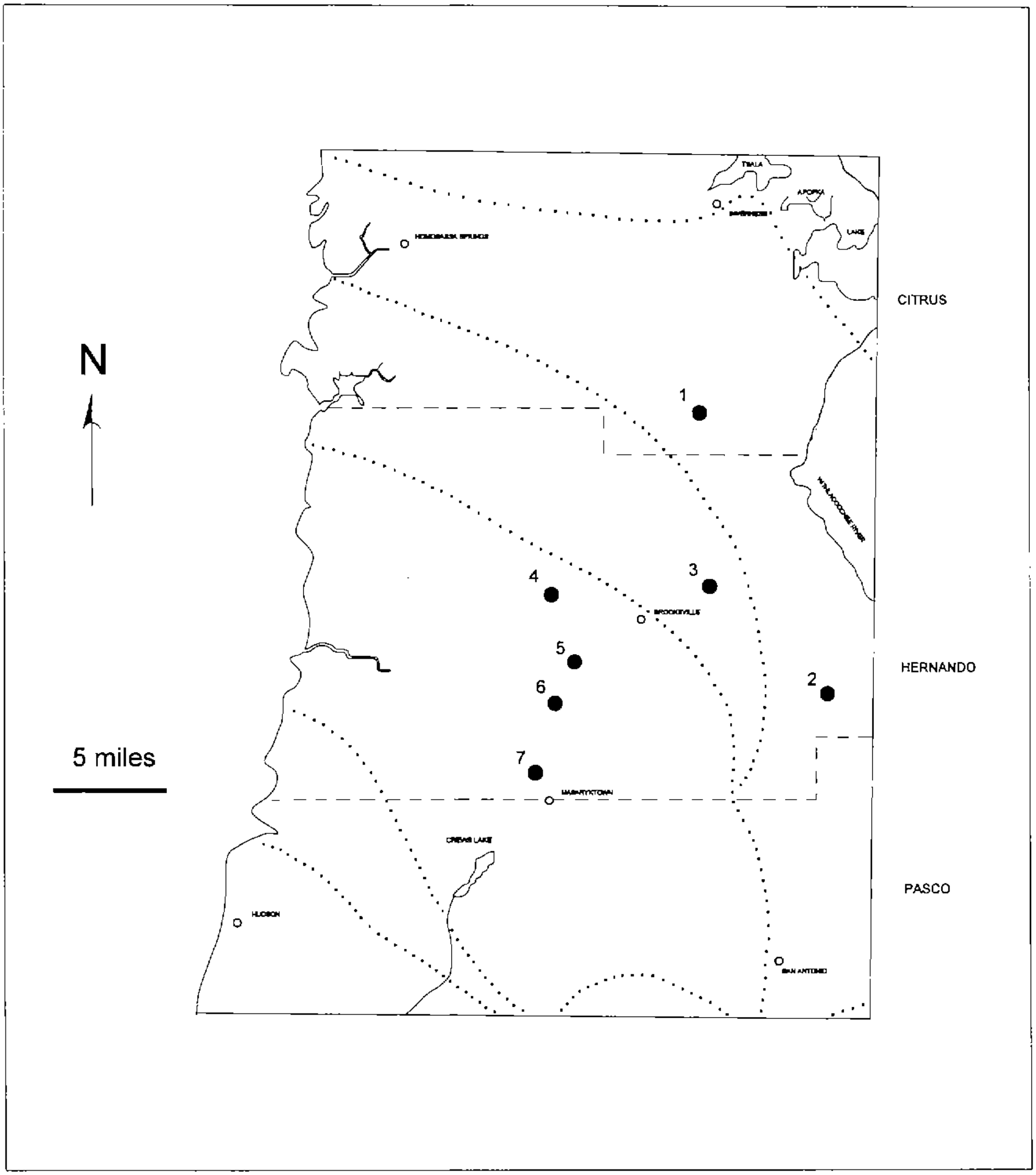


Figure 41. Sludge Spreading Sites in the Study Area.

applied to and how the sludge is applied. For Bahia Grass, a volume of sludge can be spread each year on each acre that contains approximately 320 lbs of nitrogen. If the sludge is disked into the soil first, only 160 lbs of nitrogen can be applied.

In January of 1993, disposal sites began to be permitted for the maximum amount of sludge waste they could accept each year. Disposal sites were also required to keep records of the amount of sludge applied on the property. Using the actual amount of sludge applied in 1995, as determined by the FDEP, an estimated total of 13.8 million gallons was applied in the study area. Table 16, lists the volume of sludge in gallons applied in 1995 at each of the seven disposal sites in the study area.

The following method was used to determine the amount of nitrogen in sludge applied at each disposal site. On page 110 it was calculated that 126 tons of nitrogen is contained in the sludge produced by the 98 sewage treatment plants in the study area. If it is assumed that all of the sludge processed in the study area is applied at the seven disposal sites, then the amount of nitrogen in the 13.8 million gallons of sludge must contain 126 tons of nitrogen. To determine the amount of nitrogen loaded to each site, a percentage of the 13.8 million gallons applied at each site is calculated. This percentage for each disposal site is then measured against the 126 tons of nitrogen. Using this method, nitrogen loadings from sludge disposal, broken out by ground-water basin, are included in Table 16.

Of the 126 tons of nitrogen in sludge applied in the study area, a relatively insignificant amount of sludge containing 29 tons of nitrogen is applied in the Homosassa and Chassahowitzka ground-water basins. Sludge containing the remaining 97 tons of nitrogen is disposed of at four sites in the Weeki Wachee ground-water basin. The sludge applied at each site is probably not contributing a significant amount of nitrogen to springs in the Weeki Wachee complex because it is spread over four widely dispersed sites following a program designed to promote vegetative uptake. However, the possibility of enrichment of nitrogen in ground water in the vicinity of the sites should not be ignored.

SEPTIC TANKS

Effluent

Numerous investigators have characterized septic tank effluent for various chemical species including major ions, trace metals and nutrients. Nitrogen is present in high concentrations in septic-tank effluent at a ratio of 75-80 percent ammonium-nitrogen to 20-25 percent organic nitrogen (Otis *et al.*, 1975). Total nitrogen concentrations in septic tank effluent vary from 25 to 100 mg/l with the average being in the range of 35 to 45 mg/l (U.S. E.P.A., 1980). Aerial photo analysis and delineation of the extent of sewer systems

Table 16. Sludge Disposal Information and Nitrogen Loading Estimates for Facilities in the Study Area.

Site	MAP INDEX NUMBER	GROUND-WATER BASIN	PERMITTED ACRES	PERMITTED VS. ACTUAL AMOUNT SPREAD (gals/yr)	N LOADING (tons/yr)
Cason	1	Homosassa	436	1,536,000 55,000	< 1
Ridge Manor	2	Homosassa	70	1,140,000 915,000	8.0
John Porter	3	Chassahowitzka	80	5,600,000 2,196,800	20.0
Bell Creek Farms	4	Weeki Wachee	250	7,500,000 1,526,800	14.0
Gibson	5	Weeki Wachee	30	576,000 224,640 (est)	2 (est)
Nordgen	6	Weeki Wachee	99	6,930,000 5,054,000	46.0
Hernando County Airport	7	Weeki Wachee	436	21,800,000 3,843,900	35.0
		Total	1,401	45,082,000 13,816,140 (less Gibson)	126.0

have indicated there are approximately 24,000 septic tanks within the four ground-water basins. The density of septic tanks within the ground-water basins is depicted in Figure 42. The number of septic tanks broken out by individual ground-water basins is as follows:

Ground-Water Basin	Number of Septic Tanks
Homosassa	6,300
Chassahowitzka	1,700
Weeki Wachee	12,400
Aripeka	4,000
Total	24,000

Because much of the residential development in the study area has been designed for retirees and a significant percentage of the residences may be occupied only during the winter, it is probably reasonable to assume that each septic tank services an

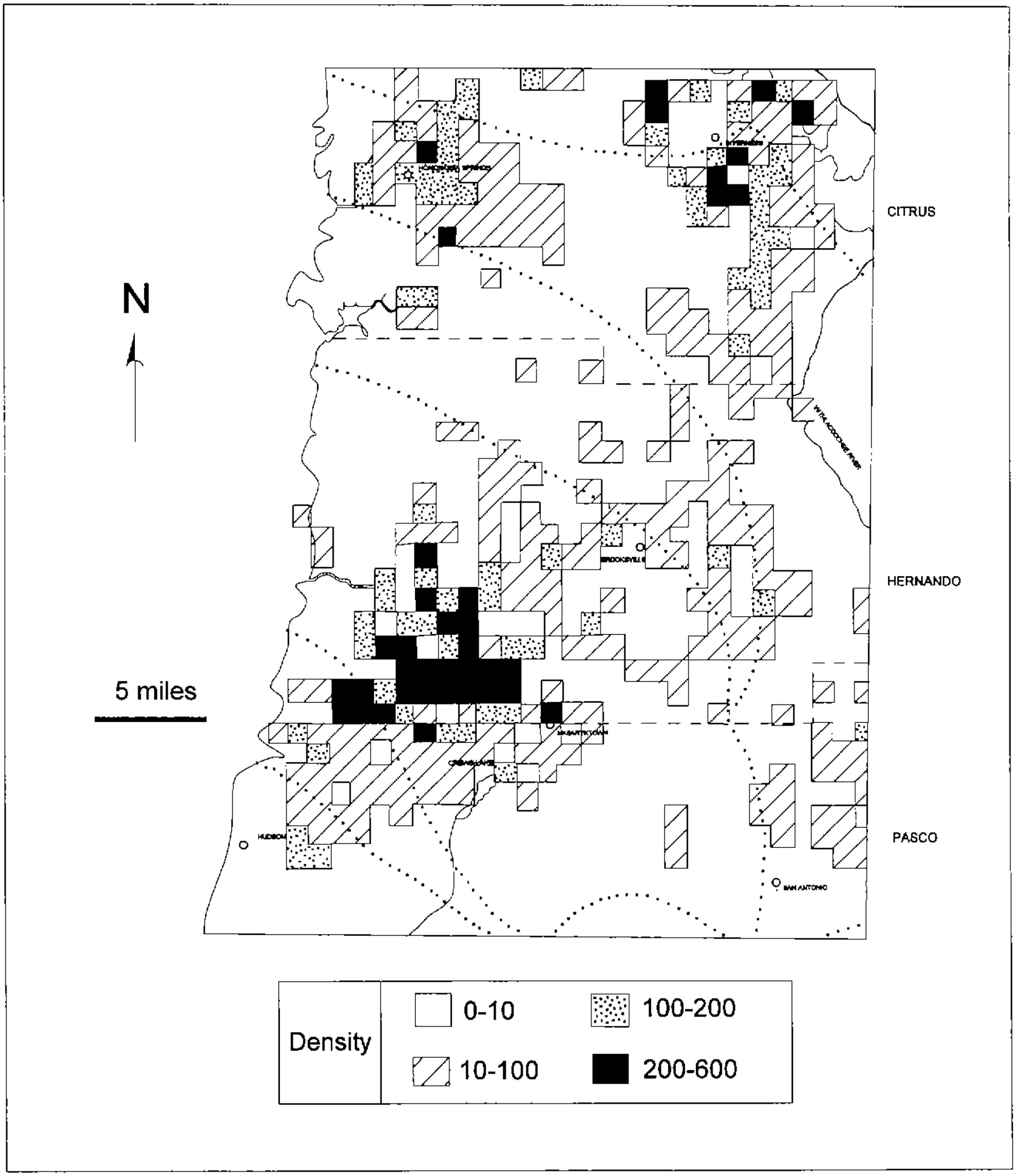


Figure 42. Septic Tank Density per Square Mile in the Study Area.

average of 3 people. The annual nitrogen contribution per septic tank would then be approximately 55 lbs (Walker *et al.,* 1973a). When broken out by ground-water basin, the loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	173
Chassahowitzka	47
Weeki Wachee	341
Aripeka	110
Total	671

Research indicates that 20 to 40 percent of the nitrogen in effluent may be removed by mineralization, denitrification, adsorption, biological uptake, fixation, or volatilization before the effluent reaches ground water (de Vries, 1972; Andreoli *et al.,* 1979; Harkin *et al.,* 1979; Peavy and Brawner, 1979; Laak, 1982). If 30 percent removal is achieved, then each septic tank contributes approximately 38.5 lbs/yr of nitrogen to ground water, which, according to Hantzsche and Finnemore (1992), is fully converted to nitrate. Using this figure, the total nitrogen contribution for septic tanks in the study area is approximately 469 tons/yr.

Septic tanks are probably contributing some nitrogen to the coastal springs because most of the septic tanks are in coastal areas close to the springs. However, septic tank nitrogen is not the dominant source because the nitrogen isotopic ratios of spring water indicate that an inorganic source, such as ammonium nitrate fertilizer, is dominant over organic sources.

Septage

Land spreading of septage waste is regulated by the Citrus, Hernando, and Pasco County Public Health units. There were four active septage disposal sites in the study area in 1995 (Figure 43).

According to the Citrus and Hernando County Public Health Units, an estimated total of 3.8 million gallons of septage was applied in the study area in 1995 (Table 17). According to the U.S. E.P.A. (1994), the nitrogen content of septage averages 588 mg/l as TKN. Using this figure, there are approximately 9.3 tons of nitrogen in the form of TKN. Upon application, TKN would convert to nitrate. Nitrogen loadings broken out by ground-water basin are included in Table 17.

The 9.3 tons of nitrogen in septage applied at each site is insignificant because the amount is very small and it is spread over 4 widely dispersed sites designed to promote vegetative uptake.

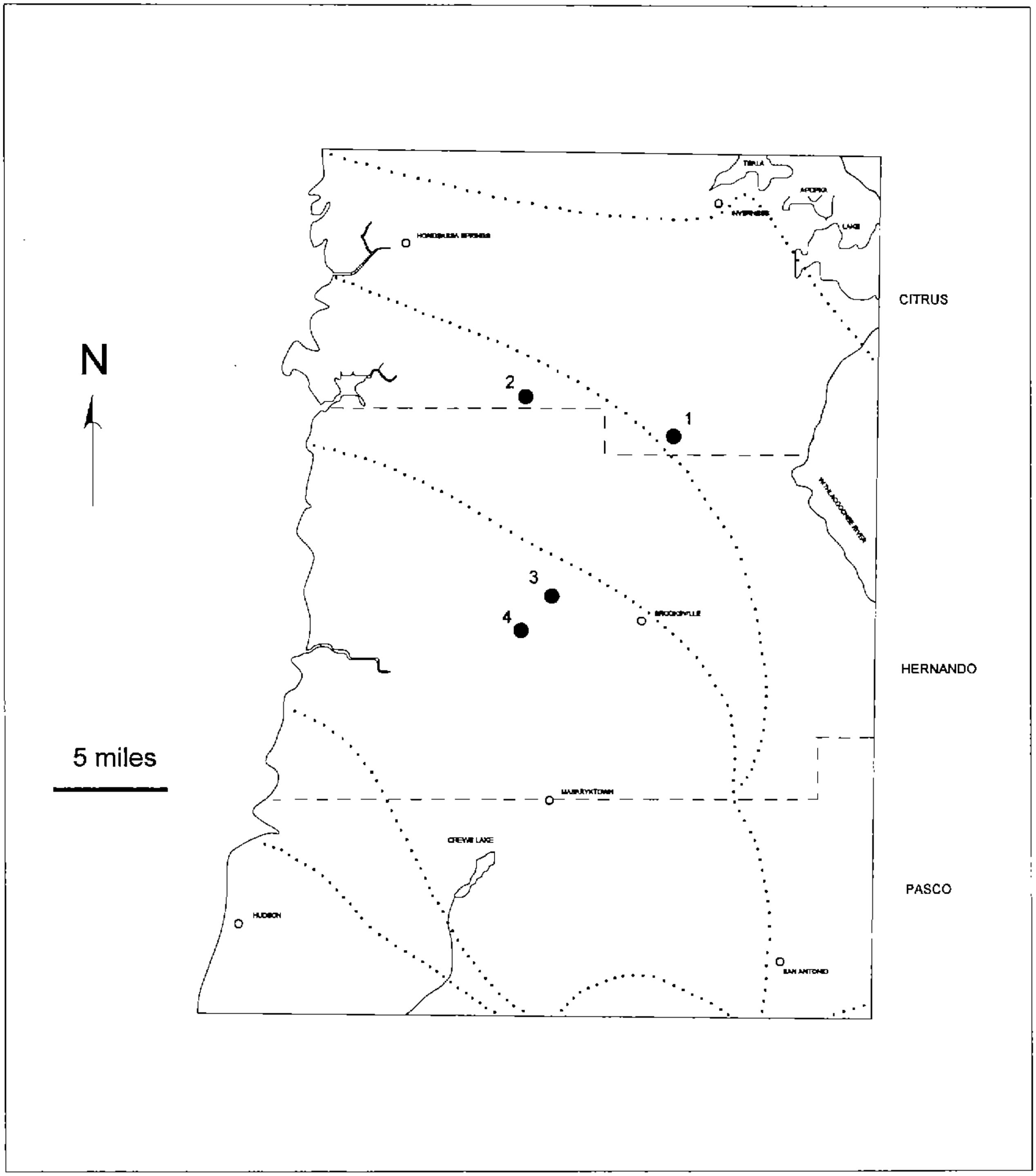


Figure 43. Septage Spreading Sites in the Study Area.

Table 17. Septage Disposal Information and Nitrogen Loading Estimates for Facilities in the Study Area.

Site	MAP INDEX NUMBER	GROUND-WATER BASIN	PERMITTED ACRES	PERMITTED VS. ACTUAL AMOUNT SPREAD (gals/yr)	N LOADING (tons/yr)
Brooks	1	Homosassa	160	9,846,154 115,450	0.3
Fitzgerald	2	Chassahowitzka	240	14,769,230 752,550	1.9
Bell Creek Farms	3	Weeki Wachee	250	7,500,000 1,526,800	3.8
Cliff's Septage	4	Weeki Wachee	69	1,324,800 1,320,500	3.3
		Total	719	33,096,744 3,715,300	9.3

AGRICULTURE

Agricultural loadings of nitrogen in the study area are subdivided into row crops, citrus, pasture, poultry, dairies, and cattle.

Row Crops

Row crops are a relatively minor land use in the study area. SWFWMD land use information indicates that row crops covered approximately 1,314 acres in the four ground-water basins in 1990. Crops in the study area include watermelons, tomatoes, squash, eggplant, corn, and legumes. Individual row crops typically cover small acreages and, if crop rotations are common, may vary seasonally. Crop rotations make it difficult to estimate accurate acreages for a particular row crop in each ground-water basin.

IFAS (1990) recommends an average application of 170 lbs N/ac/yr for the row crops common to the study area. This amount of nitrogen applied to the 1,314 acres of row crops would result in a loading of approximately 112 tons of nitrogen per year. When broken out by ground-water basin, the loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	61
Chassahowitzka	15
Weeki Wachee	36
Aripeka	0
Total	112

Even though nitrogen isotopic ratios in spring water indicate an inorganic fertilizer source, row crop fertilization is probably insignificant because the recommended application rates and spacial coverage are low, areas of application are distant from the springs and widely dispersed, and vegetative and soil removal mechanisms are probably effective. Historical nitrogen loadings from row crops are probably minor since agricultural statistics indicate that row crops have been a minor land use in the study area since the mid 1960's (U.S. Bureau of the Census, Census of Agriculture, 1964).

Citrus

Studies in Polk and Hillsborough Counties have indicated that citrus production can elevate ground-water nitrogen to high levels (FDEP/SWFWMD, 1993; Jones and Upchurch, 1993). Interpretation of historical aerial photographs indicates that citrus covered approximately 31,000 acres in the study area in the mid 1970's. According to IFAS (1992), mature citrus trees require 180-200 lbs N/ac/yr. This would have resulted in an application of approximately 2,790 tons of nitrogen per year to the study area. However, the current nitrogen loading from citrus production is insignificant because only 2,840 acres remain in the four ground-water basins in the study area (SWFWMD, 1990) as a result of freezes in the mid 1980's that devastated the industry. Application of 180 lbs N/ac/yr to this acreage would result in 256 tons of N/yr. When broken out by ground-water basin, the loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	163
Chassahowitzka	22
Weeki Wachee	63
Aripeka	8
Total	256

The 163 tons of fertilizer nitrogen currently applied to citrus in the Homosassa ground-water basin is probably not a significant contributor to springs in the Homosassa complex. This is because the citrus is widely dispersed and, for the most part, located a long distance from the spring. Citrus should be even less of a nitrogen source in the other ground-water basins because the citrus is also distant from the springs, widely dispersed, and the N loading is much smaller than in the Homosassa basin.

There is a strong possibility that the large quantities of nitrogen fertilizers applied to citrus prior to the freezes in the mid 1980's may be responsible for elevated nitrate levels in ground water in the study area. This is especially likely in the vicinity of the Brooksville Ridge where most of the citrus was located. However, since most of the citrus in the Brooksville Ridge was located as far as 10 miles from the springs, nitrate in ground water from citrus fertilization would probably be diluted to background levels prior to discharging at the springs.

Pasture Fertilization

Pasture fertilization has been determined to be a significant source of nitrate to Rainbow Springs in Marion County (Jones *et al.*, 1996). Pasture is a major land use in the study area, and occupies approximately 133,729 acres within the four ground-water basins (SWFWMD, 1990). Nitrogen fertilizers are applied to pastures to promote the growth of pasture grasses. Bahia Grass, a common pasture grass, is a warm-season perennial grown for livestock grazing and hay. It can withstand heavy grazing stress, and produces good quality hay if well fertilized. Bahia Grass readily takes up mineral nutrients in the soil and recycles them within the upper soil zone. If harvested, however, the mineral nutrients contained within the hay are not recycled into the soil and must be supplemented by fertilization (Dr. Carrol Chambliss, University of Florida, personal communication, 1995).

Accurately quantifying the nitrogen contribution from the fertilization of pasture in the study area is problematic. In previous investigations conducted by the authors (Jones and Upchurch, 1994; Jones *et al.*, 1996) of nitrogen loading in the recharge areas of springs in the SWFWMD, nitrogen loading from pasture fertilization was determined by assuming that all pasture acreage in the study area was fertilized at the rate of 50 lbs N/ac/yr.

For this report, the authors developed a new method that estimates loading using the Florida Department of Agriculture and Consumer Services (FDACS) Annual Summary of the Consumption of Fertilizer Materials and Mixtures in Florida Counties (FDACS, 1993). Because this method uses numerous assumptions and calculations, it is fully detailed in Appendix V.

According to FDACS (1993), the tonnage of nitrogen in fertilizer utilized in farming in the study area from July, 1992 to June, 1993 was 1,732 tons. Fertilizers containing this amount of nitrogen were applied to row crops, citrus and pasture; the dominant crops in the study area. To determine the total amount of nitrogen applied only to pasture, the 368 tons of nitrogen applied to row crops and citrus, calculated on page 119, were subtracted from the 1,732 tons of nitrogen used in farming. This left 1,364 tons. Broken out by ground-water basin the estimated loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	907
Chassahowitzka	177
Weeki Wachee	262
Aripeka	18
Total	1,364

While pasture fertilization may contribute a significant amount of nitrate to ground water locally, it probably does not contribute a significant amount to the springs. This is because pasture acreage is widely dispersed which may allow a large percentage of the applied nitrogen to be removed prior to reaching ground water by the numerous vegetative and soil uptake mechanisms. In addition, most of the pasture acreage is concentrated in the central to eastern portions of the study area well inland of the springs. Concentrations of nitrate in ground water in these areas, which may at least partially result from pasture fertilization, are low and therefore, would probably be attenuated to background levels before reaching the springs.

Poultry Production

Poultry production has been determined to be a significant source of nitrate to ground water in northern Florida (Hatzell, 1995). Poultry production has the potential to produce large amounts of nitrogen on relatively small plots of land.

Poultry on average produce 0.35 lbs of waste per day per animal of which 1.5 percent is nitrogen (Wilson and Vohra, 1980; IFAS, 1992). The FDACS (1993) estimates that there were 3.6 million hens in Citrus, Hernando, and Pasco Counties in 1992. Discussions with CES (personal communication, 1996) indicate that most of the poultry production in Pasco County occurs in the Dade City-Zephyrhills area. Because much of this area is outside of the study area, only half of the hen population in Pasco County was used in the nitrogen loading calculations. Therefore, approximately 2.5 million hens were estimated to be present in the study area. This number of hens would produce 2,378 tons N/yr. When broken out by ground-water basin, the loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	1,189
Chassahowitzka	333
Weeki Wachee	856
Aripeka	0
Total	2,378

It is not possible to determine accurate nitrogen loadings from poultry production because, while some of the poultry manure is stockpiled on the farm where it was produced, some is applied to pastures in or near the study area and some is shipped to south Florida and used as citrus fertilizer. In addition, at least 40 percent may be converted to ammonia (NH_3) and lost through volatilization to the atmosphere during handling and land application (Kirchmann and Witter, 1989).

The low nitrogen isotopic ratios in spring water effectively rule out nitrogen produced from poultry production as a major source of nitrate. The limited effect of poultry nitrogen on nitrate levels in springs may result from the fact that much of the poultry manure is apparently shipped out of the study area. In addition, poultry farms are located far enough inland that dilution would significantly reduce the concentration of nitrate in ground water prior to arrival at the springs. This is especially true for the Homosassa ground-water basin where most poultry nitrogen is produced.

The effect of nitrogen produced from poultry production on local ground-water quality is probably significant especially in the Masaryktown area of Hernando County. This area is the center of the highest nitrate concentrations in the study area (Figure 32). Prior to the mid 1980's, this area was a major poultry producing region. Even though poultry production dropped by a large percentage in the 1980's, nitrate levels remain high and may continue to be affected by the poultry farms that remain in the area.

Dairies

Dairies have been determined to be a significant source of nitrate to springs in Hillsborough County and north Florida (Jones and Upchurch, 1993; Andrews, 1994). There are five dairies in Hernando County, none in Citrus County, and one in the portion of Pasco County on the eastern edge of the study area boundary (Figure 44). There are approximately 3,000 dairy cows in Hernando County (FDACS, 1993) and according to IFAS (1991) a typical 1,000 pound dairy cow produces approximately 0.45 lbs N/day. If it is assumed that the individual cows weigh on average 1000 pounds, then the total amount of nitrogen supplied by dairy cows in Hernando County is approximately 246 tons N/ yr. The number of cows at the dairy in Pasco County is not known. However, if the

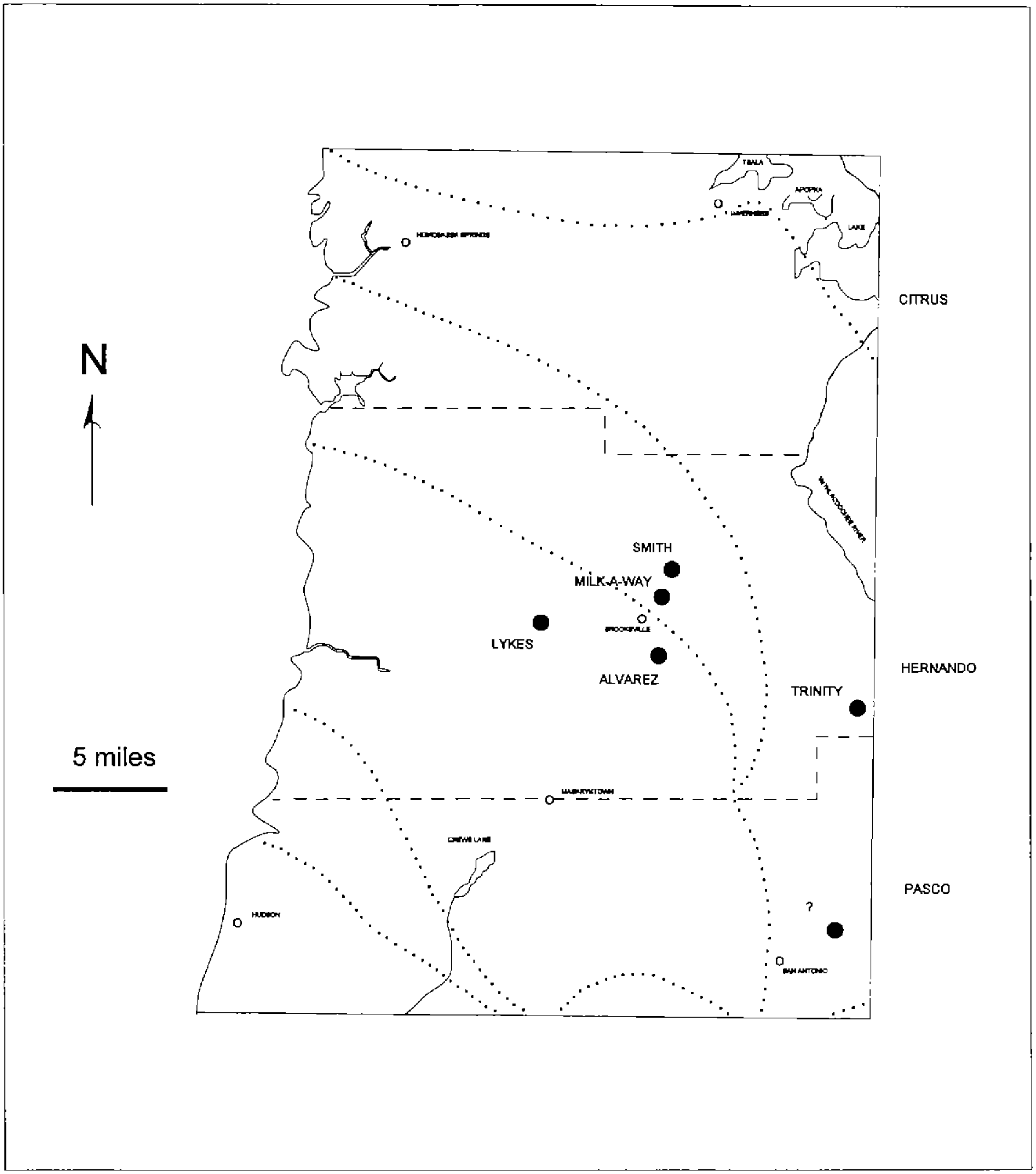


Figure 44. Location of Dairies in the Study Area.

Pasco dairy is assigned the number of cows estimated to be at each of the Hernando Dairies (500), then the Pasco dairy contributes approximately 49 tons N/yr. Broken out by ground-water basin, the estimated loadings are as follows:

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	98
Chassahowitzka	98
Weeki Wachee	98
Aripeka	0
Total	294

The low nitrogen isotopic ratios in spring water effectively rule out nitrogen produced from dairies as a major source of nitrate to the springs. The limited effect of nitrogen from dairies on nitrate levels in springs is probably the result of relatively small loadings. In addition, the dairies are located far enough inland that dilution would significantly reduce the concentration of nitrate in ground water prior to arrival at the springs. However, the concentrated nature of dairy operations may result in significant increases in local ground-water nitrate levels.

Cattle

Cattle production is a major land use, and occupies a significant portion of the study area. According to the FDACS (1993), there were approximately 64,000 head of cattle in Citrus, Hernando and Pasco Counties in 1992. If it is assumed that cattle are evenly distributed across the three counties, then approximately 36,000 head are contained within the four ground-water basins in the study area.

According to the Soil Conservation Service (pers. comm, 1990) cattle produce 0.33 lbs of nitrogen per day per 1,000 lbs of body weight. If it is assumed that the individual cattle weigh an average of 1,000 lbs, then the total amount of nitrogen supplied by the 36,000 head of cattle is approximately 2,168 tons per year. Dividing this figure by the percentage of pasture in each ground-water basin and assuming the cattle are evenly distributed across this pasture, provides the loading amounts listed on the following page.

Ground-Water Basin	Nitrogen Loading (tons/yr)
Homosassa	692
Chassahowitzka	415
Weeki Wachee	1,015
Aripeka	46
Total	2,168

The low nitrogen isotopic ratios in spring water effectively rule out nitrogen produced from cattle as a major source of nitrate to the springs. Nitrogen from cattle probably has a minimal effect on nitrate levels in springs and in local ground water because the cattle are widely dispersed and not concentrated into small feedlot areas. Because they are dispersed, the nitrogen in their waste is more likely to be removed by the many uptake mechanisms discussed previously.

STORM-WATER RUNOFF

In karst areas, storm water is responsible for transporting a wide variety of highly concentrated pollutants directly into aquifer systems through sinkholes where little or no filtration occurs. This problem is exacerbated by the fact that residential and urban storm-water systems are often designed to funnel storm water directly to sinkholes because they are the lowest points in an area.

Determining the amount of nitrogen in storm water is necessary to illustrate the importance of proper storage and treatment of storm water. It must be noted that storm water is not an additional source of nitrogen. It is simply what runs off during rainfall events from the actual sources of nitrogen calculated previously in this report.

To calculate the nitrogen in storm-water runoff from various land uses, data from the E.P.A.'s Nationwide Runoff Program (U.S.E.P.A., 1983) were utilized. Table 18 lists the event mean concentration (EC) values for nitrogen loading of storm water for a number of land uses. It is generally accepted in the field of storm-water management that these values can be used in place of local monitoring programs to quantify nitrogen loading of storm water (Sarasota Bay National Estuary Program, 1992).

For total nitrogen, the EC values are highest for golf courses, cropland, and low-to medium-density single-family residential land uses. This results from the fertilization of these areas. Industrial and commercial areas have the lowest EC values because they are not fertilized. However, it should be noted that nitrogen loading depends not only on the EC value but on the volume of surface runoff for a particular land use. Because commercial and industrial land uses have a much greater percentage of impervious area than residential land use, they tend to produce greater loadings in terms of lbs/ac/yr, even though they are characterized by lower EC values.

Table 18. Event Mean Nitrogen Concentration and Runoff Coefficient for Important Land Uses in the Study Area.

LAND USE	RUNOFF COEF	EVENT MEAN CONCENTRATION TOTAL NITROGEN (mg/l)
Golf Courses	0.15	2.70
Residential *	0.15	1.76
Commercial	0.95	1.18
Cropland	0.15	3.74

* includes low, medium, and high density single family residential, multi-family residential, and mobile homes. EC values of these residential categories were averaged to provide one value of 1.76 mg/l

The only land uses that were included for the storm-water nitrogen calculations were golf courses, residential, commercial, and cropland. Other land uses such as industrial, pasture, and unimproved areas were not included either because the acreage of the land use in the study area was insignificant or an EC value could not be found.

The equation used to determine nitrogen loading of storm water from a given land use was obtained from a pollution loading assessment of Sarasota Bay completed by the Sarasota Bay National Estuary Program (1992). This equation is:

$$N = r \cdot EC \cdot A \cdot R,$$

where:

N = total nitrogen (lbs/yr) in storm water from a given land use;

r = runoff coefficient (0.15 for pervious areas and 0.95 for impervious areas);

EC = event mean concentration (mg/l);

A = area occupied by the land use of interest (acres); and

R = total annual rainfall (gallons) occurring over the area of the land use of interest.

Table 19 lists some of the land uses that contribute significant amounts of nitrogen to storm water and the amount of nitrogen estimated to be contributed annually by each land use to storm water using the above calculation. Approximately 70 tons of nitrogen are contained in storm water from the listed land uses in the study area.

It is impossible to determine how much of the nitrogen in storm water may actually reach ground water. Many factors, such as partially blocked or plugged sinkholes and the many other uptake and removal mechanisms discussed previously, could serve to lessen the impact of storm water nitrogen on ground water. Overall, storm water does not appear to deliver a significant amount of nitrogen to ground water in the study area.

Table 19. Storm Water Nitrogen Contribution from Four Land Uses in the Study Area.

LAND USE	GROUND-WATER BASINS				TOTAL NITROGEN (tons/yr)
	HOMOSASSA	CHASSAHOWITZKA	WEEKI WACHEE	ARIPEKA	
RESIDENTIAL	6	4	16	4	30
COMMERCIAL	7	3	18	3	31
GOLF COURSES	<1	1	2	<1	3
CROPLAND	3	1	2	0	6
TOTAL	16	9	38	7	70

NITROGEN LOADING SUMMARY

Table 20 is a summary of the nitrogen contributions of the various sources in the four ground-water basins in the study area. It must be stressed that the high uncertainty involved in calculating the estimates brings the accuracy of the estimates into question. It must also be stressed that the estimates indicate the amount of nitrogen that is applied to land surface, not that which reaches ground water. Since the removal mechanisms can drastically reduce the amount of nitrogen that actually reaches ground water, the nitrogen loading estimates do not give a definitive indication of the degree to which a specific source is enriching the nitrogen content of ground water. The utility of the estimates lies in the information they provide as to the relative nitrogen contribution potential of the sources. This allows regulatory agencies to place less emphasis on sources that produce relatively small amounts of nitrate and concentrate efforts on those that produce significant quantities.

DOMINANT SOURCE CRITERIA

Research conducted as part of this study indicates that the dominant nitrogen sources to the coastal springs must meet a number of criteria including: 1) they must be inorganic, 2) they must be in close proximity to the springs, 3) the source probably did not exist prior to the mid 1960's, and 4) the magnitude of the source must not be negligible. These criteria are discussed in greater detail in the following paragraphs.

Nitrogen isotopic ratios of the coastal springs (Figure 38) are generally low enough to indicate that inorganic sources are the dominant contributors of nitrate to springs.

In considering the potential of a source to affect nitrogen levels in the coastal springs, the proximity of the source to the springs seems to be more important than the magnitude of nitrogen loading from the source. In other words, a source located 10 miles east of a spring that contributes a large amount of nitrogen to the recharge area of the spring has a smaller effect on nitrate levels in the spring than a source located one mile east of the spring that contributes a smaller amount of nitrogen. The inland source may locally elevate ground-water nitrate to high levels but because of the long distance and travel time to the spring, nitrate concentrations will be diluted to low levels before the water reaches the spring and is discharged.

An additional consideration that facilitates the identification of the nitrate sources that most affect the springs is the timing of the nitrate increases in the springs over the past 50 years (Figures 2). Nitrate concentrations, which historically were near zero in Weeki Wachee Springs, began a rapid increase around 1974. This trend is also apparent in the Homosassa Main and Chassahowitzka Main Springs, although it is not as obvious as the trend in Weeki Wachee Spring. A possible explanation for the trend is contained in the following paragraphs.

Table 20. Nitrogen Sources, Estimated Quantities Produced (tons/yr), and Effect of Source on Nitrate Concentrations in the Springs.

LAND USE	REGIONAL N LOADING (TONS/YR) HSASSA	CWITZKA	WEEKI	ARIPEKA	TOTAL	SIGNIFICANCE OF NITROGEN SOURCE TO NITROGEN CONCENTRATIONS IN THE SPRINGS
Naturally Occurring	?	?	?	?	?	Probably insignificant - ground-water N in undeveloped areas is low
Rainfall	1,219	772	1585	244	3,820	Probably insignificant - ground-water N in undeveloped areas is low - most rainfall N probably removed by vegetative uptake or immobilized in soil layer
Residential Turf/landscape Fertilizer	171	52	213	64	500	Highly significant - residential areas and golf courses are concentrated near the springs, their combined total accounts for the highest N loading near the springs, and N isotopic ratios indicate an inorganic source for the springs that is probably fertilizer
Golf Course Fertilizer	22	33	111	22	188	Significant - see above
Sewage Effluent	23	28	160	104	379	Probably insignificant - N isotope ratios indicate an inorganic source, N loading is relatively low, and disposal facilities are widely dispersed - local problems only
Sewage Sludge	9	20	97	0	126	Insignificant - N isotope ratios indicate an inorganic source, sludge sites are far from springs, N loading is relatively low, and disposal sites are designed to promote vegetative uptake
Septic Tank Effluent	173	47	341	110	671	Significant - N loadings are significant (but lower than nearby inorganic sources) and are occurring near the coastal springs - however, N isotopic ratios indicate that inorganic sources, probably fertilizers, are dominant
Septage Sludge	0.3	1.9	7.1	0.0	9.3	Insignificant - N isotope ratios indicate an inorganic source and N loading is very low
Row Crops	61	15	36	0	112	Insignificant - crops are far from springs and N loading is relatively low
Citrus	163	22	63	8	256	Insignificant - citrus is far from springs, widely dispersed, and N loading is relatively low
Pasture	907	177	262	18	1,364	Minor significance - although the calculated N loading is high, most pasture acreage is far from springs and most N is probably used by pasture grass and attenuated in soil
Poultry	1,189	333	856	0	2,378	Minor significance - may account for significant loading where they are located but are too far from springs to cause a problem - also, much is shipped out of study area and N isotope ratios indicate an inorganic source
Dairies	49	98	147	0	294	Insignificant - N isotope ratios indicate an inorganic source - also, N loading is not high and dairies are distant from springs - however, concentrated feedlots may cause local problems
Cattle	692	415	1015	46	2,168	Minor significance - N isotope ratios indicate an inorganic source - also, N loading is very high but cattle are far from springs and widely dispersed - most N in waste is probably used by pasture grass and attenuated in soil

Prior to the 1970's, most of the nitrate-producing land uses were agricultural and were located well inland of the springs. Although some of these agricultural land uses produced high levels nitrogen that may have significantly elevated nitrate levels locally in ground water, they apparently had little effect on nitrate levels in the springs because of dilution. During this time, the western portion of the study area closest to the springs was relatively undeveloped and nitrogen sources were relatively nonexistent. However, in the early to mid 1960's, residential subdivisions began to be constructed at a rapid rate in this area. The fact that nitrate concentrations began to increase rapidly shortly after significant development of subdivisions had occurred is an indication that the subdivisions are responsible for the increase in nitrate.

The final criteria is that nitrogen from the dominant source must be applied in quantities that are sufficient to raise the concentration of nitrate in ground water to levels that are significantly higher than background.

EVALUATION OF SOURCES

The dominant nitrogen sources for the springs must meet all of the criteria discussed above. They must be inorganic (low nitrogen isotopic ratios), must be applied in close proximity of the springs, probably did not exist in significant densities prior to the early 1970's, and must be produced and applied at levels that are not insignificant. The sources that best meet these criteria are residential turf/landscape and golf course fertilizers applied in the subdivisions in the western portion of the study area.

Septic tank effluent meets all of the above criteria except that it is organic. If septic tank effluent were the dominant source, it would produce much higher nitrogen isotopic ratios than are present in the spring waters. Because nitrogen loading from septic tanks (671 tons/yr) is essentially equal to loading from fertilized residential and golf course turf/landscaping (688 tons/yr), it is difficult to understand why the nitrogen isotopic ratios of spring waters are not higher and, therefore, more indicative of an organic source. Whatever the explanation, septic tank effluent, while not the dominant source, may be a significant, secondary source for all the coastal spring complexes.

Sources that may have a minor impact on nitrate levels in the springs include poultry production, pasture fertilization, and cattle production. These sources are considered to be relatively insignificant even though their nitrogen loadings are high. This is because they existed in the ground-water basins of the spring complexes long before the large increases in nitrate in the springs began in the early 1970's.

Poultry farms probably elevate nitrogen levels in the springs to a minor degree, especially in the Weeki Wachee Springs ground-water basin where several farms currently exist in the Masaryktown area and numerous others existed in the past. The highest nitrate levels in the study area are located in this area and are probably related to poultry wastes. However, poultry farms are probably not a significant source of nitrate presently found in the springs because 1) the nitrogen isotopic ratios of water discharging from the springs indicate an inorganic source, 2) the farms are located relatively far from the springs, 3) much of the poultry waste is apparently shipped out of the study area, and 4) the current level of poultry production in the area is much lower than past levels.

Nitrogen from pasture fertilization probably does not significantly elevate nitrate levels in the springs because most pasture acreage is located far from the springs. In addition, much of the fertilizer nitrogen is probably removed by vegetative and soil uptake mechanisms.

The nitrogen loading produced by cattle is very high but most of the animals are widely dispersed and located far from the springs. Most of their nitrogen may be taken up by vegetative and soil uptake mechanisms.

Sources that probably have no effect on nitrate levels in the springs include naturally occurring from organic decay, rainfall, sewage effluent, sewage sludge, septage sludge, row crops, citrus, and dairies.

Rainfall is discounted as a significant source of nitrogen to ground water because wells in undeveloped portions of the study area generally have very low concentrations of nitrate. If rainfall were a significant source, ground water would probably have uniformly elevated nitrate concentrations even in undeveloped areas. Rainfall nitrogen is probably readily removed because it is applied in small quantities to plant communities that utilize it during numerous events. In addition, a large portion is lost to the many surface removal mechanisms.

Similar to the rainfall source, the naturally occurring organic decay source is probably insignificant over most of the study area. This is because microbes and plants in the soil layer utilize and recycle the nitrogen as soon as it is made available. The limited effect of naturally occurring nitrogen on ground-water quality is verified by the fact that nitrate concentrations are low in ground water in undeveloped and unaffected areas of the study area where the only sources of nitrogen are organic decay and rainfall.

Sewage effluent is an insignificant nitrogen source because loadings are relatively low and disposal facilities are widely dispersed with many being located far from the springs. Sewage sludge and septage sludge are insignificant sources because the loading is relatively low, disposal sites are located far from the springs, and the sites are designed to promote vegetative uptake. Row crops and citrus fertilizers are insignificant sources because the loading is relatively low and the application areas are located far from the springs. Dairies are probably insignificant sources because the loadings are relatively low and they are located far from the springs. However, concentrated feedlots may cause local problems.

CONCLUSIONS

1. Thirty springs in the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring complexes, located in the area between central Citrus to northern Pasco Counties, were investigated for evidence of deteriorating water quality during a period from 1993 to 1997. The quality of ground water in a large portion of the recharge area of the spring complexes was also investigated by analyzing water samples from 121 monitor wells.

2. Water discharges from the 30 springs in the four spring complexes at the total rate of approximately 900 cubic feet per second (cfs). This is equivalent to approximately 580 million gallons per day (mgd).

3. Water discharging from springs in the four complexes originates in four separate ground-water basins that encompass a total of 1,600 square miles. Individually, the ground-water basins for the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring complexes encompass 960, 190, 390, and 60 square miles, respectively.

4. The chemistry of water discharging from the springs in the four complexes indicates that the water has moved through relatively short, shallow flow systems. That is, the water has probably not been in the aquifer for more than a few decades at most.

5. Much of the water discharging from the springs may have traveled rapidly through the Floridan aquifer in fractures, which are conduits in the limestone where large amounts of ground water can be transported to the springs.

6. The chemistry of ground water in the study area is affected by a number of geologic, hydrologic, atmospheric, and anthropogenic factors. These include 1) the thickness of Hawthorn Group clays in the Brooksville Ridge, 2) major sinkhole features, 3) the fresh-water/salt-water transition zone along the coast, 4) Lake Tsala Apopka, 5) the chemistry of rainfall, 6) the presence of extensive agricultural and urban development, and 7) the presence of large limestone quarries northwest of Brooksville.

7. Data collected as part of the study, as well as historic data collected by other agencies, indicate that nitrate concentrations have been steadily increasing in the springs since the late 1960's. The mean nitrate concentration of the Weeki Wachee Main Spring, the largest spring in the complexes in terms of discharge, is 0.53 mg/l. This is over 50 times higher than background levels (< 0.01 mg/l).

CONCLUSIONS (continued)

8. Approximately 360 tons of nitrate as N is contained each year in ground water discharging from the springs in the four spring complexes.

9. Nitrate concentrations were evaluated in the 121 wells sampled in the four ground-water basins. Five percent had concentrations that exceeded 2.5 mg/l, 9 percent had concentrations between 1.0 and 2.5 mg/l, 12 percent had concentrations between 0.5 and 1.0 mg/l, 37 percent had concentrations between 0.1 and 0.5 mg/l, 17 percent had concentrations between 0.01 and 0.1 mg/l, and 20 percent had concentrations below the detection limit (0.01 mg/l). These figures indicate that the portion of the study area where nitrate is significantly elevated above naturally occurring levels (<0.01 mg/l) is extensive. No samples met or exceeded the 10 mg/l (as N) drinking water standard.

10. Fourteen sources of nitrate were investigated in the study area. These include: 1) naturally occurring organic decay, 2) rainfall, 3) golf course turf fertilization, 4) residential turf/landscape fertilization, 5) sewage effluent disposal, 6) land disposal of sewage sludge, 7) effluent from septic tanks servicing residential and commercial development, 8) land disposal of septage sludge, 9) row crop fertilization, 10) citrus fertilization, 11) pasture fertilization, 12) poultry, 13) dairies, and 14) cattle.

11. Nitrogen isotopic data suggest that the dominant source of nitrate presently discharging in ground water from the springs is inorganic. Organic sources, although regionally less significant, may still elevate nitrate concentrations to high levels on a local scale. Organic sources include: 1) naturally occurring organic decay, 2) sewage effluent disposal, 3) land disposal of sewage sludge, 4) effluent from septic tanks servicing residential and commercial development, 5) land disposal of septage sludge, 6) poultry, 7) dairies, and 8) cattle.

12. Residential and golf course turf/landscape fertilization were identified as the principal source of nitrate in the springs. Supporting data include: 1) the inorganic nature of the source, 2) the close proximity of the source to the springs, and 3) the rapid increase in nitrate concentrations in the springs that began in the late 1960's, which correlates well with the development of the large, coastal, residential subdivisions that contain the largest densities of residential and golf course turf and landscape.

RECOMMENDATIONS

1. There is little that can be done to reduce present nitrogen loading from the springs to the coastal estuaries because that nitrogen has been applied to the study area for many years and is now entrained in the ground-water flow system. Any attempt to reduce nitrate loading in the recharge area may not result in reduced nitrate levels in the springs for a decade or longer.

2. An investigation of the application of inorganic nitrogen fertilizers in the coastal subdivisions in the study area should be initiated in the near future. The study should focus on identifying the specific areas of application, the amount applied, and the amount of nitrogen reaching ground water following application. The study should also attempt to reduce the use of fertilizers by developing best management practices and by promoting xeriscaping - the replacement of turf with native species of plants that require less fertilizer and water.

3. The importance of sources, such as residential and golf course turf/landscape fertilization, septic tank effluent, and sewage effluent disposal will greatly increase as rapid residential and commercial development proceeds in the study area. It is therefore, extremely important that best management and alternative landscape practices be developed that reduce the use of fertilizer. Waste disposal practices that are compatible with the region's karst geology and its accompanying extreme vulnerability to ground-water contamination must also be implemented. These practices include:

    a. Avoidance of high-densities of septic systems.
    b. Planning for the development of centralized, advanced waste-water treatment (AWT) systems.
    c. More stringent design, construction, and monitoring of large-scale percolation or spray field systems. These systems should stay on line only until it is feasible to construct the centralized AWT systems.
    d. Proper storage and treatment of storm water.

4. The springs should continue to be sampled quarterly for nutrients, major analytes, and trace organics and annually for nitrogen-isotopic ratios to determine the effects of changing land use and to determine the effectiveness of remedial efforts.

5. The District should work with Citrus, Hernando, and Pasco Counties and other interested agencies to formulate land-use plans that would minimize additional nitrogen loadings to the study area.

REFERENCES CITED

Adams A., 1985. Ground-Water Supplement to the Wysong-Panasoffkee Study. Southwest Florida Water Management District, Brooksville, Florida.

Anderson, W., and C.P. Laughlin, 1982. Geohydrology of the Floridan Aquifer in the Withlacoochee River Basin of the Southwest Florida Water Management District. U.S. Geological Survey Water Resource Investigation. Open File Report 82-331.

Andreoli, A., N. Bartilucci, and R. Reynolds, 1979. Nitrogen Removal in a Subsurface Disposal System. J. Water Poll. Control Fed. 51:841-854.

Andrews, W.J., 1994. Nitrate in Ground Water and Spring Water Near Four Dairy Farms in North Florida, 1990-93. U.S. Geological Survey Water Resources Investigations Report 94-4162.

Arthur, J.D., 1993. Geologic Map of Pasco County, Florida. Florida Geological Survey Open File Map Series 42.

Aucott, W.R. 1988. Areal Variation in Recharge to and Discharge from the Floridan Aquifer System in Florida: U.S. Geological Survey Water Resources Investigations Report 94-4162.

Ayers and Associates, 1991. Evaluation of Nutrient Loading Potential from Wastewater Sources in the Crystal River/King's Bay Watershed. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Bicki, T.J., R.B. Brown, M.E. Collins, R.S. Mansell, and D.F. Rothwell, 1984. Impact of On-Site Sewage Disposal Systems on Surface and Ground-Water Quality. Report to the Florida Department of Health and Rehabilitative Services under contract number LC170. Soil Science Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. 223 pp.

Bisdorf, R.J., and A.R. Zohdy, 1979. Geoelectric investigations with Schlumberger soundings near Venice, Parrish, and Homosassa, Florida: U.S. Geological Survey Open File Report 79-841, 114 p.

Black, A.P., and E. Brown, 1951. Chemical Character of Florida's Water: Water Survey and Research Paper #6, Division of Water Survey and Research, Florida State Board of Conservation.

REFERENCES CITED (continued)

Bouma, J.,1975. Unsaturated Flow During Soil Treatment of Septic Tank Effluent. J. Environ. Eng. Div. Amer. Soc. Civil Eng. 101:967-983.

Bouno, A., R.M. Spechler, G.L. Barr, and R.M. Wolansky, 1979. Generalized Thickness of the Confining Bed Overlying the Floridan Aquifer, Southwest Florida Water Mange District: U.S. Geological Survey Water Resources Investigation 79-1171.

Campell K., and T. Scott, 1992. Geologic Map of Citrus County, Florida. Florida Geologic Survey Open File Map Series 10.

Campell K., and T. Scott, 1993. Geologic Map of Hernando County, Florida. Florida Geologic Survey Open File Map Series 41.

Carroll, D., 1970. Rock Weathering: New York, Plenum Press, p. 101-102.

Cassauex , K.W. and J.D. Fretwell, 1982, Position of the Salt-Water/Fresh-Water Interface in the Upper Part of the Floridan Aquifer, Southwest Florida, 1979: U.S. Geological Survey Water Resources Investigations Open-File Report 82-90, 1 Sheet.

Causey, L.V. and G.W. Leve, 1976. Thickness of the Potable Water Zone in the Floridan Aquifer. Florida Bureau of Geology Map Series 74.

Cherry, R.N., J.W. Stewart, and J.A. Mann, 1970. General Hydrology of the Middle Gulf Area, Florida. U.S. Geological Survey, Report of Investigation No. 56.

Cooper, H.H., F.A. Kohout, H.R. Henry, and R.E. Glover, 1964. Sea water in coastal aquifers: Relation of salt water to fresh ground water: U.S. Geological Survey Water Supply Paper 1613-C, 84 p.

Cowart, J.B., 1978. The Relationship of Uranium Isotopes to Oxidation/Reduction in the Edwards Carbonate Aquifer of Texas. Earth and Planetary Science Letters, 48, 277-283. Elsevier Scientific Publishing Company, Amsterdam.

Cowart, J.B., and J.K. Osmund, 1992. Uranium Isotopes as Indicators of Ground-Water Susceptibility to Nitrate Pollution. Report to the Southwest Florida Water Management District, Brooksville Florida.

Cowart, J.B., 1995. Report to the Southwest Florida Water Management District, Brooksville, Florida.

DeHaven, E.C., 1995. Coastal Ground-Water Quality Monitoring Program Report. Ambient Ground-Water Quality Monitoring Program, Southwest Florida Water Management District, Brooksville, Florida.

deVries, J., 1972. Soil Filtration of Wastewater Effluent and the Mechanism of Pore Clogging. J. Water Poll. Control Fed. 44:565-573.

Dinkins, J.L., 1969. Dunnellon, Boomtown of the 1890's. St. Petersburg, The Great Outdoors Publishing Company.

Exley, S., 1985. Unpublished manuscript.

Faulkner, G.L., 1970. Geohydrology of the Cross Florida Barge Canal Area with Special Reference to the Ocala Vicinity. U.S. Geological Survey Publication, 4-72.

Faulkner, G.L., 1976. Flow Analysis of Karst Systems with Well Developed Underground Circulation. Karst Hydrology and Water Resources, Water Resources Publications.

Flipse, W.J., B.G. Katz, J.B. Linder, and R. Markel, 1984. Sources of Nitrate in Ground Water in a Sewered Housing Development, Central Long Island New York. Ground Water, v 22, no.4.

Florida Department of Agriculture and Consumer Services, 1993. Summary Report of Fertilizer Materials and Fertilizer Mixtures Consumed in Florida, Fiscal Year Report, July 1, 1992 - June 30, 1993.

Florida Department of Environmental Regulation, 1989a. Primary and Secondary Drinking Water Standards, Florida Administrative Code.

Florida Department of Environmental Regulation, 1989b. Domestic Wastewater Residuals, Chapter 17-640, Florida Administrative Code.

Florida Department of Environmental Protection and the Southwest Florida Water Management District, 1993. Unpublished water-quality data from the Ambient Ground-Water Quality Monitoring Program, VISA Project.

Florida Land Design and Engineering, 1989. Homosassa River Water-Quality Study. Phase 2 Final Report. Prepared for Citrus County Board of County Commissioners. Inverness, Florida.

REFERENCES CITED (continued)

Fretwell, J.D., 1983. Ground-Water Resources of Coastal Citrus, Hernando, and Southwestern Levy Counties, Florida. U.S. Geological Survey, WRI 83-4079.

Fretwell, J.D., 1985. Water Resources and Effects of Development in Hernando County, Florida. U.S. Geological Survey, WRI 84-4320.

Hall, M.W., 1975. A Conceptual Model of Nutrient Transport in Sub-Surface Systems, p. 55-64. In Jewell, W.J., and R. Swan (eds.). Water Pollution Control in Low Density Areas. Univ. Press of New England, Hanover, New Hampshire.

Hanshaw, B. B., and W. Back, 1979. Major Geochemical Processes in the Evolution of Carbonate-Aquifer Systems. Journal Of Hydrology, 43, 287-312.

Hantzsche, N.N. and J.E. Finnemore, 1992. Predicting Ground-Water Nitrate-Nitrogen Impacts. Ground Water, v.30, no. 4.

Harkin, J.M., C.J. Fitzgerald, C.P. Duffy, and D.G. Kroll, 1979. Evaluation of Mound Systems for Purification of Septic Tank Effluent. Water Resources Center Tech. Report WIS WRC 79-50. Univ. of Wisconsin, Madison, Wisconsin.

Hatzell, H.H., 1995. Effects of Waste Disposal Practices on Ground-Water Quality at Five Poultry (Broiler) Farms in North-Central Florida, 1992-93. United States Geological Survey, Water Resources Investigations Report 95-4064.

Healy, H.G., 1975. Terraces and Shorelines of Florida. U.S. Geological Survey Map Series No. 71.

Hem, J. D., 1986. Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey Water Supply Paper 2254, 263 p.

Hersch, C.K., 1968, Nitrogen, in Hampel, C.A., (ed.), The Encyclopedia of the Chemical Elements: New York, Reinhold Book Corporation, p. 454-459.

Hickey, J.J., 1990. An Assessment of the Flow of Variable-Salinity Ground-Water in the Middle Confining Unit of the Floridan Aquifer System, West-Central Florida. U.S. Geological Survey Water Resources Investigation Report 89-4142.

Hook, J.E., B.G. Ellis, L.W. Jacobs, and D.L. Mokma, 1978. Nutrient movement through soils from septic systems. Submitted to: South-central Michigan Planning Council. Dept. of Crops & Soil Sci., Michigan State Univ., E. Lansing, Michigan.

REFERENCES CITED (continued)

Institute of Food and Agricultural Sciences (IFAS), University of Florida, 1990. IFAS Standardized Fertilization Recommendations for Agronomic Crops. Notes in Soil Science #35.

Institute of Food and Agricultural Sciences (IFAS), University of Florida, 1991. Managing a Dairy Cow on the Ranchette. Circular 947.

Institute of Food and Agricultural Sciences (IFAS), University of Florida, 1992. Poultry Manure: a natural fertilizer.

Irwin, G.A., R.T. Kirkland, 1980. Chemical and Physical Characteristics of Precipitation at Selected Sites in Florida. U.S. Geological Survey, WRI 80-81.

Jones, G.W., E.C. DeHaven, L.F. Clark, J.T. Rauch, 1990. Ground-Water Quality Sampling Results from Wells in the Southwest Florida Water Management District: Southwest Florida Water Management District and the Department of Environmental Regulation.

Jones, G.W. and S.B. Upchurch, 1991. Structural Controls on Ground-Water Quality in Southwest Florida and Implications for Water Management, in Upchurch, S.B., J.E. Moore, and A. Zaporozec (eds), Proceedings of the 10th Annual Conference of the AIH Meeting in Orlando, Florida.

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

Jones, G.W. and S.B. Upchurch, 1994. Origin of Nutrients in Ground-Water Discharging from the King's Bay Springs. Southwest Florida Water Management District, Brooksville, Florida.

Jones, G.W., S.B. Upchurch, and K.M. Champion, 1996. Origin of Nitrate in Ground-Water Discharging from Rainbow Springs. Southwest Florida Water Management District, Brooksville, Florida.

Karst Environmental Services, 1992. Hydrology Study of the Main Spring, Homosassa Springs State Wildlife Park. Prepared for the Florida Department of Natural Resources, Florida Park Service, Homosassa Springs State Wildlife Park. High Springs Florida.

REFERENCES CITED (continued)

Kaufman, S., and W.J. Libby, 1954. The Natural Distribution of Tritium: Phys. Rev., v. 93, p. 1337-1344.

Kimery, J.O. and W. Anderson, 1987. Reconnaissance of Geohydrologic Areas and 1981 Low-Flow Conditions, Withlacoochee River Basin, Southwest Florida Water Management District. U.S. Geological Survey WRI 86-4203.

Kirchmann, H. and E. Witter, 1989. Ammonia volatilization during aerobic and anaerobic manure decomposition. Plant and Soil, vol 115, pp. 35-41.

Klein, H., 1975. Depth to Base of Potable Water in the Floridan Aquifer. U.S. Geological Survey/Florida Bureau of Geology Mao Series No. 42 Revised.

Kreitler, C.W., 1975. Determining the Source of Nitrate in Ground Water by Nitrogen Isotope Studies. Univ. Texas, Austin, Bur. Econ. Geology Rept. Inv. 83, 57 pp.

Kreitler, C.W. and D.C. Jones. 1975. Natural Soil Nitrate; the Cause of the Nitrate Contamination in Runnels County, Texas. Ground Water. v. 13, no. 1, pp. 53-61.

Laak, R., 1982. On-site Soil Systems, Nitrogen Removal. p. 129-141. In Elkum, A.S. and R.W. Seabloom (eds.). Alternative Wastewater Treatment. Low-cost small systems research and development. Oslo Norway. D. Reidel Pub. Co., Boston, Massachusetts.

McCarty L.B., J.B.Sartain, G.H. Snyder, and J.L. Cisar, 1993. Plant Nutrition, Fertilizers and Fertilizer Programs for Florida Golf Courses. Institute of Food and Agricultural Sciences, University of Florida.

Metz, P.A., 1995. Potentiometric Surface of the Upper Florida Aquifer System, West-Central Florida, September 1994. U.S. Geological Survey Open File Report 95-227.

Miller, J.A., 1986. Hydrogeologic Framework of the Floridan Aquifer System in Parts of Georgia, Alabama, and South Carolina. United States Geological Survey, Professional Paper 1403-B.

Osmond, J.K. and J.B. Cowart, 1976. The Theory and Uses of Uranium Isotopes in Hydrology. Atomic Energy, Rev. 14.

REFERENCES CITED (continued)

Otis, R.J., W.C. Boyle, and D.R. Sauer, 1975. The performance of Household Wastewater Treatment Units Under Field Conditions. p. 191-201. In Home Sewage Disposal. Proc. National Home Sewage Symposium, 1974. Amer. Soc. Agric. Eng. Proc. 175, St. Joseph, Michigan.

Peavy, H.S., and C.E. Brawner, 1979. Unsewered Subdivisions as a Non-Point Source of Ground-Water Pollution. National Conference on Environmental Engineering, San Francisco, California.

Piper, A.M., 1944. A Graphic Procedure in the Geochemical Interpretation of Water-Analyses. American Geophysical Union Transactions, 25:914-923.

Preul, H.C., and G.J. Schroepfer, 1968. Travel of Nitrogen in Soils. J. Water Poll. Control Fed. 40:30-48.

Puri, H.S., and R.O. Vernon, 1964. Summary of the Geology of Florida and a Guide to Classic Exposures. Florida Geological Survey Special Publication 5. Tallahassee, Fla. 312 p.

Randazzo, R.F., and J.I. Bloom, 1985. Mineralogical Changes along the Fresh-Water/Salt-Water Interface of a Modern Aquifer. Sedimentary Geology, v. 43, p. 219-239.

Randazzo, R.F., and D.J. Cook, 1987. Characterization of Dolomitic Rocks from the Coastal Mixing Zone of the Floridan Aquifer, Florida, U.S.A. Sedimentary Geology, v. 54, p. 169-192.

Rea, R.A., and S.B. Upchurch, 1980. Influence of Regolith Properties on Migration of Septic Tank Effluent. Ground Water, 18:118-125.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry, and R.W. Hull. 1977. Springs of Florida, Florida Bureau of Geology and Florida Department of Environmental Regulation, Bull. 31 (revised).

Rutledge, A.T., 1978. Hydrologic Reconnaissance of Tsala Apopka Lake, Citrus County, Florida. U.S. Geological Survey Open-File Report 77-89.

Ryder, P.A., 1985. Hydrology of the Floridan Aquifer System in West Central Florida. U.S. Geological Survey Professional Paper 1403-F.

REFERENCES CITED (continued)

Sarasota Bay National Estuary Program, 1992. Point/Non-Point Source Pollution Loading Assessment, Phase I and Phase II.

Sinclair, W. C., 1977. Preliminary Evaluation of the Water Supply Potential of the Weeki Wachee Area and the Lower Withlacoochee River, West-Central Florida: U.S. Geological Survey Water-Resources Investigation 78-74.

Southwest Florida Water Management District, 1987. Ground-Water Resource Availability Inventory: Hernando County, Florida. Southwest Florida Water Management District, Brooksville, Florida.

Southwest Florida Water Management District, 1990. Land Use Information from Aerial Photography Flown in 1990.

Stallard, R.F., and J.M. Edmond, 1981. Geochemistry of the Amazon: I. Precipitation Chemistry and the Marine Contribution to the Dissolved Load at the Time of Peak Discharge. Journal of Geophysical Research, 86:9844-9858.

Stewart, J.W., 1980. Areas of Natural Recharge to the Floridan Aquifer in Florida. Florida Bureau of Geology, MS 98.

Stewart, M.T. and M.C. Gay, 1983. Evaluation of a ground transient electromagnetic remote sensing method for deep detection and monitoring of salt water interfaces: Florida Water Resources Research Center Publication no. 73, 47 p.

Stiff, H.A., Jr., 1951. The Interpretation of Chemical Water Analysis by Means of Patterns. Journal of Petroleum Technology, vol. 3, no. 10, sec. 1, pp. 15-16, sect. 2,3.

Swancar, A., and C. Hutchinson, 1992. Chemical and Isotopic Composition and Potential for Contamination of Water in the Upper Floridan Aquifer, West-Central Florida, 1986-89. United States Geological Survey, Open-File Report 92-47.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton, 1985. Soil Fertility and Fertilizers. New York: Macmillan Publishing Co.

Ryder, P.A., 1985. Hydrology of the Floridan Aquifer System in West Central Florida. U.S. Geological Survey Professional Paper 1403-F.

REFERENCES CITED (continued)

United States Environmental Protection Agency, 1980. Handbook of Septage Treatment and Disposal. Center for Environmental Resource Information, Cincinnati, Ohio. EPA 625/1-81-013

United States Environmental Protection Agency, 1981. Process Design Manual for Land Treatment of Municipal Waste. Center for Environmental Resource Information, Cincinnati, Ohio. EPA 625/1-81-013

United States Environmental Protection Agency, 1983. Results of the Nationwide Urban Runoff Program: Volume I Final Report, Water Planning Division, Washington, DC.

United States Environmental Protection Agency, 1994. Guide to Septage Treatment and Disposal. Center for Environmental Resource Information, Cincinnati, Ohio. EPA/625/R-94/002.

United States Bureau of Census, 1965. Statistics for the State and Counties, Florida. U.S. Government Printing Office, Washington, D.C., 1967.

Upchurch, S.B., and F.W. Lawrence, 1984. Impact of Ground-Water Chemistry on Sinkhole Development Along a Retreating Scarp. In B.F. Beck (ed.), Sinkholes: Their Geology, Engineering & Environmental Impact, Rotterdam, A.A. Balkema, pp. 23-28.

Upchurch, S.B., 1993. Quality of Waters in Florida's Aquifers. In G.L. Maddox, J.M. Lloyd, T.M. Scott, S.B. Upchurch, and R. Copeland (eds.), Florida Ground Water Quality Monitoring Program -- Volume 2, Background Hydrogeochemistry, Florida Geological survey, Special Publication No. 34.

United States Geological Survey, 1994. Unpublished Water-Quality Data from the Watstore Data Base

Vernon, R. O., 1951. Geology of Citrus and Levy Counties, Florida: Florida Geological Survey Bulletin 33.

Walker, W.G., J. Bouma, D.R. Keeney, and F.R. Magdoff, 1973a. Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluent in Sands: I. Soil Transformations. Journal of Environmental Quality. v. 2, no. 4, pp. 475-480.

REFERENCES CITED (continued)

Walker, W.G., J. Bouma, D.R. Keeney, and P.G. Olcott, 1973b. Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluent in Sands: II. Ground-Water Quality Journal of Environmental Quality. v. 2, no. 4, pp. 521-525.

Wentworth, C.K., 1951. The Progress and Process of Salt-Water Encroachment. Intl. Assoc. of Sci. Hydrology Publ., 33 p., 238-248.

Wetterall, W.S., 1965. Reconnaissance of Springs and Sinks in West Central Florida. Florida Geological Survey Repot of Investigation 39, 42 p.

White, W.A., 1970. The Geomorphology of the Florida Peninsula. Florida Department of Natural Resources, Bureau of Geology, Geological Bulletin 51, 164 p.

Wilson, W.O., and P. Vohra, 1980. Animal Agriculture: the biology, husbandry, and Use of Domestic Animals (Second Edition). San Francisco, W.H. Freeman, p. 641-657.

Winston, G.O., 1976. Florida's Ocala Uplift is not an Uplift: Bulletin of the American Association of Petroleum Geologists, v. 60, no. 6, p. 992-994.

Wolterink, T.J., H.J. Williamson, D.C. Jones, T.W. Grimshaw, and W.F. Holland, 1979. Identifying Sources of Subsurface Nitrate Pollution with Stable Nitrogen Isotopes. Ada, Oklahoma, U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, EPA-600/4-79-050, 150 p.

Yobbi, D., 1989. Simulation of Steady State Ground-Water and Spring Flow in the Upper Floridan Aquifer of Coastal Citrus and Hernando Counties, Florida. United States Geological Survey, WRI 88-4036.

Yobbi, D., 1992. Effects of Tidal Stage and Ground-Water Levels on the Discharge and Water Quality of Springs in Coastal Citrus and Hernando Counties. United States Geological Survey, WRI 92-4069.

APPENDICES

APPENDIX I

Specifications of Monitor Wells

#	WELL_ID	LATITUDE	LONGITUDE	TD	CD	LSE
1	SR 52 DEEP WELL	281949.735	823300.389	73	60	65.89
2	EICHHORN	282011	823118	170		68.00
3	HAGIN	282243	823158	125	100	60.00
4	COSTON	282416	821400	90	65	105.00
5	GRACE MEMORIAL #2	282418	823937	135	50	25.00
6	DANIELS	282514	823057	135		70.00
7	MASARYKTOWN DEEP WELL	282540.457	822755.595	76	29	65.71
8	DALTON	282547	823337			50.00
9	WHITING WELL DEEP	282553	823953	97	95	8.00
10	MAGNOLIA SPRINGS WELL	282600	823926	110	85	5.00
11	ROMP 97	282605.774	823457.738	355	310	32.54
12	VOSCINAR	282629	822632	120	84	67.00
13	BLAIR	282630	822209	110	63	101.00
14	KELSO	282634	823213	157		45.00
15	WEEKI II	282637.284	822214.512	69	68	101.00
16	DANNY MORDENTI-HRS	282647	823322	125	104	50.00
17	BISARD	282650	823108	100	53	60.00
18	ROMP TR 18-2 U AVON PARK	282659	823911	480	447	7.00
19	JARVIS	282704	822218	120	80	95.00
20	BRIDGES	282717	822921	100	78	62.00
21	C V HARRISON-HRS	282726	822930	105	52	70.00
22	FUNK	282726	823404	72	63	35.00
23	ROMP TR 18-1	282742.504	823758.860	580	445	15.29
24	C BEDILLION-HRS	282759	822312	95	78	88.00
25	PARKER	282940	822205	240	92	200.0
26	BAKER	282808	822300	125	82	137.00
27	DIGGS	282842	822237	160		115.00
28	TAYLOR	282849	822600			100.00
29	ALTIZER	282850	822319	230	105	200.00
30	CORWIN	282851	823508	112	105	34.00
31	BOOTH	282901	821707	230	169	75.00
32	HERNANDO BEACH SUPPLY	282923	823803	180	?	8.00
33	STEWART	282925	822220	138	120	100.00
35	RALPH S SWOPE-HRS	282935	822732	110	91	76.00
36	KAVORIS	282942	822046			100.00
37	PAUL L BUBNICK-HRS	283024	822136	260	135	230.00
38	SPR HL BELL TOWER SH	283024.167	823259.379	35	14	35.00
39	M F BRADFORD-HRS	283104	822947	160	126	45.00
40	M POLK-HRS (HARRISON P)	283117	822358	250	137	225.00
41	BILL MEADORS-HRS	283118	822754	110	70	77.00
42	VANCE	283139	822730	119	84	90.00
43	PAUL JOHNSON-HRS	283440	822503	270	243	150.00
44	WISE	283150	822503			160.00
45	TREANOR	283153	823406	85	63	30.00
46	GREENE	283154	823540			10.00
47	FAVOT	283158	822328	195	85	160.00
48	MILDRED WATHEN-HRS 14	283159	823458	67	42	15.00
49	WEEKI WACHEE WELL	283201	823156			36.49
51	HENDRICKSON	283229	823446	197	189	30.00
53	OLSEN	283247	823321	75	63	35.00
54	STANLEY	283252	822734	120	106	120.00
55	HRS 54 KOSTER	283257	823432	120	84	22.00
56	T R EDWARDS-HRS	283308	823033	190	157	100.00
58	WARD T.	283325	822452			120.00
59	P J MULLADY-HRS	283329	823018	135	116	105.00
60	WARD B.	283335	822412			120.00
61	B MCGREERY-HRS (FLECKNEY)	283433	823306	100	80	30.00
62	WILLIAM FLAHERTY-HRS	283516	822803	138	105	95.00
63	SEESE	283517	822427	226	130	80.00
64	CURTIS CHANCEY-HRS	283522	823258	95	75	28.00
65	WEEKI WELL 2	283527	823657	125	123	8.79
66	WEEKI WELL 3	283517.190	823558.842	140	133	8.40
67	ROMP 103 DEEP	283537.426	821524.603	198	111	92.80
68	MARSHALL	283547	823153	150	84	40.00
69	DAVID ERVIN-HRS	283603	822253	130	78	109.00
70	SHAW, R.	283620	822352	210	135	94.00
71	BAGGET	283630	822754	160		160.00
72	ROMP CENTRALIA DEEP	283652.327	823131.456	170	122	39.44
73	W DARCANGELO-HRS	283659	822904	200	126	125.00
74	WYLUPEK	283707	821953			110.00
75	J H JACKSON-HRS	283719	822550	109	84	98.00
76	M T MONROE-HRS	283720	823147	125	70	50.00
77	KOLASA	283735	822646	250	180	95.00
78	DICKS	283737	822416	200	180	70.00
80	HARRISON T.	283739	822257	150		100.00
81	BARTLETT	283749	823234	128	98	30.00
82	HAROLD E SELPH-HRS	283759	822527	115	94	105.00
83	LEDINGTON	283805	822133			100.00
84	CHAPMAN	283848	821945			95.00
85	VEDDER	283858	823013	304	274	70.00
86	ROMP 107	283925.165	822723.439	240	140	116.03
87	C ELLINGHUYSEN-HRS	283942	822155	174	159	88.00
88	MILLER	283949	821624	88	40	55.00
89	HOWARD	284005	821638			93.00
90	VARN	284013	821752			75.00
91	MONCK	284034	822247	200	126	140.00
92	HOYER	284038	822332	133	110	98.00
93	BROOKS	284054	822138	159	120	118.00
94	REGNIER	284114	822103	196	189	82.00
95	BETTY JAY SPRING WELL	284130	823635	60	48	5.00
97	JACKSON C.	284314	821852			47.00
98	SHAW J.	284315	823352	78	64	7.00
99	CHASSAHOWITZKA # 1	284318.932	823306.362	178	166	9.82
100	PARKSIDE FLORAL CITY	284328.091	821811.689	103	100	40.00
101	ROMP 109 OCALA	284331.119	822153.676	260	189	157.13
102	LECANTO WELL # 2	284338.519	822705.468	41	38	32.64
103	LECANTO WELL # 1	284338.603	822705.461	169	168	32.60
104	BROWN V.	284356	822249	160	130	80.00
105	RAYUNEC	284429	823117	85	59	50.00
106	SUGARMILL MZ1 DUAL SH	284457	823303	155	75	10.00
108	WOODFIELD	284534	821451	50	40	50.00
109	HILLER	284549	821638	35	32	43.00
110	HOMOSASSA WELL 3	284551	823453	99	81	5.00
111	FICKES	284615	823128	48	42	60.00
112	DASSEL	284618	821949	170	168	80.00
113	NORTON	284634	822736	160	158	69.00
114	HOWERTON	284642	821501	70	63	42.00
116	HOMO SWD BRADSHAW 2	284736	823429	100	92	8.00
117	KREIDER	284759	822554	95	63	50.00
118	NORRIS WL AT HOMOSASSA	284803	823517	50	44	6.00
119	BRETTHAUSER	284804	822129	74	68	74.00
120	FOWLER	284828	821831	138	136	60.00
121	PINEAU	284858	821544	220	195	50.00
122	BAPTIST CHURCH PASTORIUM	284939	823447	80	UNK	10.00
123	GRETHER	285007	823118	216	181	85.00
124	HENDRY	285011	821837	67	55	45.00
125	BROWN W.	285011	822117	85	79	80.00
126	OZELLO WL 4 NR CRYSTAL RIVER	285102	823610	75	60	6.00
127	ROMP TR 21-2 DP	285112	823544	111	105	3.42
128	ROMP 113 OCALA	285124	822456	160	130	129.93
130	ROMP TR 21-3 AVON PARK	285235.329	823417.138	252	240	6.11

APPENDIX II

Water Quality Data for Sampled Monitor Wells

WELL_ID	FIELD_PH	FIELD_TEMP	FIELD_COND	HCO3_HCO3	DIS_CL	DIS_SO4	DIS_F	DIS_CA	DIS_MG	DIS_K	DIS_NA	NH3	NO3	NO2_NO3	OPO4	TOT_PO4	TDS	TOC	DIS_FE
	std pH units	degrees C	umos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
SR 52 Dp Well	7.24	25.30	376.00	167.00	4.50	0.40	0.09	77.00	2.00	0.20	3.30	0.119	-0.010	-0.010	0.05	0.05	221.00	2.92	2.136
Eichhorn	6.94	24.30	263.00	120.00	9.30	0.60	0.12	48.00	1.00	0.40	6.40	0.035	-0.010	-0.010	0.07	0.07	168.00	1.28	0.161
Hagin	7.83	24.20	184.00	80.00	4.80	5.00	0.05	34.00	0.70	-0.05	2.50	-0.010	0.132	0.132	0.01	0.01	168.00	-0.50	-0.030
Coston	7.67	22.40	243.00	108.00	6.30	1.20	0.09	45.00	1.70	-0.05	3.80	-0.010	-0.010	-0.010	0.09	0.10	230.00	0.79	0.075
Grace Memorial	7.64	23.70	280.00	109.00	11.00	9.20	0.03	54.00	1.00	0.30	6.80	-0.010	0.287	0.405	0.74	0.68	167.00	1.09	0.041
Daniels	9.06	24.10	192.00	81.00	5.40	1.50	0.05	34.00	0.90	0.20	3.10		0.952				179.00	0.06	-0.030
Massaryktown Dp	7.36	24.90	357.00	175.00	5.60	3.90	0.05	73.00	1.60	1.00	4.50	-0.010	0.462	0.463	0.04	0.04	207.00	-0.50	0.031
Dalton	7.88	24.35	195.50	86.00	4.70	6.20	0.07	30.00	3.60	-0.05	2.20	0.060	0.043	0.047	0.01	0.01	162.00	-0.50	0.184
Whiting Well	7.18	23.40	2030.00	220.00		46.00	0.08	119.00	26.00	7.20	248.00	0.179	-0.010	0.011	0.03	0.04	1113.00	3.20	3.229
Mag Sp Well	7.85	23.30	294.00	124.00	12.00	8.00	0.24	38.00	11.00	0.50	6.90	-0.010	-0.010	-0.010	-0.01	-0.01	208.00	-0.50	0.231
Romp 97	8.40	24.40	209.00	96.00	3.70	6.30	0.05	37.00	3.00	0.40	3.30	-0.010	-0.010	-0.010	0.02	0.02	125.00	-0.50	0.062
Voscinar	7.65	24.80	332.00	160.00	6.40	3.10	0.08	58.00	2.50	0.30	3.50	-0.010	0.602	0.602	0.02	0.02	165.00	-0.50	-0.030
Blair	7.73	24.10	174.00	72.00	8.50	0.80	0.09	30.00	2.90	3.10	3.10	0.226	-0.010	-0.010	0.14	0.14	132.00	15.83	0.596
Kelso	7.83	23.90	122.50	48.00	3.40	1.50	0.06	16.00	2.80	-0.05	2.00	0.060	0.060	0.060	-0.01	-0.01	69.00	-0.50	-0.030
Weeki Well II	7.18	24.10	387.00	188.00	11.00	8.80	0.12	81.00	1.50	0.90	4.10	0.391	0.013	0.016	0.10	0.08	242.00	5.34	0.556
Mordenti	8.04	22.95	171.50	73.00	3.70	5.00	0.04	29.00	2.10	-0.05	2.20	0.063	0.163	0.163	0.01	0.02	88.00	-0.50	-0.030
Bisard	8.22	25.45	154.50	62.00	4.90	1.80	0.05	27.00	0.90	-0.05	2.80	0.076	0.620	0.620	0.01	0.01	76.00	-0.50	-0.030
Romp TR 18-2	7.94	24.70	238.00	102.00	5.60	9.30	0.08	42.00	4.20	0.20	3.40	0.044	0.122	0.123	0.01	0.01	151.00	-0.50	-0.030
Jarvis	8.18	23.80	386.00	184.00	9.80	0.40	0.19	67.00	5.30	0.20	4.90	-0.010	0.062	0.062	0.04	0.04	271.00	-0.50	-0.030
Bridges	8.10	22.40	194.50	79.00	5.40	3.00	0.07	37.00	0.90	-0.05	3.00	0.011	1.880	1.883	0.02	-0.01	132.00	-0.50	-0.030
Harrison C.	7.76	24.20	221.00	97.00	5.00	3.70	0.13	41.00	2.40	-0.05	3.00	-0.010	0.958	0.962	0.02	0.02	131.00	-0.50	-0.030
Funk	7.70	22.00	378.00	167.00	8.70	3.20	0.03	70.00	1.10	-0.05	5.20		1.849				210.00	0.44	-0.030
Romp TR 18-1	8.01	25.50	227.00	98.00	5.00	7.70	0.08	39.00	4.10	0.20	3.10	0.136	0.040	0.041	0.02	0.03	133.00	-0.50	-0.030
Bedillion	7.68	21.60	433.00	200.00	7.90	2.20	0.18	74.00	6.50	-0.05	5.00	-0.010	0.029	0.029	0.03	0.02	237.00	-0.50	-0.030
Parker	7.79	22.50	513.00	248.00	15.00	2.60	0.13	87.00	6.20	-0.05	8.70	-0.010	0.013	0.013	0.07	0.07	296.00	-0.50	0.114
Baker	7.49	22.50	419.00	170.00	6.40	0.50	0.10	63.00	1.30	-0.05	4.30	0.046	0.049	0.050	0.03	0.03	212.00	1.09	0.050
Diggs	7.92	22.40	499.00	252.00	8.70	3.20	0.22	81.00	11.00	0.20	5.80	-0.010	0.021	0.021	0.04	0.04	287.00	-0.50	-0.030
Taylor	7.27	23.30	409.00	191.00	7.70	6.60	0.19	75.00	4.20	0.20	4.60	-0.010	0.287	0.287	0.04	0.01	226.00	-0.50	-0.030
Altizer	7.60	23.70	390.50	180.00	6.00	-0.10	0.10	72.00	1.70	-0.05	3.80	0.040	-0.010	-0.010	0.03	0.03	237.00	1.27	0.208
Corwin	7.00	22.80	178.00	64.00	4.80	9.50	0.06	27.00	3.40	-0.05	2.80	-0.010	0.057	0.057	-0.01	-0.01	87.00	0.50	0.031
Booth	7.87	23.80	261.00	96.00	19.00	4.60	0.12	38.00	5.30	-0.05	8.70		0.798				198.00	0.24	-0.030
Hern Bch Supply	7.73	24.85	336.50	105.00	21.00	21.00	0.10	47.00	5.60	0.50	13.00	0.065	-0.010	-0.010	0.02	0.02	190.00	1.13	0.734
Stewart	7.60	22.95	257.50	124.00	4.40	-0.10	0.18	45.00	2.10	0.70	2.90	0.670	-0.010	-0.010	0.03	0.04	205.00	6.61	0.746
Swope	7.51	23.95	421.00	170.00	8.50	4.40	0.12	74.00	4.80	0.30	5.10	-0.010	6.653	6.653	0.02	0.02	224.00	0.60	-0.030
Kavoris	7.14	22.70	514.00	244.00	13.00	1.30	0.19	84.00	12.00	0.50	7.90	0.047	-0.010	-0.010	0.08	0.07	289.00	1.02	1.098
Bubnick	7.04	24.30	468.00	224.00	15.00	3.00	0.24	71.00	10.00	0.40	7.50	0.068	0.025	0.026	0.02	0.03	267.00	-0.50	-0.030
Sp Hill Bell Twr	7.35	25.05	247.50	101.00	6.80	4.20	0.10	42.00	2.50	-0.05	4.30	0.012	1.748	1.748	0.07	0.06	149.00	0.62	-0.030
Bradford	8.49	23.20	162.00	147.00	5.40	2.60	0.08	30.00	1.70	-0.05	3.40	0.013	2.078	2.078	0.02	0.01	110.00	-0.50	-0.030
Harrison P.	7.18	23.95	456.00	225.00	8.90	1.60	0.19	80.00	10.00	0.40	7.00	0.069	0.045	0.047	0.03	0.01	321.00	-0.50	-0.030
Meadors	8.06	24.20	194.00	72.00	8.20	1.40	0.06	34.00	1.40	-0.05	4.90	-0.010	2.835	2.835	0.02	0.02	111.00	-0.50	-0.030
Vance	7.66	24.46	288.00	116.00	5.60	5.40	0.05	47.00	2.70	0.40	3.50	0.039	2.500	2.500	0.02	0.02	162.00	-0.50	-0.030

WELL_ID	FIELD_PH	FIELD_TEMP	FIELD_COND	HCO3_HCO3	DIS_CL	DIS_SO4	DIS_F	DIS_CA	DIS_MG	DIS_K	DIS_NA	NH3	NO3	NO2_NO3	OPO4	TOT_PO4	TDS	TOC	DIS_FE
	std pH units	degrees C	umos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Johnson	7.92	23.65	181.00	82.00	4.40	2.40	0.07	34.00	1.70	-0.05	2.70	0.060	0.486	0.486	0.02	0.02	109.00	-0.50	-0.030
Wise	7.79	23.35	438.00	203.00	7.60	15.00	0.22	68.00	9.00	-0.05	5.00	0.040	0.141	0.141	0.04	0.04	263.00	0.64	-0.030
Treanor	7.65	23.50	260.00	119.00	5.50	3.50	0.08	45.00	4.00	-0.05	3.50	-0.010	0.416	0.416	0.01	-0.01	138.00	-0.50	0.051
Greene	7.70	23.60	251.00	109.00	7.10	4.90	0.05	42.00	2.90	0.30	4.50	-0.010	0.704	0.707	0.01	-0.01	160.00	-0.50	-0.030
Favot	7.10	23.65	552.00	252.00	22.00	1.30	0.24	96.00	4.30	0.20	8.60	0.035	0.137	0.137	0.02	0.02	394.00	-0.50	
Wathen	7.39	24.30	301.00	133.00	6.80	6.80	0.08	56.00	4.00	0.30	4.50		1.090				246.00	-0.50	-0.030
Weeki Wachee Well	7.57	25.10	293.00	148.00	4.50	3.90	0.13	46.00	9.40	-0.05	3.20	-0.010	0.035	0.035	0.01	-0.01	152.00	-0.50	-0.030
Hendrickson	7.57	23.50	337.00	144.00	9.70	6.00	0.04	61.00	1.50	0.30	4.70	0.012	1.148	1.151	0.01	0.01	210.00	0.68	-0.030
Olsen	8.32	23.95	138.50	57.00	5.40	1.60	0.01	27.00	0.60	-0.05		0.056	0.649	0.652	-0.01	0.01	121.00	-0.50	-0.030
Stanley	7.20	22.35	486.50	226.00	9.20	10.00	0.13	85.00	4.90	0.40	4.20	-0.010	2.916	2.920	0.03	0.03	274.00	-0.50	-0.030
Koster	7.71	23.95	281.00	124.00	5.50	7.70	0.10	48.00	5.70	-0.05	3.50	-0.010	0.117	0.117	-0.01	0.02	202.00	-0.50	0.030
Edwards	7.62	24.03	328.60	148.00	6.90	7.10	0.09	56.00	4.30	0.30	4.30	0.025	0.894	0.896	0.02	0.02	187.00	-0.50	-0.030
Ward T.	7.10	22.95	572.00	267.00	13.00	1.70	0.23	112.00	2.50	-0.05	6.70	0.313	1.974	1.974	0.01	0.03	3.00	-0.50	0.053
Mullady	7.68	24.40	257.50	94.00	5.10	4.80	0.08	44.00	3.00	-0.05	3.10	0.181	0.641	0.643	0.02	0.01	152.00	-0.50	-0.030
Ward B.	6.91	20.30	658.00	311.00	24.00	1.80	0.31	138.00	3.90	-0.05	9.80	-0.010	1.820	1.824	0.03	0.02	390.00	-0.50	0.040
Flackney	7.47	23.30	268.00	118.00	6.40	2.00	0.05	46.00	1.40	-0.05	3.50	0.082	-0.010	-0.010	-0.01	0.01	157.00	0.50	0.680
Flaherty	7.41	23.86	356.00	151.00	11.00	9.70	0.07	75.00	1.00	0.20	4.50	0.069	2.980	2.988	0.03	0.15	307.00	-0.50	-0.030
Seese	7.79	23.60	253.30	118.00	6.60	7.60	0.17	40.00	8.30	-0.05	4.00	0.012	0.929	0.933	0.02	0.02	212.00	-0.50	-0.030
Chancey	7.99	23.00	237.00	90.00	9.00	2.90	0.04	38.00	1.10	-0.05	6.40	0.010	2.705	2.707	0.02	0.01	139.00	-0.50	-0.030
Weeki Well 2	6.99	21.10	460.00	170.00	54.00	11.00	0.07	64.00	9.90	0.80	29.00	0.049	-0.010	-0.010	0.02	-0.01	334.00	1.20	1.771
Weeki Well 3	7.25	22.00	377.00	131.00	41.00	17.00	0.07	57.00	6.20	0.50	22.00	0.068	-0.010	0.011	0.02	-0.01	362.00	1.37	0.326
Romp 103	7.95	24.00	198.00	82.00	5.00	5.70	0.08	31.00	3.70	0.30	3.30	-0.010	0.187	0.192	0.02	0.03	113.00	-0.50	0.040
Marshall	7.93	23.85	170.50	82.00	3.50	1.00	0.04	32.00	1.10	-0.05	2.40	0.020	0.263	0.264	0.02	0.01	104.00	-0.50	-0.030
Ervin	6.86	22.70	533.50	259.00	9.70	6.40	0.15	106.00	7.70	-0.05	5.00	0.050	0.468	0.471	0.04	0.17	372.00	-0.50	-0.030
Shaw R.	7.21	22.70	441.50	212.00	11.00	5.60	0.10	83.00	1.70	0.20	5.10	0.107	0.050	0.050	0.05	0.07	257.00	-0.50	0.201
Bagget	7.27	23.20	443.00	207.00	10.00	7.40	0.19	73.00	10.00	-0.05	5.50	-0.010	0.448	0.448	0.03	0.03	248.00	-0.50	-0.030
Romp Centralia	7.77	24.50	279.00	125.00	5.20	5.40	0.11			-0.05		-0.010	0.490	0.497	0.01	0.02	154.00	-0.50	-0.030
Darcangelo	6.99	23.50	551.00	278.00	8.40	3.00	0.11	100.00	4.40	-0.05	4.60						306.00		-0.030
Wylupek	7.68	23.20	209.00	94.00	5.30	4.70	0.13	33.00	4.80	-0.05	3.30	-0.010	0.506	0.506	0.01	0.01	166.00	-0.50	-0.030
Jackson J.	7.14	22.40	484.00	238.00	9.70	7.40	0.13	87.00	8.70	0.20	5.40	-0.010	0.429	0.432	0.03	0.03	267.00	0.71	0.032
Monroe	7.85	24.30	187.00	98.00	5.20	2.20	0.07	30.00	2.80	-0.05	3.10		0.741				106.00	0.22	-0.030
Kolasa	7.30	22.00	615.00	283.00	21.00	-0.10	0.07	111.00	4.20	0.50	11.00	0.357	-0.010	-0.010	0.13	0.02	395.00	3.26	12.377
Dicks	7.79	23.40	152.00	67.00	4.60	3.50	0.10	26.00	2.70	-0.05	2.80	-0.010	0.423	0.423	0.10	0.10	90.00	-0.50	-0.030
Harrison T.	7.61	23.20	315.00	146.00	6.00	4.30	0.10	50.00	5.80	-0.05	3.30	-0.010	0.429	0.430	0.03	0.03	190.00	-0.50	-0.030
Bartlett	8.19	23.80	142.00	61.00	3.90	1.60	0.06	24.00	2.20	-0.05	2.30	-0.010	0.329	0.329	0.02	-0.01	79.00	-0.50	-0.030
Selph	7.30	22.80	420.00	198.00	8.40	8.50	0.14	71.00	10.00	0.20	5.30	-0.010	0.440	0.443	0.04	0.04	239.00	-0.50	-0.030
Ledington	7.79	23.90	219.00	118.00	5.30	5.80	0.13	32.00	6.90	-0.05	3.50	-0.010	0.282	0.282	0.01	0.02	175.00	-0.50	-0.030
Chapman	7.47	19.30	401.00	194.00	7.50	4.80	0.13	72.00	4.20	-0.05	4.40	-0.010	0.218	0.218	0.04	0.04	215.00	-0.50	-0.030
Vedder	7.81	23.90	403.00	196.00	6.20	8.30	0.21	51.00	20.00	0.70	4.30	-0.010	-0.010	-0.010	0.02	0.02	227.00	-0.50	2.074
Romp 107	7.18	22.80	433.00	200.00	16.00	2.80	0.10	80.00	2.10	0.50	8.80	-0.010	0.171	0.171	0.03	0.02	243.00	-0.50	-0.030
Ellinghuysen	6.99	22.50	471.00	216.00	12.00	8.40	0.15	78.00	9.10	0.20	5.60	-0.010	0.458	0.458	0.03	0.03	256.00	-0.50	-0.030
Miller	7.30	23.20	426.00	192.00	13.00	-0.10	0.11	81.00	2.00	-0.05	8.30	0.343	-0.010	-0.010	0.14	0.13	237.00	6.04	4.369

WELL_ID	FIELD_PH	FIELD_TEMP	FIELD_COND	HCO3_HCO3	DIS_CL	DIS_SO4	DIS_F	DIS_CA	DIS_MG	DIS_K	DIS_NA	NH3	NO3	NO2_NO3	OPO4	TOT_PO4	TDS	TOC	DIS_FE
	std pH units	degrees C	umos	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Howard	7.22	23.00	281.00	121.00	5.70	7.80	0.10	50.00	4.30	-0.05	3.70	-0.010	0.116	0.120	0.03	0.02	155.00	-0.50	-0.030
Varn	7.86	24.00	221.00	101.00	4.70	2.50	0.09	41.00	1.60	-0.05	3.00	0.011	0.315	0.321	0.04	0.03		-0.50	-0.030
Monck	7.62	23.10	227.00	133.00	5.10	4.60	0.13	33.00	4.80	-0.05	3.30	-0.010	0.498	0.502	0.02	0.02	105.00	-0.50	0.040
Hoyer	7.38	23.30	303.00	267.00	8.30	4.10	0.08	55.00	4.60	-0.05	3.90	-0.010	0.476	0.482	-0.01	0.22	251.00	-0.50	-0.030
Brooks	7.83	23.60	246.00	106.00	5.30	7.20	0.13	42.00	5.60	-0.05	3.40	-0.010	0.288	0.288	0.02	-0.01	145.00	-0.50	-0.030
Regnier	8.06	23.40	228.00	97.00	4.90	8.60	0.11	38.00	4.90	-0.05	3.50	-0.010	0.117	0.182	0.02	0.02	115.00	-0.50	-0.030
Betty Jay Sp Well	7.61	22.40	438.00	189.00	19.00	3.80	0.14	66.00	12.00	0.40	11.00	0.197	0.095	-0.010	0.03	-0.01	312.00	1.37	1.855
Jackson C.	7.15	24.30	135.00	65.00	5.10	0.80	0.17	24.00	0.90	-0.05	3.10	-0.010	0.240	0.244	0.33	0.33	71.00	-0.50	0.032
Shaw J.	7.64	24.60	354.50	145.00	16.00	8.70	0.16	51.00	11.00	0.40	9.80	-0.010	0.476	0.487	0.03	0.02	187.00	-0.50	-0.030
Chassahowitzka #1	7.67	23.80	315.50	146.00	7.50	7.40	0.14	47.00	9.40	0.20	4.50	-0.010	0.512	0.520	0.02	0.02	178.00	-0.50	-0.030
Parkside Fld Cty	7.69	23.80	275.00	79.00	8.40	5.10	0.09	37.00	1.10	-0.05	3.30	-0.010	0.120	0.125	0.03	0.04	108.00	-0.50	0.175
Romp 109 OCALA	7.59	24.70	278.00	116.00	5.20	5.30	0.08	46.00	3.50	-0.05	3.60	-0.010	0.116	0.120	0.02	-0.01	145.00	-0.50	0.235
Lecanto 2	7.33	24.10	305.50	170.00	4.00	3.00	0.10	57.00	3.60	-0.05	2.70	0.066	0.282	0.283	0.07	0.07	254.00	-0.50	-0.030
Lecanto 1	7.58	24.10	245.50	115.00	5.10	4.50	0.11	42.00	5.20	-0.05	3.00	0.042	0.285	0.288	0.02	0.02	209.00	-0.50	-0.030
Brown V.	7.78	23.80	219.00	98.00	4.80	6.70	0.07	40.00	2.90	-0.05	2.80	-0.010	0.093	0.097	0.01	-0.01	198.00	-0.50	-0.030
Rayunec	7.82	24.30	184.00	66.00	7.80	3.50	0.05	30.00	3.10	0.40	3.30		1.728				109.00	0.02	-0.030
Sugarmill M21 Sh	7.62	23.80	282.00	132.00	4.70	6.60	0.16	33.00	13.00	0.50	3.10	-0.010	0.012	0.012	0.01	0.01	191.00	-0.50	0.100
Woodfield	7.15	24.10	516.00	226.00	12.00	15.00	0.08	99.00	2.00	0.20	8.20	-0.010	0.196	0.201	0.11	0.12	293.00	0.51	-0.030
Hiller	7.33	23.60	505.00	229.00	18.00	11.00	0.12	100.00	2.50	0.90	9.70	0.197	-0.010	-0.010	0.06	0.07	301.00	12.10	3.114
Homosassa Well 3	7.87	23.60	1533.00	132.00	459.00	67.00	0.10	54.00	31.00	8.10	243.00	0.053	0.220	0.220	0.02	0.02	966.00	-0.50	0.038
Fickes	7.86	24.15	229.50	101.00	5.50	4.30	0.09	37.00	6.50	-0.05	3.50	0.015	0.555	0.561	0.02	0.02	126.00	-0.50	0.034
Dassel	7.66	23.60	259.00	118.00	7.80	3.70	0.08	45.00	2.40	-0.05	4.30	-0.010	0.198	0.199	0.04	0.04	159.00	0.68	-0.030
Norton	7.84	24.20	246.00	110.00	5.00	4.50	0.11	44.00	4.00	-0.05	3.20	-0.010	0.075	0.078	0.04	0.04	132.00	-0.50	-0.030
Howerton	6.71	22.90	549.00	194.00	54.00	-0.10	0.12	78.00	5.20	0.20	30.00	0.377	-0.010	-0.010	0.07	0.04	388.00	5.83	3.411
Homo Spec Wat Dist	7.77	23.60	278.00	121.00	15.00	6.60	0.08	46.00	7.00	0.40	8.10	0.010	0.376	0.378	0.02	0.03	209.00	-0.50	-0.030
Kreider	7.57	23.90	386.00	134.00	34.00	4.70	0.14	63.00	3.20	0.40	12.00	0.214	0.050	0.050	0.05	0.14	251.00	6.97	0.389
Norris Well	7.31	21.80	1052.00	135.00	218.00	33.00	0.09	56.00	19.00	4.00	123.00	0.013	0.090	0.094	0.06	0.06	620.00	2.60	0.107
Breithauser	8.12	23.10	149.00	49.00	4.00	0.70	0.08	27.00	1.10	-0.05	2.50	-0.010	0.127	0.132	0.02	0.02	73.00	-0.50	0.030
Fowler	7.44	25.10	322.00	70.00	50.00	2.00	0.10	34.00	2.40	0.30	23.00	-0.010	1.472	1.473	0.12	0.27	202.00	-0.50	-0.030
Pineau	7.97	23.80	227.00	95.00	6.10	4.40	0.06	43.00	1.00	-0.05	3.60	-0.010	0.477	0.482	0.03	0.02	115.00	-0.50	-0.030
Baptist Church	7.24	22.73	666.30	242.00	47.00	7.90	0.07	97.00	7.20	2.30	26.00	0.203	2.455	2.458	0.01	0.02	350.00	1.82	-0.030
Grether	7.85	23.90	237.00	104.00	4.90	5.90	0.08	39.00	4.80	-0.05	3.20	-0.010	0.189	0.194	0.03	0.03	135.00	-0.50	0.032
Hendry	7.36	23.50	436.00	182.00	15.00	20.00	0.12	66.00	5.60	0.30	7.50	0.363	-0.010	-0.010	0.12	0.10	256.00	4.26	2.035
Brown W.	7.89	25.00	273.00	122.00	6.90	2.10	0.12	49.00	2.90	-0.05	4.30	0.058	-0.010	-0.010	0.07	0.06	175.00	0.99	0.163
Ozello 4	6.98	22.70	1665.00	232.00	362.00	25.00	0.10	88.00	25.00	6.20	190.00	0.704	-0.010	-0.010	0.32	0.07	888.00	9.06	8.619
Romp TR 21-2	7.54	23.00	1090.00	153.00	237.00	27.00	0.17	60.00	29.00	2.30	114.00	0.032	-0.010	-0.010	0.02	0.02	594.00	-0.50	-0.030
Romp 113 OCALA	8.38	24.50	158.00	72.00	4.40	1.50	0.08	29.00	1.80	-0.05	2.50	-0.010	0.172	0.172	0.03	0.06	112.00	-0.50	-0.030
Romp TR 21-3	8.59	24.90	546.00	114.00	90.00	11.00	0.31	25.00	15.00	5.80	55.00	0.017	-0.010	-0.010	-0.01	0.01	280.00	-0.50	-0.030

APPENDIX III

Water-Quality Data for Sampled Springs

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umos	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
MAGNOLIA	19940808	7.7500	24.5000	545.0000	103.0000	89.0000	20.0000	0.0700	44.0000	8.3000	1.7000	49.0000	-0.0100	0.3800	-0.0100	0.0100	283.0000	-0.5000	-30.0000
MAGNOLIA	19941024	7.7400	25.5000	493.0000	96.0000	74.0000	18.0000	0.0700	43.0000	7.9000	1.6000	42.0000	0.0100	0.3640	-0.0100	0.0140	269.0000	-0.5000	-30.0000
MAGNOLIA	19950116	7.7900	23.4000	436.0000	104.0000	60.0000	16.0000	0.0480	42.0000	6.9000	1.1000	33.0000	-0.0100	0.3390	0.0220	0.0130	248.0000	-0.5000	-30.0000
MAGNOLIA	19950404	7.7700	24.6000	447.0000	104.0000	61.0000	16.0000	0.0570	44.0000	7.2000	1.2000	35.0000	0.0100	0.3720	0.0100	0.0110	252.0000	-0.5000	41.0000
MAGNOLIA	19950727	7.7500	24.4000	539.0000	104.0000	87.0000	20.0000	0.0500	42.0000	7.2000	1.4000	45.0000	-0.0100	0.3600	0.0150	0.0140	265.0000	-0.5000	-30.0000
MAGNOLIA	19951026	7.7400	25.7000	532.0000	107.0000	84.0000	19.0000	0.0600	45.0000	8.8000	1.7000	48.0000	0.0100	0.4010	-0.0100	-0.0100	284.0000	-0.5000	-30.0000
MAGNOLIA	19960207	7.7400	24.1000	357.0000	108.0000	37.0000	13.0000	0.0500	40.0000	5.6000	0.9000	21.0000	-0.0100		0.0200	0.0180	196.0000	-0.5000	-30.0000
MAGNOLIA	19960418	7.7900	24.2000	344.0000	106.0000	32.0000	12.0000	0.0600	43.0000	5.6000	0.8000	18.0000	0.0500	0.3760	-0.0100	-0.0100	193.0000	0.8600	38.0000
MAGNOLIA	19960718	7.7500	24.6000	378.0000	108.0000	44.0000	14.0000	0.0790	53.7500	5.5700	1.1000	22.0000	0.0300	0.4050	0.0100	-0.0100	193.0000	-0.5000	-30.0000
MAGNOLIA	19961015	7.7600	23.9000	398.0000	106.0000	52.0000	15.0000	0.0640	42.0000	6.2000	1.0000	27.0000	0.1040	0.3720	0.0490	0.0440	244.0000	-0.5000	-30.0000
MAGNOLIA	19970130	8.0600	23.5000	420.0000	105.0000	60.0000	15.0000	0.0900	40.0000	6.3000	1.0000	30.0000	-0.0100	0.3920	0.0120	-0.0100	231.0000	-0.5000	-30.0000
MAGNOLIA	19970410	7.7100	23.9000	471.0000	107.0000	67.0000	16.0000	0.0640	40.0000	7.0000	1.3000	37.0000	-0.0100	0.4150	0.0170	0.0200	257.0000	-0.5000	-30.0000
ARIPEKA #2	19941024	7.7300	25.3000	423.0000	96.0000	55.0000	15.0000	0.0800	40.0000	6.2000	1.2000	30.0000	0.0200	0.5150	-0.0100	0.0180	219.0000	-0.5000	-30.0000
ARIPEKA #2	19950116	7.7500	23.7000	410.0000	104.0000	52.0000	15.0000	0.0500	44.0000	6.4000	1.1000	29.0000	-0.0100	0.4770	0.0290	0.0130	228.0000	-0.5000	-30.0000
ARIPEKA #2	19970130	7.7800	23.8000	518.0000	105.0000	77.0000	20.0000	0.0700	41.0000	7.3000	1.3000	37.0000	-0.0100	0.5030	-0.0100	0.0220	259.0000	-0.5000	30.0000
BOBHILL	19940726	7.2700	25.5000	297.0000	132.0000	5.8000	9.7000	0.0800	52.0000	3.4000	0.5000	4.0000	-0.0100	0.7700	-0.0100	0.0200	173.0000	-0.5000	-30.0000
BOBHILL	19941025	7.6500	25.1000	276.0000	110.0000	6.5000	7.8000	0.0600	45.0000	3.1000	0.4000	3.4000	-0.0100	0.5730	-0.0100	-0.0100	157.0000	0.7200	-30.0000
BOBHILL	19950118	7.5700	23.2000	272.0000	117.0000	6.8000	8.3000	0.0400	49.0000	3.1000	0.4000	3.7000	0.1900	0.5400	0.0300	0.0300	161.0000	0.8000	35.0000
BOBHILL	19950330	7.6800	24.1000	260.0000	111.0000	5.7000	7.4000	0.0500	48.0000	3.4000	0.3000	3.7000	0.0100	0.5740	0.0100	0.0100	144.0000	0.7800	43.0000
BOBHILL	19950724	7.4600	24.8000	270.0000	114.0000	6.5000	7.0000	0.0500	50.0000	3.8000	0.3000	4.3000	0.0400	0.5130	0.0100	0.0100	152.0000	1.0400	
BOBHILL	19951027	7.6900	24.3000	277.0000	114.0000	8.0000	8.0000	0.0400	46.0000	3.2000	0.3000	3.7000	0.0200	0.7920	0.0630	0.0790	163.0000	1.5500	71.0000
BOBHILL	19960131	7.6000	24.1000	259.0000	101.0000	6.4000	7.9000	0.0700	42.0000	3.1000	0.3000	4.2000	0.0230		0.0110	0.0130	150.0000	-0.5000	-30.0000
BOBHILL	19960416	7.7000	24.4000	266.0000	114.0000	6.5000	7.3000	0.0500	47.0000	3.2000	0.3000	3.9000	0.0140	0.5340	0.0120	0.0160	158.0000	0.9000	73.0000
BOBHILL	19960718	7.6000	26.7000	261.0000	114.0000	5.9000	8.1000	0.0720	47.8800	3.0100	0.4000	3.3000	0.0380	0.7010	-0.0100	-0.0100	144.0000	-0.5000	-30.0000
BOBHILL	19961014	7.5200	24.6000	263.0000	113.0000	5.8000	7.8000	0.0620	44.0000	3.2000	0.4000	3.7000	0.0160	0.6820	0.0410	0.0470	163.0000	0.8400	33.0000
BOBHILL	19970127	7.6600	22.8000	262.0000	113.0000	6.1000	8.6000	0.0500	43.0000	3.4000	0.3000	3.7000	-0.0100	0.5780	0.0120	0.0190	175.0000	0.6200	68.0000
BOBHILL	19970407	7.6800	23.8000	263.0000	111.0000	6.1000	8.8000	0.1320	44.0000	3.3000	0.4000	3.7000	0.0120	0.6770	-0.0100	0.0110	165.0000	-0.5000	41.0000
BOAT	19941024	7.5700	25.3000	1063.0000	124.0000	226.0000	37.0000	0.0800	50.0000	18.0000	4.9000	127.0000	-0.0100	0.3200	-0.0100	0.0160	536.0000	-0.5000	-30.0000
BOAT	19950116	7.5700	23.0000	640.0000	118.0000	107.0000	23.0000	0.0540	49.0000	10.0000	2.2000	61.0000	-0.0100	0.3090	0.0180	0.0140	336.0000	0.6800	-30.0000
BOAT	19950727	7.5500	24.3000	816.0000	118.0000	65.0000	16.0000	0.0600	45.0000	7.1000	1.4000	37.0000	-0.0100	0.3310	0.0150	0.0170	258.0000	0.9200	72.0000
BOAT	19951026		24.3000	978.0000	124.0000	460.0000	51.0000	0.0900	57.0000	23.0000	8.0000	168.0000	-0.0100	0.3310	-0.0100	0.0100	693.0000	0.8800	40.0000
BOAT	19960207	7.6100	22.7000	378.0000	114.0000	37.0000	12.0000	0.0600	44.0000	5.4000	1.0000	22.0000	0.0240		0.0210	0.0230	213.0000	0.5700	72.0000
BOAT	19960418	7.7500	23.4000	390.0000	118.0000	39.0000	13.0000	0.0600	47.0000	5.9000	0.9000	23.0000	-0.0100	0.3460	0.1700	0.0120	213.0000	0.7800	
BOAT	19960718	7.5800	24.3000	389.0000	116.0000	41.0000	12.0000	0.0810	58.1400	5.5400	1.3000	21.0000	0.0280	0.3650	0.0110	-0.0100	209.0000	-0.5000	-30.0000
BOAT	19961016	7.5700	24.4000	885.0000	122.0000	207.0000	34.0000	0.0630	52.0000	18.0000	5.0000	129.0000	0.0290	0.3500	0.0220	0.0390	561.0000	0.6300	-30.0000
BOAT	19970130	7.6000	22.4000	554.0000	113.0000	86.0000	19.0000	0.0800	43.0000	9.0000	2.0000	51.0000	-0.0100	0.3620	0.0100	-0.0100	313.0000	0.5800	-30.0000
BOAT	19970410	7.5300	23.5000	1106.0000	119.0000	227.0000	37.0000	0.0830	47.0000	18.0000	5.5000	135.0000		0.3430	0.0230	0.0270	568.0000	0.6200	
ARIPEKA #1	19941024	7.7700	25.3000	248.0000	107.0000	7.2000	8.2000	0.0700	43.0000	3.6000	0.2000	4.1000	-0.0100	0.5050	-0.0100	0.0160	132.0000	0.5300	-30.0000
ARIPEKA #1	19950116	7.7400	23.2000	582.0000	108.0000			0.0600	42.0000				-0.0100	0.4080	0.0180	0.0140	320.0000	0.6600	-30.0000
TWIN DEES	19931020	7.6800	24.7000	309.0000		18.0000	34.0000	0.0900	53.0000	5.6000	0.4000	3.7000	0.0100	0.4000	-0.0100	-0.0100	177.0000	-0.5000	35.0000
TWIN DEES	19940726	7.5300	23.9000	306.0000	143.0000	5.3000	6.9000	0.0900	60.0000	4.3000	0.2000	3.6000	0.0900	0.0500	-0.0100	0.0300	176.0000	0.8100	64.0000
TWIN DEES	19941025	7.6900	24.0000	295.0000	134.0000	6.2000	7.8000	0.0900	51.0000	5.4000	0.2000	3.6000	0.0100	0.5710	0.0170	0.0170	181.0000	-0.5000	-30.0000
TWIN DEES	19950118	7.7500	23.3000	303.0000	139.0000	6.8000	7.8000	0.0750	55.0000	5.4000	0.2000	3.6000	0.0100	0.4140	0.0360	0.0440	172.0000	-0.5000	35.0000
WEEKI WACHEE MAIN	19931020	7.7100	23.9000	308.0000		5.7000	8.4000	0.0900	51.0000	5.8000	0.3000	3.6000	0.0200	0.4000	-0.0100	0.0400	170.0000	0.5200	-30.0000
WEEKI WACHEE MAIN	19940726	7.9300	24.3000	303.0000	139.0000	6.0000	8.9000	0.1200	49.0000	5.3000	0.0500	3.5000	0.0100	0.5200	-0.0100	-0.0100	169.0000	-0.5000	-30.0000

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umos	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
WEEKI WACHEE MAIN	19941025	7.3900	23.8000	296.0000	135.0000	6.2000	8.0000	0.1000	49.0000	5.6000	0.2000	3.8000	0.0100	0.5070	0.0140	0.0200	177.0000	-0.5000	-30.0000
WEEKI WACHEE MAIN	19950118		23.4000	300.0000	136.0000	6.3000	8.0000	0.0800	54.0000	6.1000	0.2000	3.6000	0.0100	0.4660	0.0500	0.0500	168.0000	-0.5000	-30.0000
WEEKI WACHEE MAIN	19950330	7.6900	23.5000	304.0000	137.0000	5.6000	7.4000	0.0900	54.0000	6.1000	0.2000	3.8000	0.0100	0.4730	0.0100	0.0100	169.0000	-0.5000	30.0000
WEEKI WACHEE MAIN	19950724	7.7600	24.1000	302.0000	138.0000	5.9000	7.1000	0.0900	53.0000	6.6000	0.2000	4.1000	-0.0100	0.4790	0.0160	0.0110	183.0000	-0.5000	-30.0000
WEEKI WACHEE MAIN	19951023	7.7400	24.5000	300.0000	135.0000	6.7000	8.5000	0.1200	54.0000	5.9000	0.3000	3.9000	0.0900	0.7920	0.0100	0.0100	166.0000	-0.5000	-30.0000
WEEKI WACHEE MAIN	19960205	7.5500	20.2000	300.0000	136.0000	6.3000	8.4000	0.0900	49.0000	5.1000	0.2000	3.6000	0.0430		-0.0100	0.4470	176.0000	-0.5000	60.0000
WEEKI WACHEE MAIN	19960415	7.6600	24.0000	300.0000	135.0000	5.7000	7.9000	0.1000	52.0000	5.5000	0.2000	3.8000	-0.0100	0.5770	0.0100	0.0270	176.0000	0.5000	-30.0000
WEEKI WACHEE MAIN	19960715	7.6400	23.8000	303.0000	138.0000	6.7000	8.1000	0.1150	54.2800	5.8800	0.3000	3.7000	-0.0100	0.5680	-0.0100	-0.0100	201.0000	0.9000	-30.0000
WEEKI WACHEE MAIN	19961015	7.2300	23.8000	302.0000	136.0000	5.2000	7.9000	0.0920	49.0000	5.7000	0.3000	3.8000	0.0450	0.4360	0.0550	0.0530	184.0000	0.5300	-30.0000
WEEKI WACHEE MAIN	19970127	7.6900	24.0000	300.0000	135.0000	5.8000	9.1000	0.0900	49.0000	5.7000	0.2000	3.9000	-0.0100	0.5460	0.0100	0.0180	194.0000	-0.5000	-30.0000
WEEKI WACHEE MAIN	19970407	7.6900	23.3000	308.0000	135.0000	6.3000	9.1000	0.1560	50.0000	5.6000	0.3000	3.8000	-0.0100	0.5610	-0.0100	0.0100	172.0000	-0.5000	31.0000
SALT	19941025	7.5400	24.0000	9190.0000	125.0000	2840.0000	385.0000	0.1600	105.0000	180.0000	55.0000	1480.0000	-0.0100	0.4040	0.0130	0.0160	4990.0000	0.5000	91.0000
SALT	19950118	7.6500	23.6000	4150.0000	126.0000	1175.0000	175.0000	0.1040	76.0000	84.0000	24.0000	674.0000	0.0200	0.4150	0.0310	0.0470	2230.0000	-0.5000	34.0000
SALT	19950330	7.5200	23.9000	8520.0000	126.0000	2490.0000	350.0000	0.1450	107.0000	169.0000	51.0000	1390.0000	0.0400	0.3830	0.0100	0.0100	4552.0000	0.5200	83.0000
SALT	19950731	7.5300	26.0000	9090.0000	124.0000	2908.0000	397.0000	0.1600	110.0000	178.0000	67.0000	1547.0000	0.1000	0.3440	0.0190	0.0310	4887.0000	0.5600	61.0000
SALT	19951023	7.6000	23.8000	4670.0000	126.0000	1255.0000	196.0000	0.1400	83.0000	97.0000	30.0000	760.0000	0.0600	0.4560	0.0120	0.0140	2558.0000	-0.5000	62.0000
SALT	19960205	7.4300	23.4000	2570.0000	124.0000	608.0000	95.0000	0.1100	65.0000	49.0000	14.0000	344.0000	0.0430		-0.0100	-0.0100	1300.0000	0.7200	30.0000
SALT	19960416	7.6100	24.1000	8760.0000	127.0000	2362.0000	339.0000	0.1500	101.0000	173.0000	51.0000	1345.0000	0.0390	0.4190	0.0100	0.0120	4564.0000	0.6900	82.0000
SALT	19960715	7.5800	24.0000	6640.0000	126.0000	1918.0000	275.0000	0.1690	90.0000	130.0000	39.0000	1058.0000	0.0460	0.4430	-0.0100	-0.0100	3553.0000	1.6600	56.0000
SALT	19961016	7.5900	23.8000	4700.0000	132.0000	1231.0000	167.0000	0.1140	76.0000	91.0000	28.0000	743.0000	0.0170	0.4820	0.0310	0.0290	2538.0000	-0.5000	41.0000
SALT	19970127	7.6200	24.0000	4570.0000	123.0000	1229.0000	193.0000	0.1200	74.0000	91.0000	25.0000	729.0000	-0.0100	0.4420	0.0130	0.0160	2528.0000	0.6100	61.0000
SALT	19970407	7.5500	23.7000	12000.0000	125.0000	3920.0000	525.0000	0.2300	124.0000	236.0000	76.0000	2007.0000	0.0270	0.4210		0.0120	6891.0000		113.0000
MUD	19961029	7.3100	24.9000	34100.0000	124.0000	12175.0000	1580.0000	0.6510	305.0000	773.0000	234.0000	6805.0000	0.0870	0.1800	0.0220	0.0380	21964.0000	0.5900	108.0000
MUD	19970127	7.3300	24.0000	32100.0000	121.0000	9440.0000	1525.0000	0.2700	289.0000	737.0000	217.0000	6340.0000	0.0860	0.1830	0.1800	0.2770	20930.0000	1.5000	287.0000
MUD	19970407	7.3700	24.1000	34800.0000	123.0000	12080.0000	1711.0000	0.3470	307.0000	760.0000	249.0000	6670.0000	0.0610	0.1350	-0.0100	0.0180	21943.0000	-0.5000	184.0000
BLUE RUN	19950117		21.3000	6520.0000	165.0000	1865.0000	270.0000	0.1430	100.0000	130.0000	37.0000	957.0000	-0.0100	0.1690	0.0400	0.0290	3440.0000	8.6200	193.0000
BLUE RUN	19950405	7.3400	22.3000	7940.0000	165.0000	2249.0000	329.0000	0.1660	118.0000	164.0000	46.0000	1316.0000	0.0100	0.2560	0.0100	0.0190	4704.0000	1.3800	38.0000
BLUE RUN	19950731	7.3400	24.4000	9870.0000	159.0000	3134.0000	507.0000	0.1800	128.0000	195.0000	62.0000	1694.0000	0.3500	0.2970	-0.0100	0.0500	5384.0000	1.3300	52.0000
BLUE RUN	19951023	7.2800	23.4000	6800.0000	166.0000	1892.0000	288.0000	0.1900	113.0000	146.0000	45.0000	1147.0000	0.0200	0.2480	0.0120	0.0180	3636.0000	6.9600	208.0000
BLUE RUN	19960207	7.2600	21.4000	5700.0000	166.0000	1560.0000	230.0000	0.1600	108.0000	116.0000	38.0000	896.0000	0.0210		0.0240	0.0190	3030.0000	4.1000	116.0000
BLUE RUN	19960422	7.3500	23.8000	6950.0000	164.0000	2014.0000	285.0000	0.1600	105.0000	136.0000	43.0000	1080.0000	-0.0100	0.2720	-0.0100	0.0170	3803.0000	1.7100	84.0000
BLUE RUN	19960717	7.3700	23.4000	6840.0000	168.0000	1956.0000	294.0000	0.1880	107.0000	140.0000	41.0000	1121.0000	0.0390	0.2520	0.0130	-0.0100	3812.0000	3.1200	140.0000
BLUE RUN	19961016	7.2700	23.3000	8160.0000	172.0000	2751.0000	353.0000	0.1510	115.0000	166.0000	51.0000	1252.0000	-0.0100	0.2680	0.0500	0.0480	4602.0000	4.0600	61.0000
BLUE RUN	19970127	7.3600	23.1000	7250.0000	167.0000	2210.0000	308.0000	0.1600	103.0000	143.0000	41.0000	1167.0000	-0.0100	0.2630	0.0210	0.0260	4137.0000	1.3900	44.0000
BLUE RUN	19970422	7.3300	23.2000	11640.0000	165.0000	3706.0000	539.0000	0.2060	135.0000	235.0000	74.0000	2002.0000	0.0280	0.3070		0.0390	6784.0000	0.7700	68.0000
BETTY JAY	19950117	6.9200	22.3000	426.0000	157.0000	32.0000	10.0000	0.1250	56.0000	11.0000	0.6000	17.0000	-0.0100	0.1960	0.0480	0.0280	264.0000	8.0000	38.0000
BETTY JAY	19950405	7.4300	22.8000	636.0000	167.0000	81.0000	17.0000	0.1360	60.0000	15.0000	1.2000	47.0000	0.0100	0.2870	0.0100	0.0110	333.0000	0.9500	30.0000
BETTY JAY	19950731	7.4100	23.5000	944.0000	167.0000		31.0000	0.1600	60.0000	19.0000	3.3000	94.0000	0.0300	0.3000	0.0210	0.0310	499.0000	0.9600	-30.0000
BETTY JAY	19951023	7.3300	23.2000	465.0000	168.0000	37.0000	9.6000	0.1700	63.0000	12.0000	0.6000	20.0000	-0.0100	0.2260	-0.0100	0.0130	263.0000	8.9600	71.0000
BETTY JAY	19960207	7.3300	21.4000	417.0000	168.0000	25.0000	8.4000	0.1400	57.0000	10.0000	0.4000	14.0000	-0.0100		-0.0100	0.0250	249.0000	4.5300	59.0000
BETTY JAY	19960422	7.4200	23.2000	473.0000	172.0000	38.0000	11.0000	0.1500	59.0000	12.0000	0.7000	21.0000	0.0110	0.2890	0.0130	0.0130	345.0000	1.6900	37.0000
BETTY JAY	19960717	7.3700	24.9000	430.0000	170.0000	29.0000	11.0000	0.1990	71.7000	11.8100	0.7000	17.0000	0.0340	0.2400	-0.0100	-0.0100	281.0000	8.2300	35.0000
BETTY JAY	19961016	7.3200	23.2000	512.0000	174.0000	53.0000	13.0000	0.1310	58.0000	13.0000	1.0000	28.0000	0.0200	0.2800	0.0430	0.0460	296.0000	3.2300	-30.0000
BETTY JAY	19970127	7.4700	22.9000	765.0000	167.0000	130.0000	24.0000	0.1400	58.0000	18.0000	2.2000	67.0000	-0.0100	0.2930	0.0160	0.0320	434.0000	0.7400	-30.0000
BETTY JAY	19970422	7.3700	23.4000	1398.0000	165.0000	311.0000	52.0000	0.1770	62.0000	28.0000	6.0000	164.0000	-0.0100	0.3340	-0.0100	0.0390	752.0000	0.6600	-30.0000
BAIRD	19941025	7.4400	23.6000	10700.0000	159.0000	3480.0000	480.0000	0.1600	132.0000	219.0000	68.0000	1990.0000	-0.0100	0.1960	0.0150	0.0260	6247.0000	0.5000	-30.0000
BAIRD	19950117	7.4600	22.9000	11240.0000	150.0000	3455.0000	488.0000	0.1390	133.0000	227.0000	64.0000	1920.0000	-0.0100	0.2030	0.0320	0.0210	6392.0000	0.6900	-30.0000

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umos	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
BAIRD	19960208	7.4100	23.8000	11700.0000	146.0000	3586.0000	523.0000	0.1600	161.0000	264.0000	82.0000	2072.0000	0.0270	0.2050	0.0170	0.0240	6565.0000	0.8300	71.0000
BAIRD	19970128	7.4100	23.4000	12230.0000	149.0000	3673.0000	538.0000	0.1700	130.0000	238.0000	74.0000	2100.0000	-0.0100	0.2040	0.0110	0.0250	7020.0000	0.9000	91.0000
BAIRD	19970408	7.4900	23.2000	11520.0000	157.0000	3914.0000	541.0000	0.2200	123.0000	232.0000	73.0000	2000.0000	0.0120	0.2200	0.0230	0.0170	6740.0000		104.0000
CHASSAHOWITZKA MAIN	19941026	7.4300	23.6000	1205.0000	132.0000	258.0000	43.0000	0.1300	51.0000	23.0000	5.0000	144.0000	-0.0100	0.4220	0.0200	0.9870	631.0000	1.0000	45.0000
CHASSAHOWITZKA MAIN	19950117	7.6900	22.8000	1163.0000	139.0000	240.0000	40.0000	0.1090	52.0000	13.0000	4.7000	138.0000	-0.0100	0.3780	0.0370	0.0640	641.0000	1.3100	-30.0000
CHASSAHOWITZKA MAIN	19950406	7.5800	23.8000	1832.0000	142.0000	432.0000	69.0000	0.1270	59.0000	34.0000	8.4000	250.0000	0.0100	0.4410	0.0100	0.0590	956.0000	-0.5000	30.0000
CHASSAHOWITZKA MAIN	19950726	7.5400	24.4000	2530.0000	143.0000	656.0000	101.0000	0.1200	61.0000	44.0000	12.0000	349.0000	-0.0100	0.3800	-0.0100	-0.0100	1320.0000	-0.5000	-30.0000
CHASSAHOWITZKA MAIN	19951023	7.4400	23.4000	902.0000	140.0000	174.0000	31.0000	0.1400	62.0000	19.0000	3.4000	93.0000	-0.0100	0.4380	0.0290	0.0440	458.0000	-0.5000	39.0000
CHASSAHOWITZKA MAIN	19960208	7.5600	24.0000	923.0000	139.0000	181.0000	31.0000	0.1300	53.0000	20.0000	4.0000	103.0000	0.0390		0.0220	0.0230	476.0000	-0.5000	53.0000
CHASSAHOWITZKA MAIN	19960416	7.5900	23.2000	1030.0000	142.0000	207.0000	35.0000	0.1300	54.0000	23.0000	4.5000	120.0000	0.0140	0.4380	0.0220	0.0380	546.0000	-0.5000	49.0000
CHASSAHOWITZKA MAIN	19960717	7.5800	24.2000	1424.0000	142.0000	322.0000	52.0000	0.1690	66.0900	32.1200	7.5000	186.0000	0.0390	0.3800	-0.0100	-0.0100	785.0000	-0.5000	-30.0000
CHASSAHOWITZKA MAIN	19961016	7.6100	23.6000	1828.0000	142.0000	413.0000	61.0000	0.1120	68.0000	36.0000	9.3000	248.0000	0.0310	0.3590	0.0350	0.0450	996.0000	0.5200	42.0000
CHASSAHOWITZKA MAIN	19970128	7.5800	23.7000	2430.0000	139.0000	747.0000	109.0000	0.1400	60.0000	47.0000	12.0000	344.0000	-0.0100	0.4280	0.0220	0.0370	1412.0000	-0.5000	-30.0000
CHASSAHOWITZKA MAIN	19970408	7.5700	23.7000	3760.0000	149.0000	1145.0000	162.0000	0.2020	67.0000	71.0000	21.0000	549.0000		0.4580	0.0240	0.0320	1994.0000		59.0000
CHASSAHOWITZKA #1	19941025	7.3500	23.7000	682.0000	146.0000	105.0000	20.0000	0.1300	51.0000	15.0000	2.0000	57.0000	-0.0100	0.4540	0.0210	0.0370	358.0000	-0.5000	36.0000
CHASSAHOWITZKA #1	19950117	7.6000	23.4000	750.0000	141.0000	127.0000	24.0000	0.1120	53.0000	17.0000	2.4000	70.0000	-0.0100	0.4440	0.0360	0.0220	373.0000	-0.5000	-30.0000
CHASSAHOWITZKA #1	19950406	7.5600	23.8000	755.0000	140.0000	125.0000	25.0000	0.1260	55.0000	16.0000	2.6000	74.0000	0.0100	0.4650	0.0100	0.0140	387.0000	-0.5000	30.0000
CHASSAHOWITZKA #1	19950726	7.6000	23.7000	50.0000	147.0000	179.0000	29.0000	0.1200		17.0000	3.0000	94.0000	0.0400	0.3860	-0.0100	-0.0100	468.0000	-0.5000	-30.0000
CHASSAHOWITZKA #1	19951023	7.6500	23.3000	548.0000	145.0000	69.0000	16.0000	0.1400	52.0000	13.0000	1.3000	39.0000	-0.0100	0.4920	0.0120	0.0230	281.0000	-0.5000	48.0000
CHASSAHOWITZKA #1	19960208	7.6000	23.5000	497.0000	142.0000	60.0000	14.0000	0.1300	50.0000	12.0000	1.3000	34.0000	0.0300		0.0290	0.0220	270.0000	-0.5000	33.0000
CHASSAHOWITZKA #1	19960416	7.6300	22.9000	594.0000	144.0000	85.0000	17.0000	0.1300	51.0000	14.0000	1.8000	49.0000	-0.0100	0.4790	0.0230	0.0230	349.0000	-0.5000	-30.0000
CHASSAHOWITZKA #1	19960717	7.5500	23.9000	702.0000	146.0000	119.0000	22.0000	0.1670	63.4700	16.4800	2.6000	64.6000	0.0190	0.4920	-0.0100	-0.0100	408.0000	-0.5000	-30.0000
CHASSAHOWITZKA #1	19961016	7.6700	24.2000	714.0000	148.0000	114.0000	20.0000	0.1120	50.0000	16.0000	2.5000	66.0000	-0.0100	0.4580	-0.0100	0.0180	371.0000	-0.5000	-30.0000
CHASSAHOWITZKA #1	19970128	7.8100	23.5000	936.0000	153.0000	191.0000	34.0000	0.1400	50.0000	19.0000	3.3000	98.0000	-0.0100	0.4790	0.0220	0.0300	503.0000	0.5200	63.0000
CHASSAHOWITZKA #1	19970408	7.5800	23.2000	1395.0000	146.0000	340.0000	55.0000	0.1940	53.0000	28.0000	6.4000	171.0000		0.4810	0.0150	0.0390	752.0000		32.0000
CRAB	19941025	7.6500	23.7000	4780.0000	137.0000	1336.0000	195.0000	0.1500	82.0000	92.0000	27.0000	760.0000	-0.0100	0.4540	0.0170	0.0330	2626.0000	-0.5000	60.0000
CRAB	19950117	7.5400	23.6000	4830.0000	142.0000	1365.0000	200.0000	0.1280	83.0000	97.0000	28.0000	751.0000	-0.0100	0.4470	0.0360	0.0300	2530.0000	-0.5000	44.0000
CRAB	19960208	7.6400	23.1000	3840.0000	144.0000	1114.0000	158.0000	0.1400	83.0000	86.0000	25.0000	618.0000	0.0160	0.4970	0.0210	0.0250	2136.0000	0.5100	39.0000
CRAB	19970128	7.5000	23.7000	5690.0000	143.0000	1752.0000	252.0000	0.1600	84.0000	109.0000	35.0000	894.0000	-0.0100	0.4620	0.0140	0.0310	3183.0000	0.6800	64.0000
CRAB	19970408	7.4400	23.5000	7330.0000	179.0000	2288.0000	331.0000	0.2050	93.0000	144.0000	44.0000	1188.0000	0.0160	0.4570	0.0270	0.0370	4056.0000		78.0000
POTTERS CREEK	19941025	7.1800	23.3000	10280.0000	152.0000	3150.0000	452.0000	0.1500	120.0000	195.0000	65.0000	1740.0000	0.0300	0.3580	0.0220	0.0410	5649.0000	2.0800	274.0000
POTTERS CREEK	19950117	7.3300	22.0000	9260.0000	154.0000	2830.0000	401.0000	0.1230	130.0000	187.0000	54.0000	1535.0000	0.0100	0.3070	0.0470	0.0480		3.9000	305.0000
RUTH	19941025	7.5300	23.3000	2360.0000	152.0000	595.0000	89.0000	0.1300	59.0000	42.0000	11.0000	315.0000	-0.0100	0.4280	0.0230	0.0400	1238.0000	1.8100	34.0000
RUTH	19950117	7.4700	21.2000	1849.0000	144.0000	435.0000	68.0000	0.1050	60.0000	37.0000	8.4000	251.0000	0.0100	0.3890	0.0390	0.0280		4.3900	40.0000
RUTH	19950406	7.4200	22.9000	2630.0000	143.0000	658.0000	104.0000	0.1230	63.0000	47.0000	12.0000	383.0000	0.0100	0.4360	0.0100	0.0140	1368.0000	1.4800	30.0000
RUTH	19960208	7.4700	22.3000	1761.0000	154.0000	431.0000	67.0000	0.1200	68.0000	39.0000	9.4000	249.0000	-0.0100	0.4220	0.0230	0.0200	963.0000	1.6300	86.0000
RUTH	19970128	7.5000	22.9000	2250.0000	137.0000	607.0000	89.0000	0.1400	58.0000	43.0000	11.0000	321.0000	-0.0100	0.5030	0.0190	0.0340	1215.0000	0.9400	30.0000
RUTH	19970408	7.4900	22.9000	7010.0000	145.0000	2190.0000	316.0000	0.1980	91.0000	139.0000	42.0000	1117.0000		0.4610	0.0200	0.0480	3938.0000		67.0000
HIDDEN RIVER HEAD	19940726	7.9700	25.0000	2000.0000	121.0000	500.0000	74.0000	0.1200	59.0000	37.0000	8.6000	282.0000	0.0100	0.6600	-0.0100	0.0200	1080.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19941027	7.6900	23.4000	2060.0000	123.0000	515.0000	77.0000	0.1250	53.0000	37.0000	9.2000	275.0000	-0.0100	0.5290	0.0360	0.0320	1032.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19950123	7.7400	23.1000	1658.0000	120.0000	395.0000	63.0000	0.0770	51.0000	32.0000	8.4000	230.0000	-0.0100		0.0420	0.0420	839.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19950330	7.7300	23.6000	1453.0000	119.0000	343.0000	52.0000	0.1010	47.0000	29.0000	7.3000	199.0000	0.0200	0.4910	0.0170	0.0900	745.0000	-0.5000	30.0000
HIDDEN RIVER HEAD	19950724	8.0100	23.6000	1651.0000	120.0000	414.0000	62.0000	0.0900	53.0000	34.0000	8.6000	241.0000	0.1400	0.5300	0.0270	0.0260	868.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19951017	7.7000	23.6000	1607.0000	117.0000	386.0000	61.0000	0.1100	55.0000	34.0000	9.2000	235.0000	0.0100	0.5360	0.0160	0.0230	836.0000	0.5800	-30.0000
HIDDEN RIVER HEAD	19960131		23.3000	1283.0000		274.0000	46.0000	0.1100	41.0000	26.0000	6.8000	168.0000	0.2050		0.0260	0.0250	658.0000	-0.5000	70.0000

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umcs	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
HIDDEN RIVER HEAD	19960415	7.7900	23.4000	1120.0000	118.0000	232.0000	40.0000	0.1100	41.0000	25.0000	6.3000	145.0000	-0.0100	0.5810	0.0240	0.0200	578.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19960711	7.5200	23.2000	1078.0000	120.0000	237.0000	39.0000	0.1470	46.9000	23.7600	6.9000	140.0000	-0.0100	0.6060	-0.0100	-0.0100	585.0000	-0.5000	-30.0000
HIDDEN RIVER HEAD	19961028	7.8200	23.6000	1027.0000	118.0000	232.0000	37.0000	0.0840	40.0000	22.0000	5.1000	129.0000	-0.0100	0.5870	0.0840	0.0900	542.0000	0.5000	-30.0000
HIDDEN RIVER HEAD	19970123	7.7000	23.5000	1174.0000	117.0000	268.0000	44.0000	0.1200	42.0000	25.0000	5.4000	149.0000	-0.0100	0.5670	0.0300	0.0270	645.0000	0.5100	33.0000
HIDDEN RIVER HEAD	19970409	7.7000	23.7000	1285.0000	121.0000	302.0000	50.0000	0.1670	42.0000	26.0000	6.1000	161.0000		0.6000	0.0240	0.0280	338.0000		
HIDDEN RIVER #2	19940726	7.9200	24.8000	2740.0000	123.0000	725.0000	107.0000	0.1400	63.0000	51.0000	13.0000	392.0000	0.0100	0.6200	0.0200	0.0300	1419.0000	0.5900	-30.0000
HIDDEN RIVER #2	19941027	7.6500	23.3000	3030.0000	125.0000	810.0000	117.0000	0.1240	64.0000	53.0000	15.0000	460.0000	0.0100	0.5250	0.0360	0.0380	1550.0000	-0.5000	-30.0000
HIDDEN RIVER #2	19950123	7.7300	22.8000	2390.0000	121.0000	625.0000	92.0000	0.0830	59.0000	46.0000	12.0000	346.0000	-0.0100	0.4570	0.0410	0.0440	1228.0000	-0.5000	-30.0000
HIDDEN RIVER #2	19950330	7.7300	23.5000	2250.0000	123.0000	689.0000	86.0000	0.1020	55.0000	42.0000	12.0000	331.0000	0.0300	0.4800	0.0260	0.0310	1102.0000	-0.5000	30.0000
HIDDEN RIVER #2	19950724	7.8100	23.4000	2610.0000	118.0000	677.0000	95.0000	0.0900	63.0000	53.0000	14.0000	413.0000	-0.0100	0.5210	0.0280	0.0270	1332.0000	-0.5000	-30.0000
HIDDEN RIVER #2	19951017	7.7100	23.5000	2720.0000	119.0000	711.0000	107.0000	0.1000	69.0000	55.0000	17.0000	435.0000	-0.0100	0.5090	0.0150	0.0240	1375.0000	-0.5000	40.0000
HIDDEN RIVER #2	19960131		23.3000	2040.0000	120.0000	500.0000	78.0000	0.1200	50.0000	41.0000	11.0000	296.0000	0.0900		0.0290	0.0260	1058.0000	-0.5000	104.0000
HIDDEN RIVER #2	19960415	7.7900	24.1000	1710.0000	120.0000	388.0000	65.0000	0.1100	46.0000	36.0000	9.8000	248.0000	0.1840	0.5780	0.0280	0.1380	885.0000	0.5200	-30.0000
HIDDEN RIVER #2	19960711	7.5300	23.3000	1577.0000	124.0000	319.0000	54.0000	0.1400	52.0000	30.6700	8.2000	193.0000	-0.0100	0.4990	0.0380	0.0350	767.0000	1.5900	-30.0000
HIDDEN RIVER #2	19961028	7.8200	23.6000	1468.0000	128.0000	358.0000	55.0000	0.0770	43.0000	30.0000	7.7000	201.0000	0.0160	0.5870	0.0710	0.0800	776.0000	0.5300	-30.0000
HIDDEN RIVER #2	19970123	7.8100	22.9000	1568.0000	119.0000	361.0000	62.0000	0.1100	46.0000	32.0000	7.8000	216.0000	-0.0100	0.4210	0.0290	0.0240	832.0000	0.5000	53.0000
HIDDEN RIVER #2	19970409	7.6600	23.6000	1946.0000	119.0000	483.0000	79.0000	0.1560	47.0000	38.0000	9.8000	262.0000		0.5970	0.0190	0.0350	1032.0000		
HOMOSASSA RIVER #1	19941026	7.7400	23.1000	4230.0000	111.0000	1460.0000	175.0000	0.1540	68.0000	84.0000	24.0000	635.0000	-0.0100	0.4220	0.0330	0.0330	2090.0000	-0.5000	-30.0000
HOMOSASSA RIVER #1	19950119	6.8000	23.0000	4090.0000	130.0000	1210.0000	166.0000	0.1090	75.0000	83.0000	23.0000	655.0000	-0.0100	0.3510	0.0460	0.0380	2172.0000	1.5900	-30.0000
HOMOSASSA #1	19941026	7.7100	23.5000	3920.0000	110.0000	1060.0000	155.0000	0.1380	57.0000	72.0000	21.0000	590.0000	-0.0100	0.4230	0.0290	0.0330	2090.0000	-0.5000	84.0000
HOMOSASSA #1	19950119	7.5300	23.4000	2830.0000	107.0000	735.0000	109.0000	0.1070	55.0000	59.0000	15.0000	434.0000	-0.0100	0.4130	0.0400	0.0420	1441.0000	-0.5000	54.0000
HOMOSASSA #1	19950405	7.5500	23.4000	3430.0000	106.0000	898.0000	138.0000	0.1140	58.0000	61.0000	17.0000	524.0000	0.0200	0.4180	0.0110	0.0240	1729.0000	-0.5000	70.0000
HOMOSASSA #1	19950726	7.6500	23.3000	3170.0000	110.0000	834.0000	121.0000	0.1000	55.0000	55.0000	16.0000	452.0000	0.0600	0.4310	0.0220	0.0240	1571.0000	0.7200	56.0000
HOMOSASSA #1	19951024	7.6200	23.5000	3520.0000	106.0000	1020.0000	139.0000	0.1300	63.0000	70.0000	21.0000	540.0000	-0.0100	0.4350	0.0100	0.0100	1798.0000	-0.5000	35.0000
HOMOSASSA #1	19960205	7.7900	22.1000	3160.0000	106.0000	831.0000	129.0000	0.1100	61.0000	67.0000	18.0000	468.0000	-0.0100		0.0240	0.0160	1691.0000	1.0600	70.0000
HOMOSASSA #1	19960417	7.7000	23.3000	3060.0000	108.0000	820.0000	121.0000	0.1200	57.0000	62.0000	18.0000	462.0000	0.0110	0.4500	0.0120	0.0210	1645.0000	-0.5000	66.0000
HOMOSASSA #1	19960716	7.7100	23.8000	3020.0000	108.0000	832.0000	120.0000	0.1500	123.0000	60.9500	18.0000	442.0000	-0.0100	0.4190	-0.0100	-0.0100	1570.0000	-0.5000	59.0000
HOMOSASSA #1	19961014	7.6900	23.4000	2620.0000	109.0000	692.0000	104.0000	0.1140	51.0000	49.0000	14.0000	377.0000	-0.0100	0.4510	0.0670	0.0680	1359.0000	0.5200	58.0000
HOMOSASSA #1	19970130	7.6700	23.1000	3470.0000	105.0000	792.0000	112.0000	0.1100	64.0000	63.0000	18.0000	494.0000	0.0120	0.4050	0.0140	-0.0100	1844.0000	-0.5000	153.0000
HOMOSASSA #1	19970410	6.8400	23.6000	3500.0000	115.0000	978.0000	134.0000	0.1730	54.0000	67.0000	19.0000	509.0000	0.0400	0.4430	0.0330	0.0380	1929.0000		89.0000
HOMOSASSA #2	19941026	7.6300	23.5000	6220.0000	114.0000	1790.0000	270.0000	0.1570	79.0000	109.0000	34.0000	1000.0000	-0.0100	0.4180	0.0330	0.0420	3390.0000	0.5000	166.0000
HOMOSASSA #2	19950119	6.5400	23.3000	5400.0000	109.0000	1580.0000	226.0000	0.1190	79.0000	114.0000	33.0000	882.0000	-0.0100	0.3920	0.0370	0.0440	2888.0000	-0.5000	127.0000
HOMOSASSA #2	19950405	7.4700	23.3000	5920.0000	120.0000	1634.0000	248.0000	0.1280	83.0000	116.0000	34.0000	972.0000	0.0400	0.3950	0.0100	0.0190	3266.0000	-0.5000	125.0000
HOMOSASSA #2	19950725	7.7800	23.4000	5380.0000	110.0000	1499.0000	224.0000	0.1100	73.0000	96.0000	30.0000	812.0000	0.0200	0.4110	0.0220	0.0220	2769.0000	0.8800	75.0000
HOMOSASSA #2	19951024	7.6100	23.7000	5860.0000	89.0000	1668.0000	251.0000	0.1400	85.0000	116.0000	38.0000	1004.0000	0.0400	0.4220	0.0100	0.0240	3068.0000	0.7700	179.0000
HOMOSASSA #2	19960205	7.7400	22.8000	6430.0000	109.0000	1839.0000	270.0000	0.1300	75.0000	127.0000	24.0000	1062.0000	0.0610		0.0210	0.0240	3594.0000	-0.5000	174.0000
HOMOSASSA #2	19960417	7.6000	23.3000	5900.0000	111.0000	1678.0000	246.0000	0.1300	82.0000	123.0000	38.0000	971.0000	0.0320	0.4240	0.0120	0.0180	3299.0000	-0.5000	182.0000
HOMOSASSA #2	19960716	7.5700	23.9000	5410.0000	108.0000	1430.0000	223.0000	0.1610	98.0000	107.1000	35.0000	886.0000	0.0490	0.4130	-0.0100	-0.0100	3060.0000	0.5000	113.0000
HOMOSASSA #2	19961014	7.6900	23.6000	4850.0000	111.0000	1433.0000	200.0000	0.1180	69.0000	95.0000	29.0000	767.0000	0.0350	0.4530	0.0700	0.0730	2655.0000	0.7000	105.0000
HOMOSASSA #2	19970130	7.6100	23.2000	5830.0000	109.0000	1418.0000	205.0000	0.1400	72.0000	110.0000	33.0000	902.0000	0.0320	0.4160	0.0110	-0.0100	3146.0000	0.5600	164.0000
HOMOSASSA #2	19970410	7.5800	23.6000	5430.0000	115.0000	1565.0000	221.0000	0.1800	69.0000	101.0000	32.0000	830.0000	0.0570	0.4190	0.0340	0.0320	2900.0000		94.0000
HOMOSASSA #3	19941026	7.8200	23.4000	1711.0000	105.0000	424.0000	86.0000	0.1360	43.0000	32.0000	8.1000	253.0000	-0.0100	0.4270	0.0340	0.0270	895.0000	-0.5000	-30.0000
HOMOSASSA #3	19950119	7.1700	23.4000	1079.0000	104.0000	255.0000	39.0000	0.0980	44.0000	23.0000	5.0000	140.0000	-0.0100	0.4210	0.0340	0.0480	562.0000	0.7500	-30.0000
HOMOSASSA #3	19950405	7.7800	23.0000	1589.0000	100.0000	371.0000	63.0000	0.1080	46.0000	30.0000	7.5000	212.0000	0.0600	0.4360	0.0100	0.0190	822.0000	0.8200	30.0000
HOMOSASSA #3	19950725	7.7300	23.3000	1653.0000	106.0000	397.0000	62.0000	0.1000	44.0000	29.0000	7.7000	231.0000	0.0400	0.4500	0.0240	0.0250	841.0000	0.7800	-30.0000
HOMOSASSA #3	19951024	7.7500	23.6000	1484.0000	103.0000	362.0000	58.0000	0.1200	47.0000	30.0000	8.3000	203.0000	-0.0100	0.4720	0.0100	0.0160	750.0000	-0.5000	-30.0000
HOMOSASSA #3	19960205	7.6900	22.1000	932.0000	103.0000	192.0000	33.0000	0.1000	38.0000	18.0000	4.1000	113.0000	0.0220		0.0170	0.0100	482.0000	-0.5000	49.0000

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umos	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
HOMOSASSA #3	19960417	7.7200	23.3000	1000.0000	104.0000	216.0000	36.0000	0.1000	41.0000	22.0000	4.7000	125.0000	-0.0100	0.4540	0.0160	0.0140	516.0000	-0.5000	53.0000
HOMOSASSA #3	19960716	7.8300	23.7000	1240.0000	108.0000	282.0000	45.0000	0.1400	41.0000	24.0000	5.7000	155.0000	0.0190	0.4350	-0.0100	-0.0100	653.0000	-0.5000	33.0000
HOMOSASSA #3	19961014	7.8000	23.4000	109.0000	111.0000	208.0000	33.0000	0.1030	39.0000	19.0000	4.1000		-0.0100	0.4810	0.0690	0.0780	495.0000	-0.5000	-30.0000
HOMOSASSA #3	19970130	7.6400	23.1000	1554.0000	103.0000	344.0000	56.0000	0.1200	42.0000	29.0000	7.5000	188.0000	-0.0100	0.4010	0.0110	-0.0100	816.0000	-0.5000	36.0000
HOMOSASSA #3	19970410	7.7100	23.6000	1558.0000	105.0000	357.0000	65.0000	0.1650	41.0000	30.0000	7.5000	207.0000		0.4610	0.0330	0.0450	822.0000		
TROTTER MAIN	19931101	7.6500	22.6000	597.0000		103.0000	19.0000	0.0900	45.0000	12.0000	1.8000	56.0000	0.0100		0.0200	0.0200	370.0000	3.1100	-30.0000
TROTTER MAIN	19940808	7.6500	25.2000	497.0000	111.0000	28.0000	43.0000	0.1100	40.0000	11.0000	1.3000	41.0000	0.0100	0.5000	0.0200	0.0300	269.0000		-30.0000
TROTTER MAIN	19941026	7.7100	23.4000	455.0000	111.0000	60.0000	13.0000	0.1200	37.0000	9.8000	1.2000	33.0000	0.0100	0.4470	0.0240	0.0300	244.0000	-0.5000	-30.0000
TROTTER MAIN	19950119	7.7400	22.8000	458.0000	114.0000	63.0000	13.0000	0.0850	42.0000	11.0000	1.2000	37.0000	0.0100	0.4010	0.0360	0.0400	243.0000	-0.5000	-30.0000
TROTTER MAIN	19950405	7.3800	21.7000	410.0000	110.0000	59.0000	13.0000	0.0950	43.0000	10.0000	1.2000	35.0000	0.0100	0.4290	0.0120	0.0190	240.0000	-0.5000	30.0000
TROTTER MAIN	19950725	7.7600	23.7000	447.0000	114.0000	63.0000	11.0000	0.0900	38.0000	8.9000	1.0000	35.0000	-0.0100	0.4630	0.0250	0.0270	254.0000	-0.5000	-30.0000
TROTTER MAIN	19951024	7.6800	23.8000	329.0000	112.0000	50.0000	11.0000	0.1000	40.0000	9.5000	1.0000	28.0000	-0.0100	0.4730	0.0100	0.0200	208.0000	-0.5000	-30.0000
TROTTER MAIN	19960205	7.6500	21.1000	396.0000	114.0000	47.0000	11.0000	0.0900	39.0000	8.7000	1.0000	26.0000	0.0180		0.0170	0.0110	218.0000	-0.6000	-30.0000
TROTTER MAIN	19960417	7.7600	24.4000	385.0000	112.0000	43.0000	9.7000	0.1000	40.0000	9.1000	0.9000	25.0000	0.0210	0.4490	0.0200	0.0190	227.0000	-0.6000	-30.0000
TROTTER MAIN	19960716	7.7500	24.1000	371.0000	114.0000	43.0000	10.0000	0.1220	48.3400	9.1300	0.9000	24.5000	-0.0100	0.4430	0.0100	-0.0100	226.0000	0.8100	-30.0000
TROTTER MAIN	19961014	7.7300	23.6000	377.0000	113.0000	43.0000	9.7000	0.0910	37.0000	8.8000	0.9000	23.0000	-0.0100	0.4770	0.0600	0.0730	209.0000	0.6900	-30.0000
TROTTER MAIN	19970130	7.7900	21.4000	415.0000	109.0000	44.0000	8.7000		37.0000	9.2000	1.0000	28.0000	-0.0100	0.4570	0.0200	0.0180	238.0000	-0.5000	-30.0000
TROTTER MAIN	19970410	7.7800	23.8000	447.0000	111.0000	60.0000	12.0000	0.1540	36.0000	9.9000	1.2000	34.0000	0.0280	0.4620	0.0300	0.0230	248.0000	-0.5000	118.0000
TROTTER #1	19940808	7.9200	25.3000	495.0000	110.0000	35.0000	55.0000	0.1100	38.0000	10.0000	1.3000	41.0000	0.0100	0.4700	0.0200	0.0300	257.0000	-0.5000	-30.0000
TROTTER #1	19941026	7.7000	23.2000	441.0000	111.0000	58.0000	12.0000	0.1210	36.0000	9.1000	1.0000	31.0000	0.0100	0.4490	0.0240	0.0270	226.0000	-0.5000	-30.0000
TROTTER #1	19950119	7.7400	22.8000	451.0000	109.0000	62.0000	13.0000	0.0870	42.0000	10.0000	1.2000	35.0000	0.0100	0.3920	0.0350	0.0440	244.0000	-0.5000	-30.0000
McCLAIN	19940808	7.7100	24.3000	613.0000	118.0000	105.0000	19.0000	0.1000	44.0000	12.0000	1.6000	57.0000	-0.0100	0.3700	-0.0100	0.0200	313.0000	-0.5000	36.0000
McCLAIN	19941026	7.6700	23.9000	533.0000	118.0000	76.0000	14.0000	0.1120	42.0000	11.0000	1.2000	42.0000	-0.0100	0.3720	0.0300	0.0300	271.0000	0.8500	-30.0000
McCLAIN	19950119	7.6000	21.5000	499.0000	117.0000	80.0000	16.0000	0.0820	48.0000	12.0000	1.4000	45.0000	0.0400	0.3290	0.0290	0.0420	292.0000	1.9500	-30.0000
PUMPHOUSE	19931021	7.7300	24.1000	668.0000		125.0000	21.0000	0.1000	47.0000	14.0000	2.2000	66.0000	-0.0100	0.3800	-0.0100	-0.0100	346.0000	0.6700	-30.0000
PUMPHOUSE	19940725	7.6500	23.5000	667.0000	116.0000	112.0000	19.0000	0.1200	44.0000	13.0000	2.0000	60.0000	-0.0100	0.4200	0.0200	0.0200	343.0000	1.9800	-30.0000
PUMPHOUSE	19941026	7.6800	24.1000	560.0000	119.0000	83.0000	15.0000	0.1130	43.0000	11.0000	1.2000	44.0000	-0.0100	0.3810	0.0330	0.0280	285.0000	1.0300	-30.0000
PUMPHOUSE	19950119	7.5100	21.0000	508.0000	120.0000	83.0000	15.0000	0.0820	46.0000	11.0000	1.4000	48.0000	0.0100	0.3270	0.0310	0.0400	295.0000	1.8900	-30.0000
PUMPHOUSE	19950405	7.7800	22.3000	554.0000	118.0000	84.0000	17.0000	0.0880	47.0000	12.0000	1.5000	49.0000	0.0100	0.3760	0.0100	0.0190	333.0000	-0.5000	30.0000
PUMPHOUSE	19950725	7.6300	24.6000	627.0000	116.0000	82.0000	13.0000	0.0800	41.0000	9.9000	1.2000	45.0000	-0.0100	0.3750	0.0220	0.0220	287.0000	0.8100	-30.0000
PUMPHOUSE	19951024	7.5600	23.1000	361.0000	119.0000	64.0000	13.0000	0.1000	44.0000	10.0000	1.1000	38.0000	-0.0100	0.4060	0.0160	0.0180	251.0000	1.2300	-30.0000
PUMPHOUSE	19960205	7.7300	19.9000	456.0000	120.0000	59.0000	12.0000	0.0900	40.0000	8.8000	1.0000	33.0000	-0.0100		0.0190	0.0280	254.0000	1.0300	66.0000
PUMPHOUSE	19960417	7.6900	21.7000	459.0000	124.0000	58.0000	12.0000	0.0900	44.0000	10.0000	1.2000	36.0000	-0.0100	0.3860	0.0160	0.0190	254.0000	-0.6000	-30.0000
PUMPHOUSE	19960716	7.6000	23.8000	424.0000	122.0000	54.0000	11.0000	0.1200	51.5500	9.8800	1.1000	30.8000	0.1650	0.3740	0.0150	-0.0100	258.0000	1.4400	-30.0000
PUMPHOUSE	19961014	7.6400	22.9000	419.0000	119.0000	53.0000	11.0000	0.0980	40.0000	9.5000	1.0000	29.0000	-0.0100	0.4140	0.0350	0.0630	236.0000	1.0800	-30.0000
PUMPHOUSE	19970130	7.7500	21.2000	468.0000	117.0000	56.0000	11.0000		39.0000	9.9000	1.2000	34.0000	-0.0100	0.4240	0.0240	0.0190	264.0000	-0.5000	-30.0000
PUMPHOUSE	19970410	7.6900	22.8000	514.0000	119.0000	75.0000	14.0000	0.1470	39.0000	11.0000	1.4000	42.0000	0.0350	0.4370	0.0260	0.0480	273.0000	-0.5000	-30.0000
BELCHER	19940808	7.9000	24.1000	485.0000	110.0000	35.0000	55.0000	0.1000	39.0000	11.0000	1.3000	40.0000	-0.0100	0.4400	0.0200	0.0200	261.0000	-0.5000	-30.0000
BELCHER	19941026	7.7300	22.8000	437.0000	109.0000	57.0000	13.0000	0.1130	35.0000	9.4000	1.0000	32.0000	-0.0100	0.4500	0.0240	0.0240	233.0000	-0.5000	31.0000
BELCHER	19950119	7.7700	23.1000	441.0000	109.0000	60.0000	12.0000	0.0860	42.0000	10.0000	1.2000	35.0000	-0.0100	0.4160	0.0330	0.0430	242.0000	-0.5000	-30.0000
ABDONEY	19940808	7.8100	24.3000	563.0000	107.0000	97.0000	18.0000	0.1100	38.0000	12.0000	1.8000	53.0000	-0.0100	0.5100	0.0200	0.0300	297.0000	-0.5000	-30.0000
ABDONEY	19941026	7.8000	24.3000	496.0000	108.0000	68.0000	14.0000	0.1320	34.0000	9.6000	1.3000	36.0000	-0.0100	0.4540	0.0360	0.0300	260.0000	-0.5000	-30.0000
ABDONEY	19950119	7.6500	22.1000	408.0000	107.0000	60.0000	13.0000	0.0900	40.0000	10.0000	1.2000	34.0000	-0.0100	0.4160	0.0320	0.0430	233.0000	-0.5000	-30.0000

SPRING NAME	SAMP_DATE	FIELD_PH std pH units	FIELD_TEMP degrees C	FIELD_COND umos	HCO3_HCO3 mg/l	DIS_CL mg/l	DIS_SO4 mg/l	DIS_F mg/l	DIS_CA mg/l	DIS_MG mg/l	DIS_K mg/l	DIS_NA mg/l	DIS_NH3(N) mg/l	DIS_NO3(N) mg/l	DIS_OPO4 mg/l	TOT_PO4 mg/l	TDS mg/l	TOC mg/l	DIS_FE ug/l
HALLS RIVER HEAD	19961029	7.7200	23.6000	7110.0000	112.0000	2043.0000	289.0000	0.1210	86.0000	138.0000	40.0000	1148.0000	-0.0100	0.3470	0.0330	0.0280	3903.0000	-0.5000	30.0000
HALLS RIVER HEAD	19970130	7.7100	22.7000	8340.0000	115.0000	2112.0000	283.0000		94.0000	162.0000	49.0000	1319.0000	-0.0100	0.3070	0.0250	0.0180	4664.0000	-0.5000	-30.0000
HALLS RIVER HEAD	19970410	7.7300	24.3000	6440.0000	117.0000	1826.0000	268.0000	0.1720	77.0000	128.0000	39.0000	1028.0000	0.0160	0.3060	0.0280	0.0380	3534.0000	-0.5000	45.0000

APPENDIX IV

Data References for Figure 12; Generalized Thickness of the Potable Water Zone in the Floridan Aquifer in the Northern Portion of the Southwest Florida Water Management District

Data Table for Figure 12, Generalized Thickness of the Potable Water Zone in the Floridan Aquifer in the Northern Portion of the Southwest Florida Water Management District.

LON	LAT	SITE	WATER LEVEL (~ ft. bls)	POTABLE DEPTH (ft. bls)	POTABLE THICKNESS (ft)	REFERENCE
823403	285355	ROMP 114	3	229	226	SWFWMD / ROMP corehole data, 1977.
822645	285330	WRWSA Citrus Hills WF. MTW	130	390	260	Atlanta Testing and Engineering, 1989.
821341	285250	ROMP 112	14	339	325	SWFWMD / ROMP qw data, 1989.
820743	284628	ROMP LP-4	10	140	130	SWFWMD / ROMP geophysical data, 1983.
820740	284623	Altman #2	9	200	191	SWFWMD / ROMP geophysical data, 1984.
820904	284309	Jumper Creek JC3	n/a	390 *	390	USGS WRI-OFR 82-331.
820546	284208	Jumper Creek JC19	5	721	716	USGS WRI-OFR 82-331.
823544	285112	ROMP TR 21-2	2	130	128	SWFWMD / ROMP corehole data, 1978.
823419	285234	ROMP TR 21-3	6	270	264	SWFWMD / ROMP corehole data, 1978.
821312	284513	ROMP 110	10.5	168.5	158	SWFWMD / ROMP corehole data, 1989.
823610	285102	Ozello #4	3	60 *	57	SWFWMD, 1996 AGWQMP Citrus Co. report.
823453	284551	Homosassa #3	1	81	80	SWFWMD, 1996 AGWQMP Citrus Co. report.
823303	284457	Sugarmill Woods MZ1-Deep	5	330	325	Geraghty and Miller, 1979.
823402	284244	ROMP TR 20-1	31	282	251	SWFWMD / ROMP corehole data, 1982.
823432	284243	HRS 19A Zolinger	n/a	72 *	72	SWFWMD, 1996 Citrus Co. qw data; SWFWMD, 1995 CGWQMP report.
823038	283959	ROMP 107X 16" well	78	368	290	SWFWMD / ROMP geophysical data, 1983; Geraghty & Miller, 1979.
823657	283243	ROMP TR 19-2	1	277 *	276	SWFWMD / ROMP geophysical data, 1983.
823702	283203	Presb. Youth Camp\ Weeki Wachee	7	66 *	59	SWFWMD, 1996 AGWQMP Hernando Co. report.
823227	283253	WHCWS MW-1 Deep	12	530	518	USGS geophysical data, 1983.
822416	283321	ROMP 105	65	509	444	SWFWMD / ROMP drilling data, 1983.
823911	282659	ROMP TR 18-2	1	524	525	SWFWMD / ROMP geophysical data, 1983.
823953	282553	Whiting Well Deep	n/a	95 *	95	SWFWMD, 1996 Pasco Co. qw data; SWFWMD, 1995 CGWQMP report.
824209	281917	ROMP TR 17-1	5.5	148.5	143	SWFWMD / ROMP corehole data, 1978.
824039	281922	ROMP TR 17-3	27	193	166	SWFWMD / ROMP corehole data, 1978.
823340	281905	North Pasco Wellfield NPMW-2	3	880	877	Geraghty & Miller, 1990; WCRWSA 1992.
822828	282259	Cross Bar Ranch WF. B-1 Deep	10	960	950	Leggatte, Brashears & Graham, 1979; USGS WRI Report 89-4142.
820828	282137	ROMP 90	5	520	515	SWFWMD / ROMP geophysical, drilling data, 1983.
822244	281809	Cypress Cr. WF. E-106 Deep	12	1010 *	997	USGS WRI Report 87-4188.
824243	281518	ROMP TR 16-2	34.5	131.5	97	SWFWMD / ROMP drilling data, 1989.
822300	281743	Cypress Creek WF. CCWQ-1	10	870	860	AT&E / WCRWSA report, 1995.
823953	281310	Aloha Utilities Deep Test Well	9	735	726	Leggatte, Brashears & Graham, 1980 letter report to SWFWMD.
824240	281142	NW HILLS WRAP 3D	7	350	343	CH2M HILL, 1990 SWFWMD report.
824428	281051	Ross Trailer Sales supply well	n/a	69 *	69	USGS WRI Report 87-4188.
823104	281053	St. Pete Pasco WF. E-105 Deep	17	1012 *	995	SWFWMD, 1996 AGWQMP Pasco Co. report.

* well casing dep

n/a data not availat

APPENDIX V

Assumptions and Calculations Used in the Determination of Nitrogen Loading from Pasture Fertilization.

Assumptions and Calculations Used in the Determination of Nitrogen Loading from Pasture Fertilization.

Nitrogen loading from pasture fertilization was determined using the Florida Department of Agriculture and Consumer Services (FDACS) Annual Summary of the Consumption of Fertilizer Materials and Mixtures in Florida Counties (FDACS, 1993). An analysis of data contained in the report indicated that from July, 1992 to June, 1993, farm uses in the study area consumed an estimated 1,732 tons of fertilizer nitrogen. Because the level of detail for fertilizer information in the report was highly variable for each county, numerous assumptions were required to arrive at this value. These assumptions and calculations are explained below.

In Hernando County, 983 tons of single nutrient fertilizer were sold between July, 1992 and June, 1993. Because the composition of the fertilizer was not specified, a nitrogen content of 28% was assumed for 75% of this tonnage (75% of the single-nutrient fertilizers listed on page 7 of FDACS (1993) are nitrogen bearing, and of those nitrogen fertilizers the average nitrogen composition is 28%). Of the 6,101 tons of multinutrient fertilizer sold, 1,042 tons was listed as 16-4-8. The composition of the remaining 5,000 tons was not specified and a nitrogen composition of 11% nitrogen was assumed (11% nitrogen is the average nitrogen composition of the 280 multi-nutrient fertilizers listed on pages 8-13, FDACS (1993). This procedure was repeated where necessary for Pasco and Citrus Counties.

Having calculated the nitrogen tonnage for known and unknown grades of single and multi-nutrient fertilizers, the nitrogen tonnage values were combined to obtain a county-wide nitrogen tonnage. Using GIS land-use data and interpretation of land-use maps, the percentage of farm use in the study area was determined. Assuming a uniform distribution of nitrogen over the land use, the percentage of farm use in the study area was multiplied by the county-wide nitrogen tonnage to get the tonnage of N in the study area. Using GIS land-use data and interpretation of land-use maps, the percentage of farm use in the individual ground-water basins was determined. Assuming a uniform distribution of nitrogen over the land use, the percentage of farm use in the ground-water basin was multiplied by the study area nitrogen tonnage to get the tonnage of N in the ground-water basin.

Because the calculated value of nitrogen (1,732 tons) was that which was contained in all fertilizers dedicated to farm use, not just pasture, the calculated amount of nitrogen contained in fertilizers applied to citrus and row crops (368 tons) had to be subtracted from the total. This resulted in approximately 1,364 tons of nitrogen in fertilizer applied to pasture.