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National Water-Quality Assessment

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U.S. Geological Survey

National Water Quality Assessment Program—Preliminary Assessment of Nitrate Distribution in Ground Water in the Georgia-Florida Coastal Plain Study Unit, 1972-90

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Abstract

The U.S. Geological Survey has implemented the National Water Quality Assessment program to describe the quality of the surface- and ground-water resources in 60 large areas or study units in the Nation. The Georgia-Florida Coastal Plain study unit was 1 of the first 20 selected for study when the full-scale program was implemented in 1991. The study unit has an area of about 54,000 square miles and is located on the southeastern coast of the United States. The primary source of water supply in this study unit is water from the Upper Floridan aquifer of the Floridan aquifer system. The Upper Floridan aquifer is unconfined or semiconfined in some parts of the study unit, but in other parts is confined by the overlying surficial aquifer system and other confining units. The surficial aquifer system is also used for water supply in some parts of the study unit. Three land resource areas have been delineated in the study unit on the basis of generalized soil categories: the Central Florida Ridge, Coastal Flatwoods, and Southern Coastal Plain. Predominant land use and land cover, as classified in the 1970's, are forest, agriculture, wetlands, and urban.

Nitrate data for water from the Upper Floridan aquifer and the surficial aquifer system were obtained from the National Water Information System data base of the U.S. Geological Survey for the years 1972-90. In the Upper Floridan aquifer, the highest median nitrate (as nitrogen) concentrations (0.43 and 0.26 milligrams per liter) were in water samples from wells in agricultural and urban areas where the aquifer was unconfined or semiconfined. The maximum contaminant level for nitrate (as nitrogen) in drinking water of 10 milligrams per liter was exceeded in 25 of the 726 water samples from this aquifer. These 25 samples were from wells in urban areas. In water samples from the surficial aquifer system, the highest median nitrate concentration, 8.7 milligrams per liter, was for water samples from agricultural areas in the Central Florida Ridge. Nitrate (as nitrogen) concentrations exceeded 10 milligrams per liter in 50 of the 421 water samples from wells completed in the surficial aquifer system. Most of these 50 water samples were from wells in agricultural and urban areas (sewage spraying areas) in the Central Florida Ridge.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began implementation of the National Water Quality Assessment (NAWQA) program. The goals of this program are to describe the status and trends in the quality of large, representative parts of the surface- and ground-water resources in large areas of the Nation and to provide a scientific understanding of the natural and human factors that affect the quality of these resources. The NAWQA program is designed to integrate water-quality information at different areal scales and consists of 60 study units nationwide. The study units have been selected to include parts of most of the major river basins and aquifer systems in the Nation. These study units cover areas of 1,200 to more than 50,000 square miles (mi^2) and represent about 60 to 70 percent of the Nation's water use. The Georgia-Florida Coastal Plain study unit was among the first 20 NAWQA study units selected when the full-scale implementation plan was initiated in 1991.

One of the first activities undertaken as part of the NAWQA program was to compile, screen, and analyze available water-quality data for nutrients (nitrogen and phosphorus compounds) in the study units. Nitrogen and phosphorus compounds were selected because these compounds cause eutrophication of surface waters, and because of the possible health risk associated with the nitrogen compound, nitrate, in drinking water. This report provides a preliminary assessment of nitrate concentrations in ground water in the Georgia-Florida Coastal Plain study unit. The assessment is based on data available from the USGS water-quality data base, the National Water Information System (NWIS). Nitrate concentrations in ground water are the focus of this report for several reasons: analytical data are more abundant for nitrate than for other nitrogen or phosphorus compounds, elevated concentrations of nitrate in drinking water poses a possible health risk, and nitrate is the only major nutrient for which a maximum contaminant level (MCL) has been established for drinking water. The MCL for nitrate (as nitrogen) in drinking water is 10 milligrams per liter (mg/L) (U.S. Environmental Protection Agency, 1990). This report briefly describes the relations between nitrate concentrations and hydrogeology, land use, and general soils groups as represented by land resource areas. The report also lists the numbers of samples that have concentrations of nitrate that exceed the drinking-water MCL.

DESCRIPTION OF THE STUDY UNIT

The Georgia-Florida Coastal Plain study unit, an area of about 54,000 mi^2, is located on the southeastern coast of the United States (fig. 1). The study unit has a large population of more than 7 million people that relies primarily on ground water for drinking water. The primary source of water in the study unit is the Floridan aquifer system, which is one of the largest sources of ground-water in the Nation. Surface-water resources are also abundant in the study unit but are not extensively used for drinking water supply. Total freshwater use within the study unit is approximately 4,300 million gallons per day (Mgal/d), with 2,800 Mgal/d withdrawn from ground water (R.M. Marella, U.S. Geological Survey, written commun., 1992). Nearly 95 percent of the ground water used in the study unit is withdrawn from the Upper Floridan aquifer, the uppermost unit of the Floridan aquifer system.

The Floridan aquifer system that underlies the study unit is composed of a sequence of carbonate (limestone and dolomite) rocks that include units of high permeability (aquifers) as well as units of low permeability (confining units). The rocks that compose the aquifer system dip to the southeast and are exposed at land surface in a thin band near the northern boundary of the study unit and in north-central Florida. The aquifer system thickens in a southeasterly direction to a thickness of more than 3,000 feet (ft) in the southern part of the study unit. The Upper Floridan aquifer is considered confined where the thickness of overlying confining units is greater than 100 ft, semiconfined where the overlying confining units are less than 100 ft thick or are breached, and unconfined where the units are virtually absent and the Upper Floridan aquifer is at or near land surface (Miller, 1986). These confining units overlying the Upper Floridan aquifer contain the intermediate aquifer system, also referred to as the Brunswick aquifer in Georgia (fig. 2). The intermediate aquifer system consists of limestone, clay, and sand, and is overlain by the surficial aquifer system. Both of these aquifer systems are used for water supply, but substantially less than the Upper Floridan aquifer. The Claiborne aquifer in Georgia is also used for water supply in localized areas in northern parts of the study unity where it underlies the Upper Floridan aquifer.

The general proportions of land use and land cover in the study unit were determined using data from the USGS geographic information retrieval and analysis system (GIRAS) (Mitchell and others, 1977). This land-use and land-cover classification was done in the mid-1970's on a national scale. The general level of land-use and land-cover classification in the study unit includes forest land, agricultural land, wetland, urban or built-up land, water, rangeland, and barren land (Anderson and others, 1976). The percentages of area in the study unit covered by various land uses and land-cover classification are listed in the following table:

Land-use or land-cover classifications	Percentage of study unit covered
Forest	38
Agricultural	26
Wetland	18
Urban or built-up	7.3
Water	4.6
Rangeland	3.5
Barren	1.6

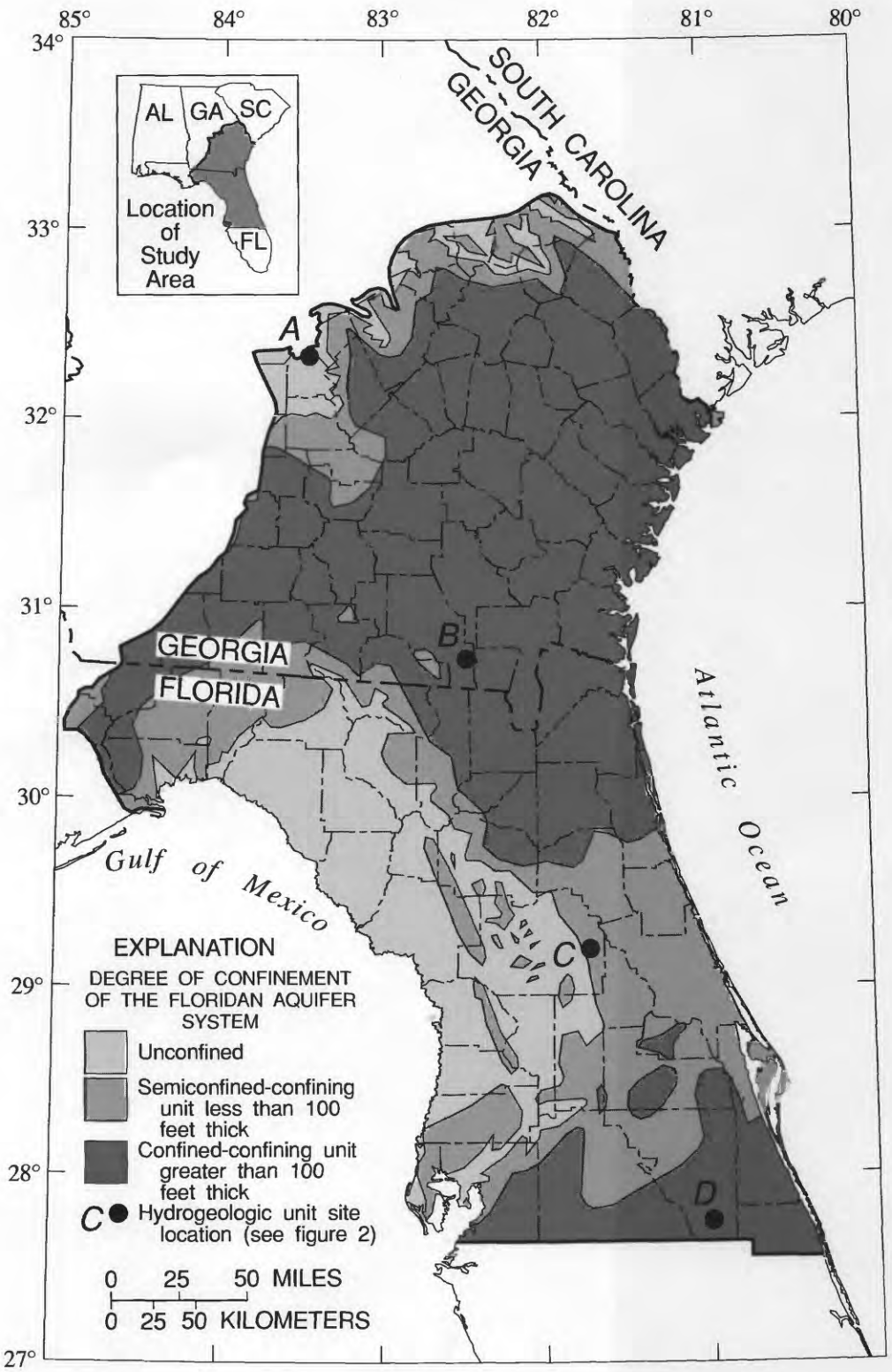

Figure 1. Location of the study unit and of areas of confined, semiconfined, and unconfined conditions for the Upper Floridan aquifer (from Miller, 1986).

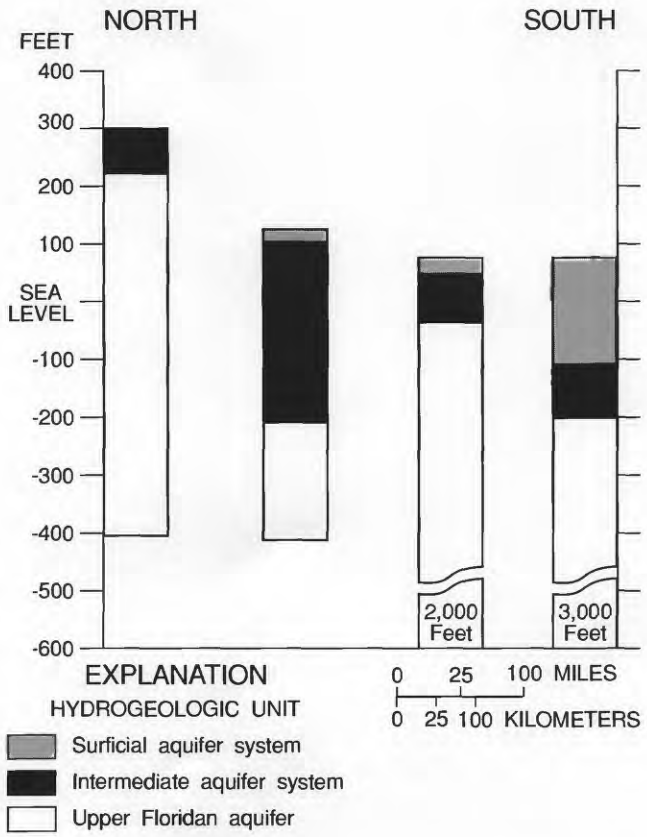

Figure 2. Hydrogeologic units at selected locations in the Georgia-Florida Coastal Plain study unit.

The study unit was subdivided into three land resource areas based on generalized soil maps prepared by the U.S. Department of Agriculture in cooperation with the States of Georgia and Florida (Perkins and Shaffer, 1977; Caldwell and Johnson, 1982). These land resource areas are the Coastal Flatwoods, Southern Coastal Plain, and Central Florida Ridge (fig. 3). The Coastal Flatwoods area includes the coastlines of Georgia and Florida, and is characterized by nearly level soils on plains and marshes and some low terraces. The water table is generally near land surface in the Coastal Flatwoods, and numerous large springs flow along the Gulf Coast. The Southern Coastal Plain is characterized by broad, interstream areas with gentle to moderate slopes and shallow to deeply incised valleys. The Central Florida Ridge includes much of the central uplands of Florida. This area is characterized by hills, ridges, terraces, and many lakes, and is marked by karst topography. Sinkhole lakes, sinking streams, and springs are common in the area. Most areas in the Central Florida Ridge have few streams, with most of the drainage recharging ground water.

NITRATE DATA IN NATIONAL WATER INFORMATION SYSTEM

Nitrate data for ground-water samples and ancillary information about the wells where the samples were collected were retrieved from NWIS for all wells that had available water-quality and well-depth data. From October 1972 to September 1990, 1,380 wells in the study unit were sampled at least once for analysis of dissolved or total phases of nitrate. Because most nitrate in ground water is in the dissolved phase, no distinction was made between the total and dissolved phases of nitrate in this preliminary assessment. Dissolved and total nitrate as nitrogen will be referred to as nitrate hereafter. Where analyses for more than one sample from a well were available, only the most recent analysis was used in this preliminary assessment.

The nitrate data in NWIS represent ground-water samples collected for many types of studies. The objectives of the individual studies determined the geographic and temporal extent of the data collection, as well as the aquifer and depth zones sampled. For example, regional ground-water quality investigations usually include the collection of water-quality data over much larger geographic areas than do investigations of the effects of landfills on local ground-water quality. No effort was made to distinguish between the data collected for resource appraisal and local contamination assessment studies for this preliminary assessment. The data retrieved contained data for water samples from numerous contamination studies; therefore, this summary probably is biased toward areas of ground-water contamination. A more rigorous assessment of the NWIS data would be needed to identify and eliminate some of the data bias.

DISTRIBUTION OF NITRATE IN GROUND WATER

More than 90 percent of the samples for which nitrate data are available were collected from wells completed in either the Upper Floridan aquifer or the surficial aquifer system (fig. 4). Only the nitrate concentrations in water from these two aquifers are discussed here. For this assessment, the variability of

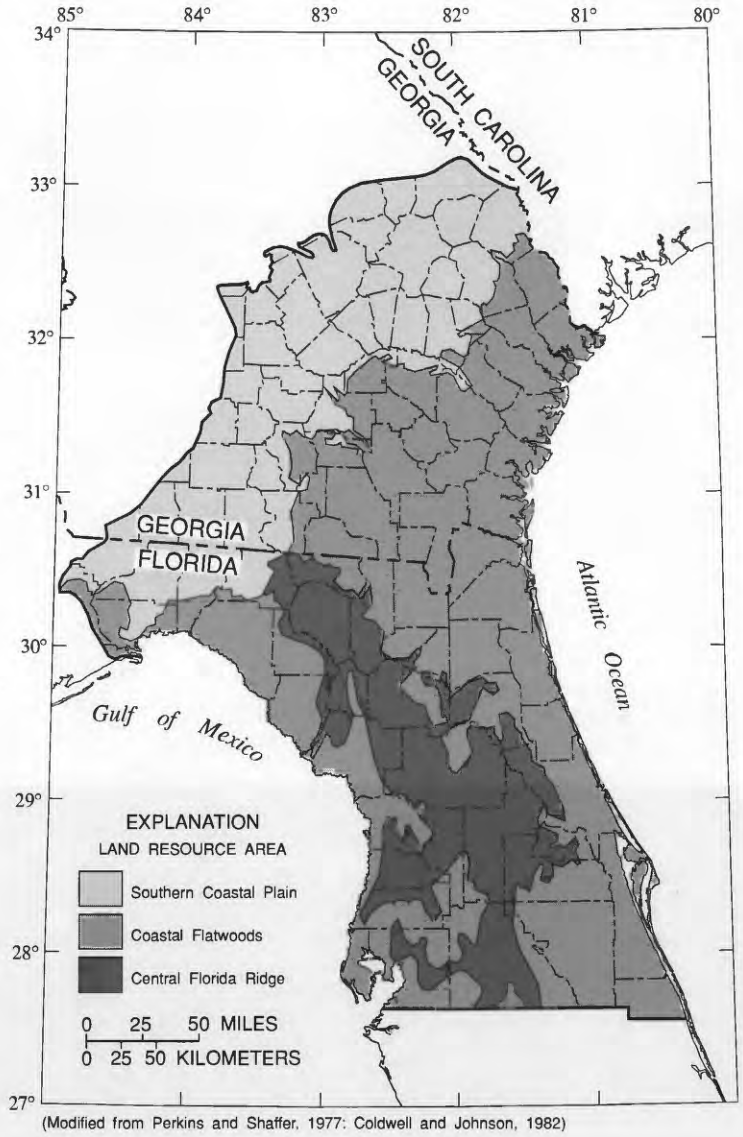

Figure 3. Land resource areas in the Georgia-Florida Coastal Plain study unit (Modified from Perkins and Shaffer, 1977; Coldwell and Johnson, 1982).

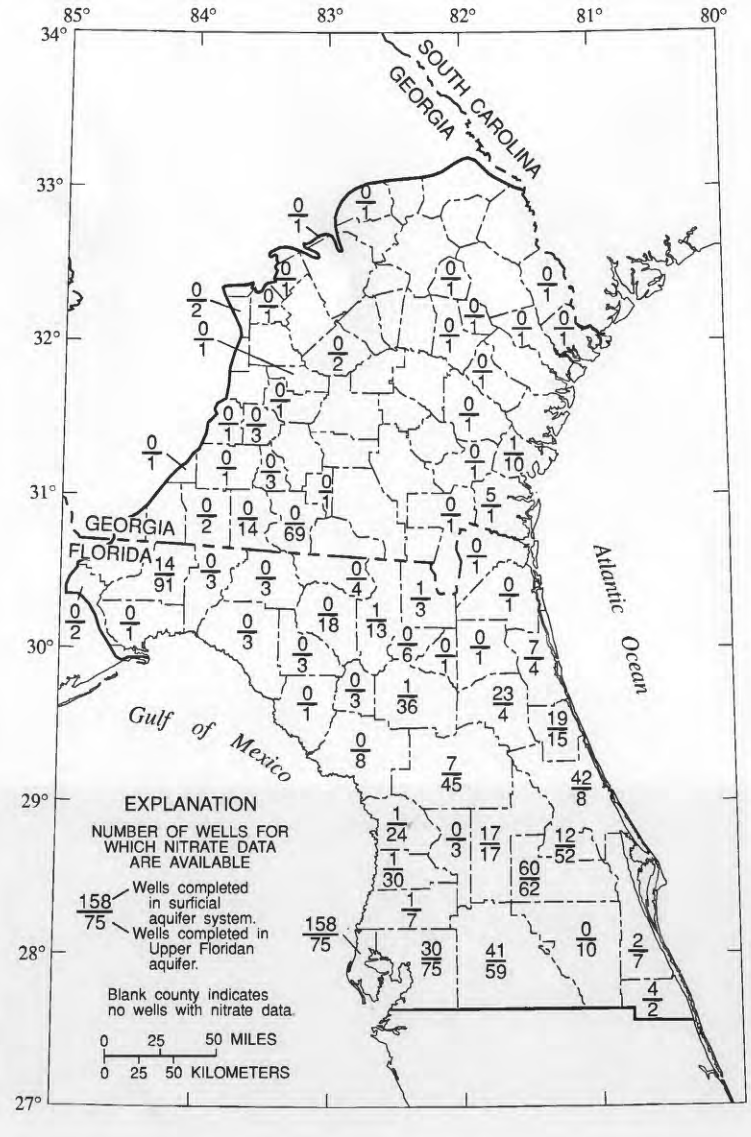

Figure 4. Number of wells for which nitrate data are available, with nitrate analyses by county.

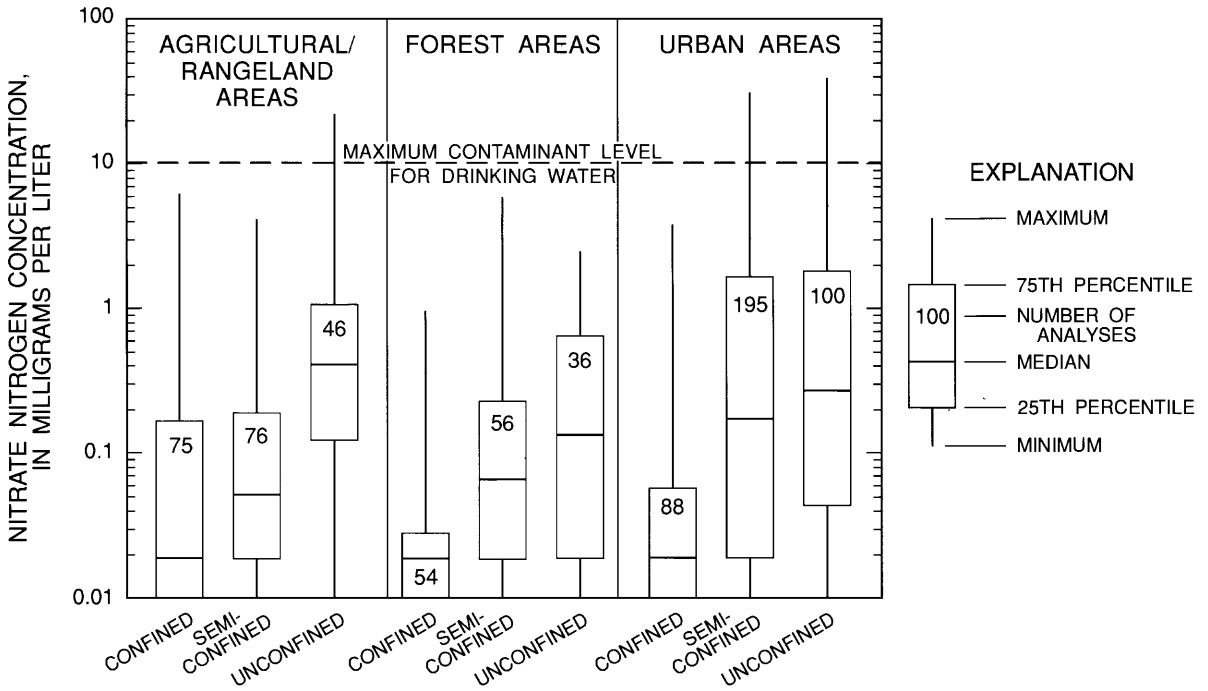

Figure 5. Nitrate concentration in water from the Upper Floridan aquifer in confined, semiconfined, and unconfined areas for the three major land-use areas of the Georgia-Florida Coastal Plain study unit.

nitrate concentrations in water from the Upper Floridan aquifer was determined for various categories of degree of confinement and land use near the sampled well. Nitrate distribution in water from the surficial aquifer system was determined for the three land resource areas and categories of land use.

Land use at each well site was determined from the USGS GIRAS data (Mitchell and others, 1977) and updated as necessary. The major land-use classifications were grouped into categories that were used to assess the relation between nitrate concentrations and land use. These categories were urban, agricultural/rangeland, forest, and barren. Agricultural areas and rangeland were combined into one category (agricultural/rangeland), because only a small number of ground-water samples were collected in rangeland areas. Barren areas were included only for sampling from the surficial aquifer system, because less than 5 percent of the water samples from the Upper Floridan aquifer were collected from wells in barren areas. Most of the ground-water nitrate data stored in NWIS were collected in Florida; many counties in Georgia had no ground-water nitrate data (fig. 4).

Of the 726 water samples collected from wells completed in the Upper Floridan aquifer in the land-use categories of agricultural/rangeland, forest, and urban, 137 samples (19 percent) had nitrate concentrations less than analytical detection limits. These detection limits ranged from 0.01 to 0.30 mg/L during 1972-90 because of changes in analytical methods. Detection limits of 0.01 or 0.02 mg/L were most common (125 of the 137). For this preliminary assessment, all nitrate concentrations less than analytical detection limits were set equal to the detection limits established at the time of analysis.

The variability of nitrate concentrations in water from the Upper Floridan aquifer is affected by the presence of and thickness of the overlying confining units and by land use near the well site (fig. 5). Nitrate concentrations in water samples from the Upper Floridan aquifer generally were low (less than 0.50 mg/L). Median concentrations in the categories ranged from 0.02 to 0.43 mg/L. Water from the confined areas of the Upper Floridan aquifer had the lowest median nitrate concentrations in all three land-use categories, with median concentrations less than or near analytical detection limits. Water from unconfined areas of the aquifer

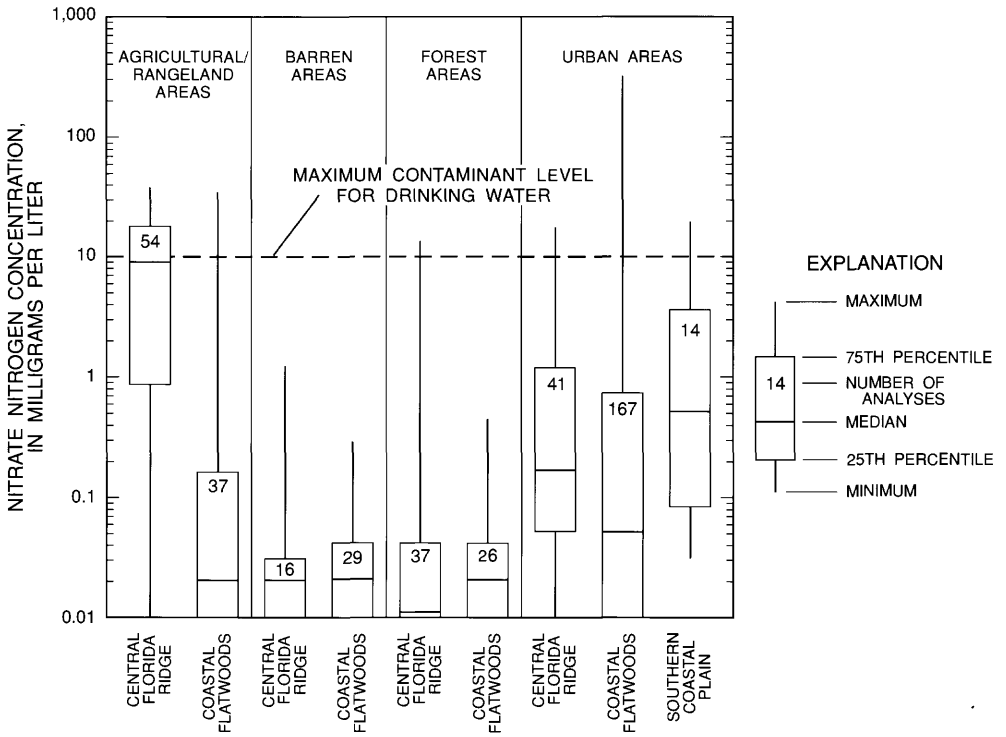

Figure 6. Nitrate concentration in water from the surficial aquifer by land use at well locations in the three land resource areas of the Georgia-Florida Coastal Plain study unit.

had the highest median nitrate concentration in all three land-use categories. Median nitrate concentrations in water from semiconfined areas of the aquifer in each land-use category was between the medians for confined and unconfined areas. The two highest median nitrate concentrations, 0.43 and 0.26 mg/L, were in water from wells completed in unconfined areas of the aquifer in agricultural/rangeland and urban land-use areas, respectively (fig. 5). In forest areas, the median nitrate concentration in water from unconfined areas of the aquifer was higher than that in semiconfined and confined areas but was lower than the median concentrations in unconfined areas of the aquifer in the other land-use areas.

The drinking water MCL of 10 mg/L for nitrate was exceeded in 25 of the 726 water samples (6 percent) from the Upper Floridan aquifer. All 25 water samples were from wells located in areas where the aquifer is unconfined or semiconfined, and 24 of these samples were collected from wells in urban areas near sewage-treatment plant effluent-spray areas or landfill sites (Berndt, 1990; 1993, and Trommer, 1992). One water sample in which the MCL for nitrate was exceeded was from a well at a dairy farm in an agricultural/rangeland area (Andrews, 1992).

Of the 421 water samples from wells completed in the surficial aquifer system in the land-use categories of agricultural/rangeland, barren, forest, and urban, 60 (14 percent) had nitrate concentrations less than analytical detection limits. Detection limits ranged from 0.008 to 0.10 mg/L. For this preliminary assessment, nitrate concentrations less than analytical detection limits were set equal to the detection limit at the time of analyses, except for the 12 samples with a detection limit of 0.008 mg/L. For those samples, the detection limit was rounded to 0.01 mg/L. These 12 samples were from wells in forest areas in the Central Florida Ridge.

The median nitrate concentrations in water from the surficial aquifer system differed among various categories of land use near the well site and, to a lesser extent, by land resource area (fig. 6). No nitrate data for water from the surficial aquifer system were available in the Southern Coastal Plain land resource area for agricultural/rangeland, barren, and forest areas. For the surficial aquifer system, the highest median nitrate concentration, 8.7 mg/L, was for water samples from wells in agricultural/rangeland areas in the Central Florida Ridge. In contrast, the median nitrate concentration for water samples from wells in agricultural/

rangeland areas in the Coastal Flatwoods was 0.02 mg/L. In the four categories for barren and forest areas in the Central Florida Ridge and Coastal Flatwoods, median nitrate concentrations in water from the surficial aquifer system were less than or near detection limits. In the Central Florida Ridge and Coastal Flatwoods, the median nitrate concentrations in water from the surficial aquifer system in urban areas were 0.16 and 0.05 mg/L, respectively. The median nitrate concentration in samples from urban areas in the Southern Coastal Plain was 0.50 mg/L.

Concentrations of nitrate exceeded the MCL for drinking water in 50 of the 421 water samples (12 percent) from wells completed in the surficial aquifer system. Nitrate concentrations that exceeded the MCL for nitrate were present in 25 of the 50 samples from wells located in the Central Florida Ridge and in agricultural/rangeland areas. Many of these 25 wells were in citrus agricultural areas in the Central Florida Ridge (E.R. German, U.S. Geological Survey, written commun., 1991; and Lee and others, 1991). In urban areas in the Coastal Flatwoods land resource area, 18 water samples from wells completed in the surficial aquifer system had nitrate concentrations that exceeded the MCL for nitrate. Many of these samples were from wells located at a site of sewage-effluent disposal (Trommer, 1992). Four samples from wells located within agricultural areas in the Coastal Flatwoods had nitrate concentrations that exceeded the MCL for nitrate. Three other samples with nitrate concentrations that exceeded the MCL were from wells in forest and urban areas in the Central Florida Ridge and from an urban area in the Southern Coastal Plain.

This preliminary assessment of available nitrate data for ground water in the Georgia-Florida Coastal Plain study unit indicates a possible relation between land use and nitrate concentrations. Further study is needed to determine the relation between land uses and ground-water quality. Studies might consist of data-collection activities, such as random sampling of ground-water within selected land-use areas of interest in the Georgia-Florida Coastal Plain study unit. Analysis of these ground-water samples for a comprehensive suite of chemical constituents and physical properties would further aid in determining the relation between land use and ground-water quality.

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