CHEMICAL CHARACTERISTICS OF WATER IN THE SURFICIAL AQUIFER SYSTEM, DADE COUNTY, FLORIDA

By Wayne H. Sonntag

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ABSTRACT

Hydrogeologic test drilling was conducted throughout Dade County to describe the chemical characteristics of water from hydrogeologic units in the surficial aquifer system. Water-quality analysis of samples collected from the test wells completed in central Dade County indicates that the Biscayne aquifer (unit A), the upper clastic unit of the Tamiami Formation (unit B), and parts of a limestone, sandstone, and sand unit of the Tamiami Formation (unit C) have been effectively flushed of residual seawater and contain primarily calcium bicarbonate ground water. The lower parts of unit C and the lower clastic unit of the Tamiami Formation (unit D) primarily contain calcium sodium bicarbonate or sodium bicarbonate type water. An analysis of variance test indicates that water in units A and B is not significantly (0.05 probability level) different in composition. Mean concentrations of dissolved solids, sodium, and chloride are significantly different between units A and C, whereas mean concentrations of dissolved solids, calcium, sodium, and chloride are significantly different between units A and D.

Ground water in the surficial aquifer system in northwestern Dade County is more mineralized than ground water that occurs elsewhere in the county (except in coastal areas affected by saltwater). An analysis of variance test indicates that mean concentrations of dissolved solids, sodium, and chloride at sites in northwestern Dade County developed in units A and C are significantly different from the mean concentrations of these constituents at sites throughout the rest of the county. Water in this part of the surficial aquifer system is similar to highly mineralized water found in western Broward County. However, in northwestern Dade County, the ground water has been diluted to a greater extent by less mineralized recharge water. Overall, ground water in the four major hydrogeologic units of the surficial aquifer system of Dade County is suitable for most uses. Maximum concentrations of sodium, chloride, color, fluoride, iron, and dissolved solids in some areas of Dade County, however, exceed maximum contaminant levels established by the Florida Primary and Secondary Drinking Water Regulations standards.

INTRODUCTION

Dade County is a rapidly developing area of about 2,000 mi^2 along the southeast coast of Florida within which is located the city of Miami (fig. 1). Beneath Dade County is the surficial aquifer system, which consists of materials of varying permeability from land surface to depths of 150 to 400 feet (J.E. Fish, U.S. Geological Survey, written commun., 1986). The permeability of these materials varies from highly permeable cavernous limestone to silts and clays of low permeability. The highly permeable material, which includes the Biscayne aquifer, is the sole source of drinking water for Dade County.

Generally, the surficial aquifer system is unconfined, and water levels are usually less than 10 feet below land surface. Because of this, ground water in the surficial aquifer system is susceptible to water-quality changes caused by downward percolation of contamination from the land surface.

Previous investigations of the surficial aquifer system in southeast Florida focused on the Biscayne aquifer beneath the coastal ridge, and virtually no data were collected for the surficial aquifer system to the west of the coastal ridge. Because of persistent increases in water demand from the aquifer system by the highly populated areas in southeast Florida and attendant concerns for the protection and management of the water supply, the U.S. Geological Survey, in cooperation with the South Florida Water Management District, has undertaken a regional study to define the geologic, hydrologic, and chemical characteristics of the surficial aquifer system. The water-quality investigation of the surficial aquifer system in Dade County, discussed in this report, is part of the broader regional study that also includes delineation of the geologic and hydrologic characteristics of the surficial aquifer system of Dade, Broward, and Palm Beach Counties.

The overall objectives of the study are to determine the hydrogeologic framework and the extent and thickness of the surficial aquifer system, the areal and vertical water-quality distribution and factors that affect the water quality, the hydraulic characteristics of the surficial aquifer system, and to describe ground-water flow in the system. Results of the investigation are being published in a series of reports that provide information for each county as it becomes available.

Purpose and Scope

The purpose of this report is to describe the chemical characteristics of water in the surficial aquifer system in Dade County and to compare concentrations of selected constituents with the Primary and Secondary Drinking Water Regulations maximum contaminant levels established by the Florida Safe Drinking Water Act. This report presents water-quality data collected in the summer of 1983 during the drilling of test holes at 31 sites throughout the county, and supplementary data collected during subsequent samplings in 1983 and 1984. Additional data from two wells drilled in Dade County during 1981 are presented. Selected water-quality data are also presented from two wells drilled in southern Broward County during 1981 as part of the Broward County phase of the investigation.

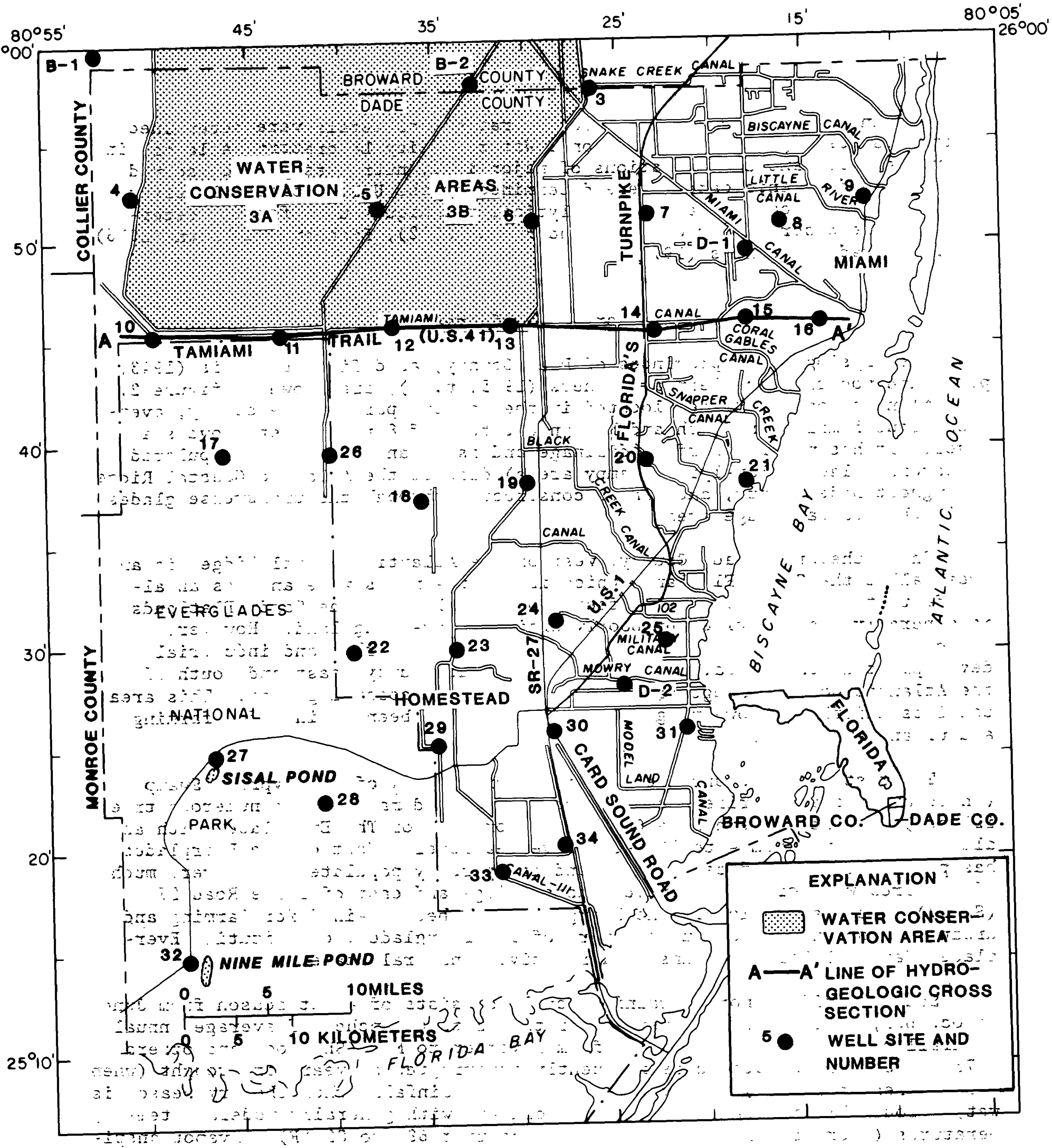


Figure 1.--Location of well sites, Dade and Broward Counties.

This report is intended to provide a broad countywide characterization of the water quality of the surficial aquifer system in Dade County. These data will also provide baseline information for regional analysis, and for future water-resources management and ground-water monitoring in Dade County.

Methods and Procedures

Hydrogeologic test drilling was conducted during May through October 1983 at selected sites throughout Dade County. The well sites (fig. 1) were approximately equidistant (about 5 miles apart) from each other, except where surface features made drilling infeasible. A total of 34 test wells (including two wells drilled in 1981 and one drilled in 1985) were drilled in Dade County through the surficial aquifer system to the underlying, relatively impermeable units of the Tamiami and Hawthorn Formations. A reverse-air dual-tube drilling method was used in which air circulates downward between the tubes and back to the surface in the inner tube with entrained rock samples and water. Measurements were made of flow variation, specific conductance, and temperature at 10-foot intervals during drilling. The test holes were generally completed as wells in the deepest permeable unit found and were numbered sequentially from 1 to 34. (The two wells drilled in Dade County during 1981 are shown in figure 1 as well sites D-1 and D-2; the two wells drilled in southern Broward County during 1981 as part of the Broward County phase of the investigation are shown in figure 1 as well sites B-1 and B-2.)

An additional 90 wells were drilled at 31 of the 34 sites and finished at selected depths. The depths were selected to permit sampling of the major permeable hydrogeologic units at each site as determined from the deep test holes. Additional wells at each site were given the same number as the test well plus an arbitrary letter designation of A, B, C, or D. All wells are constructed of 1 1/2- or 2-inch threaded polyvinyl chloride (PVC) pipe, were screened (PVC screen length was 3.0 feet; screen slot size was 0.010-0.030 inch) in unconsolidated units, or left as open hole in consolidated rock units.

After the wells were installed, each well was developed by pumping and airlift to ensure good connection and flow from the hydrogeologic unit in which the well was finished. After development, an additional 3 months was allowed to pass for stabilization of water-quality conditions before water-quality sampling was begun. Water-quality sampling was begun in April 1984 and was completed in September 1984. Prior to sampling, water was pumped from each well in sufficient quantity to ensure that at least five well casing volumes of water were removed before sampling. After five well casing volumes of water had been removed from the well, specific conductance, pH, and temperature were determined, using a specialized inline-measuring chamber which allows measurement of water without exposure to the atmosphere. In addition to specific conductance, pH, and temperature, alkalinity was also determined onsite at the time of sampling. Water samples for laboratory analysis of specific conductance, pH, alkalinity, dissolved major ions, dissolved nutrients, and dissolved and suspended organic carbon were collected at all sites and preserved in the field using the method prescribed by Brown and others (1970). Water samples for dissolved trace metals were collected only at sites in the urbanized eastern parts of Dade County and at sites located along major highways in western Dade County. Concentrations of metals were determined by the U.S. Geological Survey National Water Quality Laboratory, Atlanta, in Doraville, Ga., and concentrations of major ions, nutrients, and dissolved and suspended organic carbon were determined by the U.S. Geological Survey Service Unit in Ocala, Fla. The analytical techniques used for the determination are described by Goerlitz and Brown (1972), Fishman and Brown (1976), and Skougstad and others (1979).

Description of Area

The physiographic provinces of Dade County, as defined by Davis (1943, p. 4) and modified by Klein and others (1975, p. 8), are shown in figure 2. The Atlantic Coastal Ridge, located in the eastern part of the county, averages about 5 miles in width and has an altitude of 8 to 22 feet above sea level. It has natural surface drainage and is urban and densely populated. Transverse glades (low-lying swampy areas) dissect the Atlantic Coastal Ridge throughout Dade County, and canals constructed through the transverse glades drain the coastal ridge area.

In northeastern Dade County, west of the Atlantic Coastal Ridge, is an area called the Sandy Flatlands which is about 4 miles wide and has an altitude that ranges from 5 to 10 feet above sea level. The Sandy Flatlands is generally characterized by poorly drained, low-lying land. However, the construction of drainage canals has facilitated urban and industrial development in this area. In southeastern Dade County, east and south of the Atlantic Coastal Ridge, are the mangroves and coastal glades. This area consists chiefly of low-lying wetlands which have been drained for farming and urban development.

The rest of the county, except for a small area of Big Cypress Swamp (those areas characterized by flat, poorly drained marshes and numerous tree islands) in northwestern Dade County, is composed of The Everglades with an altitude ranging from 4 to 13 feet above sea level. Most of The Everglades has poor, natural surface drainage and is sparsely populated. However, much of the area west of the Atlantic Coastal Ridge and east of State Road 27 (SR-27) that was previously The Everglades has been drained for farming and urban development. The southern part of The Everglades, constituting Everglades National Park, remains in a relatively natural state.

South Florida's normal rainfall cycle consists of a wet season from June to October, during which 75 percent of the 52 to 60 inches of average annual rainfall occurs, and a dry season from November to May (Sherwood and others, 1973, p. 8). This pattern is frequently interrupted by years of drought (when the wet season is dry) and by years of excess rainfall (when the dry season is wet). South Florida has a subtropical climate with generally moderate temperatures (average daily temperatures range from 68° to 82 °F). Evapotranspiration in south Florida removes as much as 70 percent of annual rainfall in urban areas (Meyer, 1971) and as much as 95 percent of rainfall in undeveloped areas, such as The Everglades (Leach and others, 1972).

The annual periodicity of rainfall in south Florida can sometimes result in deficient supplies of freshwater. To alleviate problems associated with

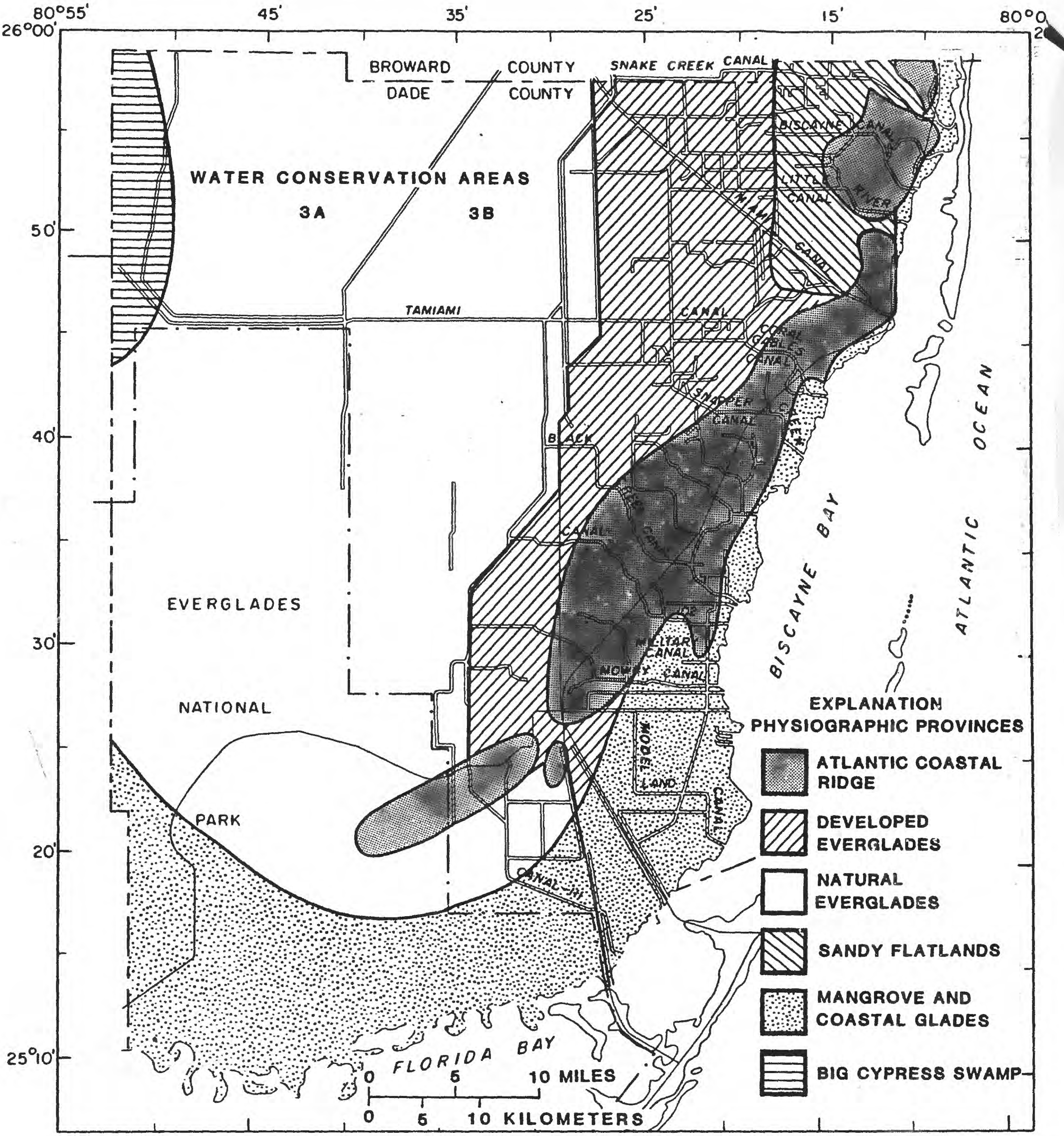


Figure 2.--Physiographic provinces of Dade County. (modified from Klein and others, 1975, p. 8.)

these variations in rainfall, northwestern Dade County is partitioned into Water Conservation Areas 3A and 3B (fig. 1). These areas are part of The Everglades province and are used for water catchment and impoundment during periods of excess rainfall. During dry periods, water can be conveyed from the conservation areas to coastal urban areas in Dade County through an extensive canal system to protect and replenish the supply of potable ground water by infiltration from the canals and help maintain ground-water levels in the canals and underlying aquifers to retard saltwater intrusion.

HYDROGEOLOGIC SETTING

The surficial aquifer system underlying Dade County is the sole source of freshwater supply for the county. It is composed of limestone, sandstone, sand, shell, and silt from land surface to the top of the intermediate confining system which separates the surficial aquifer system from the Floridan aquifer system (Southeastern Geological Society, 1986). Figure 3 shows a generalized hydrogeologic cross section of the surficial aquifer system in Dade County.

The surficial aquifer system consists of materials that have a wide range of permeability, and locally may be divided into one or more aquifers with intervening zones of sands and silts having low permeability (Fish, 1987). Due to the interfingering of these materials, some permeable units (aquifers or small sections of aquifers) may exhibit confined characteristics. In general, the surficial aquifer system has hydraulically interconnected ground-water flow with fluid potentials at all depths closely related to the water table (Fish, 1987). A detailed study of the hydraulic characteristics of the components of the surficial aquifer system and a description of ground-water flow in the system is currently underway as part of the overall objectives of the study.

The Biscayne aquifer (referred to as unit A in this report, fig. 3) is the best known part of the surficial aquifer system. It is a highly permeable nonartesian limestone aquifer and consists primarily of oolite and other cavernous cavity-riddled limestones. Parker and others (1955, p. 160) assigned the sediments of the Biscayne aquifer to the following general stratigraphic sequence in ascending order: Permeable limestone of the Tamiami Formation that immediately underlies the Fort Thompson Formation or Anastasia Formation, Caloosahatchee Marl, Fort Thompson Formation, Key Largo Limestone, Anastasia Formation, Miami Oolite, and Pamlico Sand. The Caloosahatchee Marl was not found in any wells drilled for the Dade County study (Causarás, 1987) or the Broward County study (Causarás, 1985).

Underlying unit A in western and central Dade County is unit B, a low to moderately permeable greenish layer of sand, shell, and silt. This material is the upper clastic unit of the Tamiami Formation and forms the base of the Biscayne aquifer in western Dade County and interfingers with limestones to the east (Causarás, 1987). In southeastern Dade County, this unit decreases in thickness and interfingers with layers of shelly sand, sand, siltstone, and claystone.

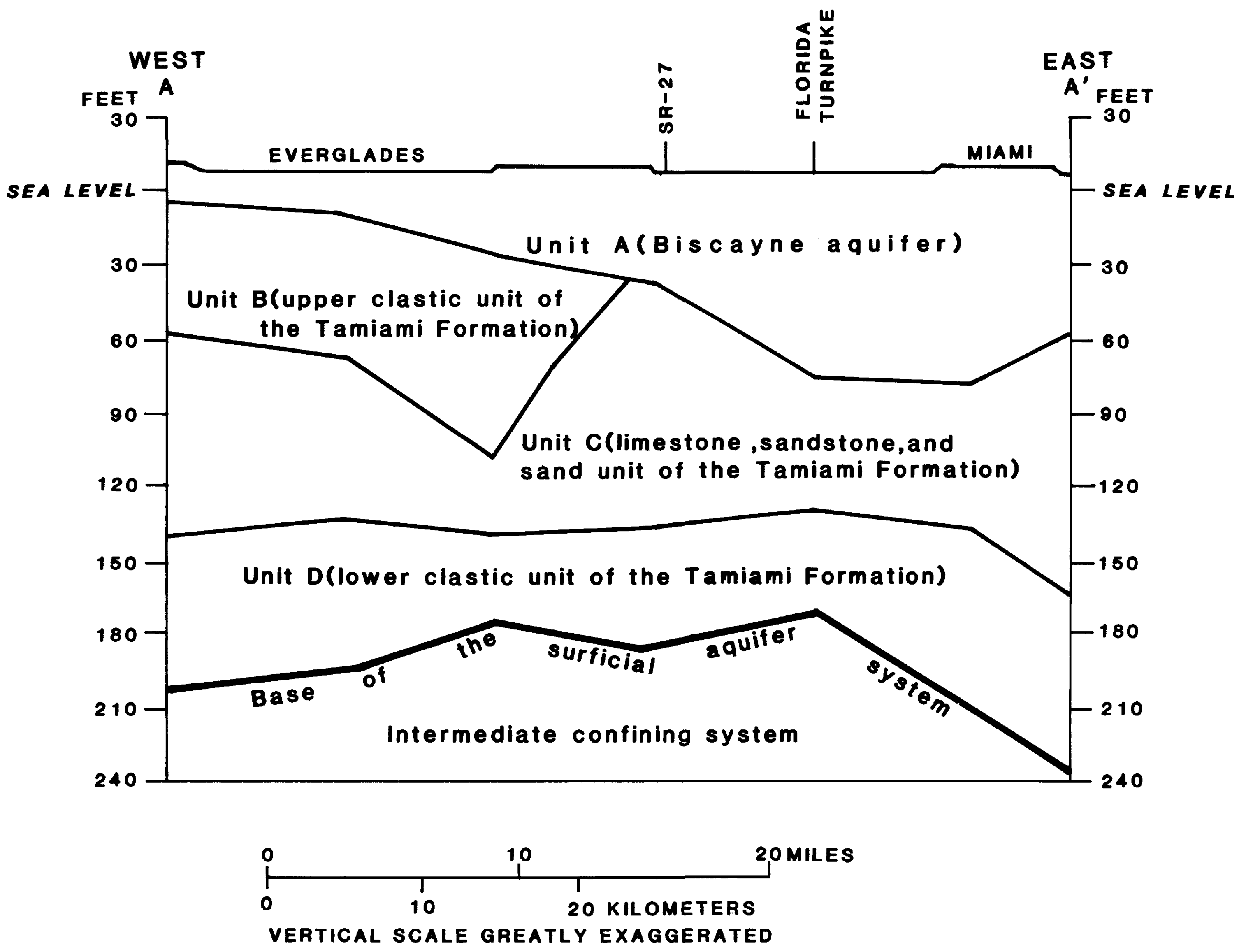


Figure 3.--Generalized hydrogeologic cross section of the surficial aquifer system, Dade County. (modified from Causarás, 1987.)

Underlying unit A in eastern Dade County and unit B in western and central Dade County is unit C, a limestone, sandstone, and sand unit of the Tamiami Formation. In northwestern Dade County, unit C is composed of the gray limestone of the Tamiami Formation. In southern Dade County, the gray limestone decreases in thickness and grades into sandstone, shelly sand, silt, and other limestones (Causarás, 1987).

Underlying unit C is unit D, the lower clastic unit of the Tamiami Formation. This unit is primarily very coarse to fine-grained quartz sand with some clay, shelly sand, and sandstone. Also included are phosphorite, heavy minerals, and mica as accessory minerals (Causarás, 1987). This unit generally has relatively low permeability (J.E. Fish, U.S. Geological Survey, oral commun., 1985). The underlying clay beds of the Hawthorn Formation form the base of the surficial aquifer system. A more complete description of the units comprising the surficial aquifer system of Dade County is discussed by Causarás (1987).

CHEMICAL CHARACTERISTICS OF WATER IN THE SURFICIAL AQUIFER SYSTEM

The chemical characteristics of ground water in the study area are controlled by several factors. In the surficial aquifer system of southeast Florida, both the permeability and the mineral composition of the aquifer material can vary considerably with depth. This often results in variability of the chemical composition of ground water with depth. In addition, in parts of Dade County, the effects of residual water from periodic Pleistocene inundations of the sea are found in the form of diluted seawater (Parker and others, 1955, p. 821). Parker and others state that the mineralized nature of ground water in The Everglades has resulted in part from saline residues not completely flushed out of the ground.

Along coastal Dade County, saltwater movement up uncontrolled canal reaches (canals open to the ocean) or in the aquifer in areas with low-water levels (often caused by heavy pumping or excessive drainage) can also affect ground-water quality. Elsewhere, construction of artificial impoundments, such as the water-conservation areas, and the potential for contamination from landfill leachate, chemical spills, urban-industrial runoff, agricultural chemical percolation, and leaky artesian wells can locally affect ground-water quality.

Because water composition can be significantly affected by the hydrogeologic units with which it is associated, water-quality data for Dade County were analyzed not only on a countywide basis, but also by comparing water from the four hydrogeologic units comprising the surficial aquifer system. These units are described in the previous section.

Vertical Profiles of Specific Conductance

Specific conductance is a measure of the ability of water to carry an electric current (Hem, 1985, p. 66) and gives an approximate expression of the quantity of dissociated ions in solution. Conductance determinations are useful in areal extrapolation of ground-water quality and are valuable in establishing differences in water quality with depth. Plate 1 shows the specific conductance of ground water throughout Dade County. Specific conductance profiles are based on measurements of specific conductance made at 10- to 20-foot intervals during hydrogeologic test drilling. Also shown on plate 1 are the approximate depths at which 100 and 250 mg/L (milligrams per liter) dissolved chloride concentrations were found or first exceeded. The 250-mg/L chloride concentration is emphasized, as it is the maximum level allowed in community water systems as set forth in the Florida Secondary Drinking Water Regulations standard (Florida Department of Environmental Regulation, 1982). The 100-mg/L chloride concentration is used as an arbitrary concentration to illustrate water quality of ground water containing less than 250 mg/L of chloride.

Figure 4 shows areal variations in specific conductance. Specific conductance contours are based on data collected from the four hydrogeologic units of the surficial aquifer system. (For this presentation, data from units A and B were combined.)

Coastal Areas

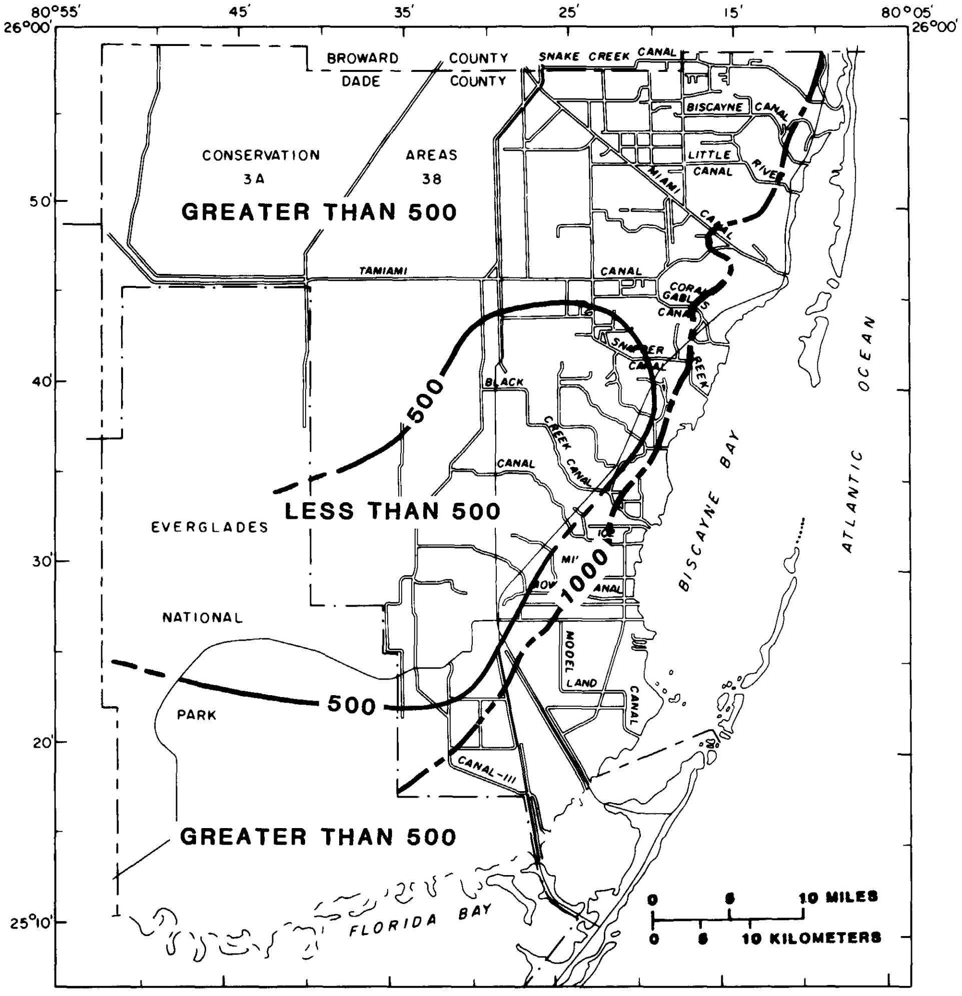
Most of the coastal areas of Dade County exhibit saltwater intrusion. The 1,000-mg/L chloride contour, as described by Klein and Waller (1985) and illustrated in figure 4, shows the extent of saltwater intrusion along coastal Dade County. Several well sites (9, 16, 25, and 31) drilled during this project are located in coastal areas subject to saltwater intrusion (Klein and Waller, 1985) and exhibit a profile of increasing specific conductance with depth (pl. 1). Specific conductance is generally less than 1,000 μS/cm (microsiemens per centimeter at 25 °C) to a depth from land surface to 50 feet, increasing sharply as saltwater is found. Three exceptions to this type of specific conductance profile are coastal well sites 21, 33, and 34 (pl. 1).

During drilling in October 1983, samples of water collected at site 21, 1.5 miles from the ocean, showed no saltwater intrusion effects to a depth of 210 feet below land surface. However, during subsequent sampling in September 1984, a well completed 110 feet below land surface at this site contained water with a specific conductance of about 3,700 μS/cm. A possible explanation for the difference in specific conductance between October 1983 and September 1984 is that ground-water levels in this area during October 1984 were slightly lower than during September 1983. Water-level contour maps show that the 2- and 3-foot water-level contour lines were located farther inland in October 1984 than during September 1983 (R.S. Sonenshein, U.S. Geological Survey, written commun., 1983) which may have allowed saltwater to move farther inland. The surficial aquifer system in this area is composed of highly permeable limestone (of units A and C) from land surface to a depth of 110 feet. The high specific conductance of water found at 110 feet below land surface indicates that saltwater intrusion has occurred in the lower part of this high permeability zone. No evidence of saltwater intrusion was observed in the upper part of this zone. The specific conductance of water from wells completed at 27 and 53 feet below land surface at this site during September 1984 was 525 μS/cm at both depths.

EXPLANATION

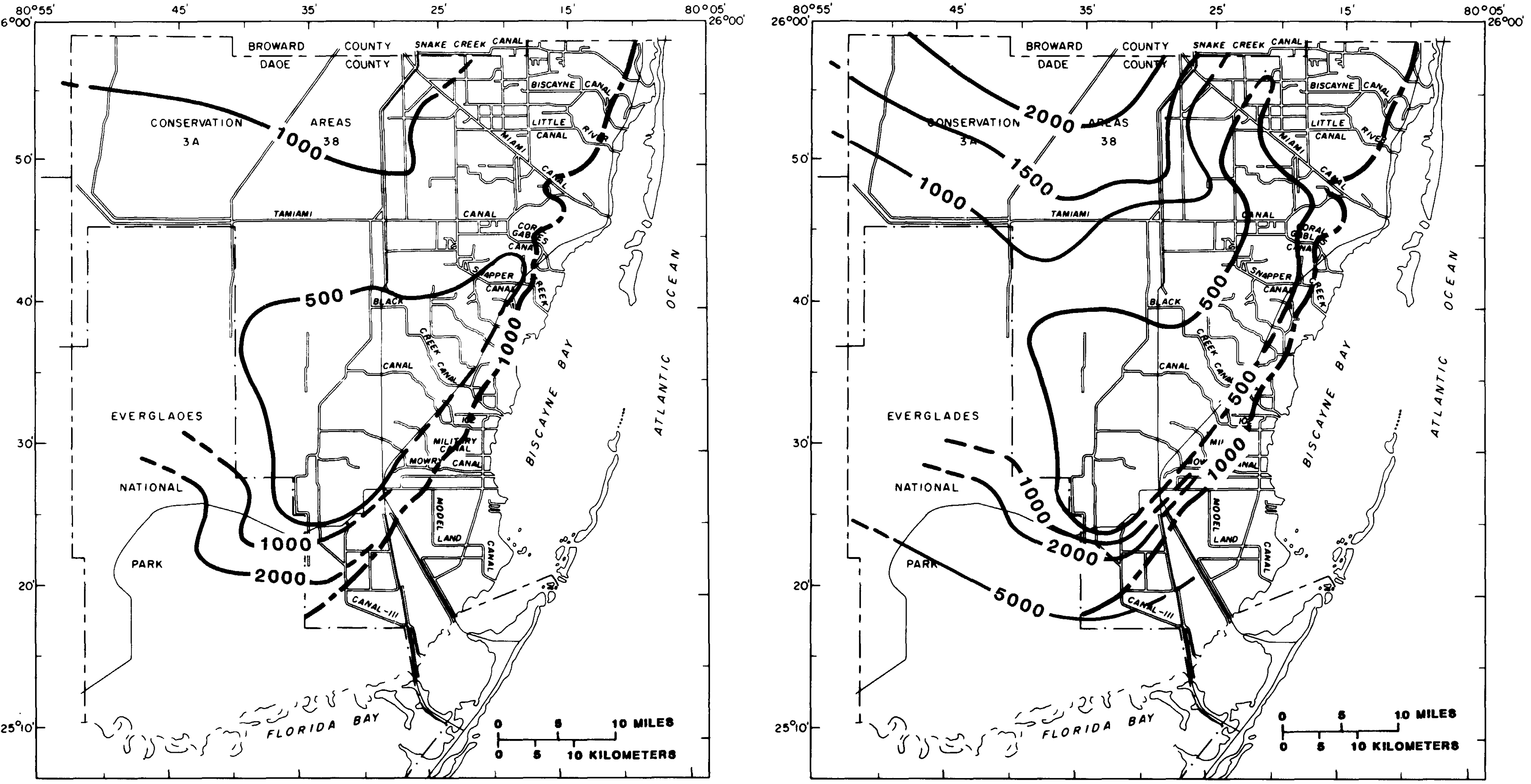
—500— LINE OF EQUAL SPECIFIC CONDUCTANCE-- Dashed where approximately located. Interval, in microsiemens per centimeter, is variable

--·1000--- LINE SHOWING APPROXIMATE INLAND EXTENT OF WATER CONTAINING 1000 MILLIGRAMS PER LITER OF CHLORIDE NEAR THE BASE OF BISCAYNE AQUIFER-- From Klein and Waller, 1985.



UNITS A AND B CONBINED

Figure 4.--Areal variation of specific conductance in selected hydrogeologic units of the surficial aquifer system, Dade County.



UNIT C

UNIT D

Figure 4.--Areal variation of specific conductance in selected hydrogeologic units of the surficial aquifer system, Dade County--Continued.

Between 110 and 210 feet below land surface, the surficial aquifer system is primarily composed of low permeability materials such as shelly sand, sandstone, clay, and siltstone (of units C and D). During October 1983, specific conductance of water at selected depths between 110 and 210 feet was generally less than 500 μS/cm (pl. 1). Samples of water collected during September 1984 from a well finished at 213 feet below land surface produced water with a specific conductance of 435 μS/cm. Because the lithology of the surficial aquifer system changes abruptly from high to low permeability materials, the hydrogeologic units comprising the surficial aquifer system in this area may respond differently to saltwater intrusion. Freshwater in the low permeability unit may not be affected or may not have yet been displaced by saltwater.

Specific conductance profiles at coastal sites 33 and 34 in southeastern Dade County further illustrate how local aquifer hydraulics and lithology may affect water quality. Site 33 is in southeastern Dade County along C-111 (Canal 111), 10 miles south-southwest of the city of Homestead, and about 7 miles from the ocean. Site 34 is on U.S. 1, 7.1 miles south of the Card Sound Road-U.S. 1 intersection, and about 6 miles from the ocean (see fig. 1). Specific conductance of ground water at site 34 ranges from about 560 μS/cm (at a depth of 30 feet below land surface) to more than 30,000 μS/cm (at a depth of about 60 feet) (pl. 1). Lithologic logs for site 34 show that the upper part of the surficial aquifer system (0-70 feet) in this area (unit A and parts of unit C) is composed of highly permeable limestones (Causarás, 1987). Water levels in this area are often less than 1 foot above sea level (R.S. Sonenshein, U.S. Geological Survey, written commun., 1984), and saltwater intrusion occurs throughout this upper part of the surficial aquifer system (Klein and Waller, 1985). Beneath this highly permeable zone is a layer of dense limestone, sandstone, and muddy silt of low permeability between 72 and 89 feet. This low permeability zone separates the high permeability limestone zone, which is influenced by saltwater intrusion, from the semiconfined sand, sandstone, and limestone of unit C. Specific conductance in this semiconfined unit is much lower, ranging from 700 to 1,800 μS/cm. The low specific conductance of water found in the lower unit indicates incomplete displacement of freshwater by saltwater. This unit is partially confined at depth and has heads that are higher than the water table (J.E. Fish, U.S. Geological Survey, oral commun., 1986), thereby restricting saltwater intrusion at depth. Site 33 shows a similar specific conductance profile, although specific conductance of the water in the lower semiconfined unit is not as low as that at site 34 (pl. 1).

Southern Dade County-Everglades National Park

Another area in which ground-water quality is influenced by saltwater is southern Dade County within Everglades National Park (sites 27, 28, and 32). The specific conductance profile for site 32 indicates saltwater is present throughout the vertical extent of the surficial aquifer system at this site (pl. 1). The specific conductance at 10 feet below land surface was as high as 4,000 μS/cm, whereas a nearby surface-water source (fig. 1, Nine Mile Pond) had a specific conductance of 655 μS/cm. Between 30 and 100 feet below land surface, the surficial aquifer system is composed of low permeability silt, sand, and some shell (units B and C). Because of the small amount of water that could be produced from this zone, specific conductance could not be determined. From 100 feet to the base of the surficial aquifer system (about 200 feet below land surface), specific conductance generally ranged from 25,000 to 32,000 µS/cm (pl. 1), indicating saltwater intrusion.

The lithology of the surficial aquifer system at site 27, 5 miles north of site 32, is similar to that at site 32 (Causarás, 1987). However, between land surface and 30 feet below land surface, the specific conductance was 350 µS/cm. Between 30 and 87 feet below land surface (unit B) is a layer of organic-rich sand. Because of the small amount of water produced from this interval, specific conductance could not be determined. Specific conductance of ground water at site 27 at depths between 100 and 200 feet (parts of unit B and most of units C and D) ranges from 4,200 to 5,300 µS/cm, which is much higher than that found at shallower depths. However, the specific conductance is considerably less than that found at the same depths at site 32 (25,000-32,000 µS/cm). Both greater freshwater recharge to the upper part of the surficial aquifer system (0-30 feet) and distance inland from the saltwater source probably account for the lower specific conductance in the surficial aquifer system at site 27.

Site 28, 5 miles east of site 27, is in Everglades National Park about 7 miles west of the park entrance. From 0 to 40 feet below land surface (in primarily permeable limestone of unit A and parts of unit B), specific conductance was generally less than 400 µS/cm (pl. 1). At about 57 feet is a layer of silt and sand, similar to that found at sites 27 and 33 between 30 and 100 feet. However, at site 28, this layer is slightly thicker, extending to a depth of about 130 feet (Causarás, 1987). This layer of silt and sand restricts the flushing of higher specific conductance of water from the lower permeable units (units C and D) between 130 and 180 feet, and specific conductance generally ranged from 2,800 to 3,100 µS/cm (pl. 1).

The specific conductance profiles for sites 27, 28, and 32 indicate that saltwater has intruded into the surficial aquifer system in this area. This is probably due to low-water levels which occur in southern Dade County. At site 32, water levels in the surficial aquifer system during drilling (June 1983) were less than 1 foot above sea level. At sites 27 and 28, water levels during drilling (June 1983) were between 1 and 2 feet above sea level (R.S. Sonenshein, U.S. Geological Survey, written commun., 1983). In addition, the occurrence of silt and sand material relatively close to land surface (30 feet below land surface at sites 27 and 32; 57 feet below land surface at site 28) may restrict freshwater recharge to lower units, thereby reducing the flushing and dilution of saltwater at depth.

Central Dade County

Sites located between the coastal areas affected by saltwater intrusion and the eastern part of The Everglades, generally east of SR-27 (referred to as central Dade County), show low specific conductance (less than 1,000 µS/cm) of water from land surface to the base of the surficial aquifer system (pl. 1 and fig. 4). The surficial aquifer system in this area is mainly comprised of units A and C. The permeable limestone and sandstone constituting units A and C have apparently allowed freshwater recharge to migrate downward into these units, resulting in water with low specific conductance.

Northwestern Dade County

In northwestern Dade County (considered to be those areas of Dade County north of U.S. 41 and west of the Florida Turnpike), specific conductance of ground water in the surficial aquifer system generally increases to the west and to the north (fig. 4) with chloride concentrations less than 250 mg/L to depths of 200 feet or more below land surface. Site 4 in the northwest corner of Dade County (fig. 1) shows low specific conductance of ground water (less than 500 µS/cm) from land surface (unit A) to about 30 feet (pl. 1). Below 30 feet, specific conductance gradually increases to about 850 µS/cm at 90 feet, remaining generally constant to the base of the surficial aquifer system (near 220 feet). This gradual increase in specific conductance with depth probably indicates dilution of ground water by the downward migration of freshwater. Low chloride concentrations at these depths (97 mg/L at 220 feet below land surface) also indicate that little residual seawater remains in this part of the aquifer.

At site 5, about 13.5 miles east of site 4, ground water with specific conductance less than 700 µS/cm occurs in the surficial aquifer system from land surface to about 120 feet below land surface (pl. 1, units A, B, and C). The presence of low to moderate permeable materials between 40 and 50 feet below land surface (unit B) does not appear to have restricted freshwater recharge to this part of the surficial aquifer system. However, below 120 feet (units C and D), specific conductance of the ground water increases sharply, as much as 1,800 µS/cm at 170 feet below land surface, which represents the highest specific conductance found in the surficial aquifer system in this area of northwestern Dade County. The specific conductance of ground water below 120 feet at site 5 is similar to that observed at site B-2 and other sites located 5 to 10 miles north in west and central southern Broward County (Howie, 1987), and probably reflects limited flushing of residual seawater from this part of the surficial aquifer system.

The lithology of the surficial aquifer system in northwestern Dade County at sites 6, 10, 11, 12, and 13 (fig. 1) is similar to that at site 5. However, there seems to be more downward migration of freshwater presumably due to better hydraulic connection between the major hydrogeologic units of the surficial aquifer system at these sites, resulting in less residual seawater as indicated by lower specific conductance throughout the vertical extent of the surficial aquifer system to its base (pl. 1).

Water from one well at site 17 in western Dade County (fig. 1) completed in the lower part of a silt and sand layer (unit B) had a specific conductance of 2,250 µS/cm when sampled in June 1984. Earlier sampling during drilling produced only a sandy slurry, and specific conductance could not be determined. The low permeability of this layer probably has prevented the complete flushing of residual seawater from this part of the surficial aquifer system.

Ground water in northwestern Dade County is probably an extension of more mineralized ground water also found in western Broward County (Howie, 1987). Both the degree of mineralization of the water and the lithology of the surficial aquifer system in northwestern Dade County is similar to that in Broward County (Causarás, 1987) and reflects similar hydrogeologic conditions.

The specific conductance of ground water in Broward County generally increases to the west and north with the most mineralized water occurring in north-central Broward County where specific conductance at 190 feet below land surface ranges from 5,800 to 6,600 μS/cm. However, unlike Broward County, downward leakage of less mineralized ground water through the upper permeable units of the surficial aquifer system in Dade County is indicated by lower specific conductance in the upper units. This downward leakage has apparently caused greater dilution of more mineralized ground water (some of which is presumably residual seawater) found at depth in the surficial aquifer system. However, between 90 and 220 feet below land surface (pl. 1), more highly mineralized water as indicated by higher specific conductance occurs. This water is probably affected by either residual seawater not completely flushed from the surficial aquifer system and to some extent by localized geochemical processes.

It appears that in many parts of Dade County, the hydraulic connection between the various hydrogeologic units of the surficial aquifer system has allowed the residual seawater to be flushed from the surficial aquifer system.

Water Types in the Surficial Aquifer System

The relative proportions of selected dissolved ion species in ground water can be used to indicate different types of water which occur in an aquifer or aquifer system. The ions most commonly used for interpretive work are generally those most abundant in ground water--calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride. To best illustrate the concentration and relative proportion of these ions, Stiff diagrams were used (pl. 2). A Stiff diagram is constructed by converting the concentration of each major ion from milligrams per liter to milliequivalents per liter, and then plotting the ion pairs along three horizontal axes and one vertical axis. The cations are plotted on the left side of the diagram, and the anions are plotted on the right side. Connecting the points that represent anion and cation concentrations gives a closed figure or pattern whose shape is characteristic of a given water type, and whose area indicates the degree of mineralization of the water. In addition to Stiff diagrams, ratios of selected ions found in ground water along with the actual concentrations may be used to compare and perhaps further distinguish between water types and the chemical processes involved.

Unit A (Biscayne Aquifer) and
Unit B (Upper Clastic Unit of the Tamiami Formation)

Calcium bicarbonate water occurs at less than 90 feet below land surface in the surficial aquifer system throughout most of Dade County (pl. 2). Calcium bicarbonate water generally results from the dissolution of limestone, calcite-cemented sandstone, and carbonate sands. Calcium solubility is generally controlled by chemical equilibrium involving carbonate materials. This water type is generally associated with the permeable zones of unit A and some parts of unit B (pl. 2). A calcium bicarbonate water, illustrated by a Stiff diagram, shows the calcium spike (cation side) and the bicarbonate spike (anion side) to be the longest. Generally, calcium bicarbonate water has at least 50 percent of its cation composition as calcium and 50 percent of its anion composition as bicarbonate.

Calcium concentrations in unit A are variable, ranging from 55 to 140 mg/L (table 1). The maximum concentration of calcium was measured in water from a well at site 25, finished 30 feet below land surface along southeastern coastal Dade County. The minimum concentration of calcium was measured in water from a well at site 34, finished 18 feet below land surface, also along southeastern coastal Dade County. Generally, in unit A, calcium concentrations in ground water not affected by saltwater intrusion are less than 100 mg/L. The mean calcium concentration of water in unit A is 90 mg/L (table 1).

Water associated with unit B is similar to that found in unit A (pl. 2). The mean concentration of dissolved solids in unit B is 330 mg/L, about the same as that of unit A, which is 333 mg/L (table 1). The mean calcium concentration for water associated with unit B is 80 mg/L, slightly less than that of unit A (90 mg/L). Calcium concentrations, however, are more variable in unit B, ranging from a minimum of 10 mg/L at site 29 in central Dade County to a maximum of 150 mg/L at site 26 in western Dade County.

In northwestern Dade County (north of U.S. 41 and west of the Florida Turnpike; sites 3, 5, 7, and 11), calcium concentrations in unit A (72 to 90 mg/L) are not as variable and slightly less than those in the rest of the unit. Concentrations of sodium, however, are higher in this part of unit A (43 to 77 mg/L) than elsewhere throughout Dade County. The mean sodium concentration for samples of water from wells developed in unit A throughout Dade County is 26.6 mg/L (table 1). The highest sodium concentrations (77 and 66 mg/L) were measured in water from two wells at sites 11 and 3 in northwestern Dade County. The shallow well at site 11 (14 feet below land surface) was developed at the boundary between units A and B and was included in unit A. The calcium concentration in each of these two wells was 72 mg/L. Ground water from these two wells was the only calcium sodium bicarbonate water found in unit A.

Two wells developed in unit B in northwestern Dade County (at sites 6 and 12) also had calcium sodium bicarbonate water (pl. 2). One well at site 17 in western Dade County developed in this unit contained sodium chloride water. Both the sodium concentration (300 mg/L) and the chloride concentration (600 mg/L) of water from this well were much higher than those concentrations found in any other wells developed in either unit B or unit A. The specific conductance of water in this well was 2,250 μS/cm. This well is developed in the lower part of a silt and sand layer which is high in organic matter. As a result, flushing of residual seawater from this part of the surficial aquifer system is probably not complete. Because water from the well was not considered representative of the type of water found in unit B, water-quality data from this well was not included in the statistical summary (table 1).

In addition to the use of Stiff diagrams to characterize water types, expression of the relation among ions in terms of mathematical ratios can also distinguish between water types. Calcium sodium bicarbonate ground

Table 1.--Statistical summary of selected dissolved constituents in ground water from hydrogeologic units

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. °C, degrees Celsius; µS/cm, microsiemens per centimeter; CaCO3, calcium bicarbonate; Pt-Co, platinum-cobalt. Concentrations shown in milligrams per liter, except where noted.]

	Temperature (°C)	pH (units)	Specific conductance (µS/cm)	Dissolved solids (residue at 180 °C)	Alkalinity (as CaCO3)	Hardness (as CaCO3)	Color (Pt-Co units)
			Hydrogeologic unit A				
Number of samples[1]	33	33	33	38	33	38	37
Maximum	29.0	7.8	735	478	624	370	90
Minimum	23.5	6.8	320	196	157	150	5
Mean	25.7	7.1	533	333	263	249	24
Standard deviation	1.5	.2	103	64	72	38	23
Median	25.5	7.1	525	332	253	250	10
10th percentile	23.7	6.9	399	245	221	209	5
90th percentile	27.5	7.3	691	431	296	290	60
			Hydrogeologic unit B				
Number of samples[1]	12	12	11	12	12	12	12
Maximum	26.0	8.0	1,027	574	512	450	80
Minimum	24.0	6.9	348	206	171	54	5
Mean	25.0	7.3	574	330	299	238	12
Standard deviation	.7	.4	244	121	101	97	22
Median	25.0	7.3	512	290	248	235	5
10th percentile	24.0	6.9	348	213	187	80	5
90th percentile	26.0	8.0	1,022	568	482	405	62
			Hydrogeologic unit C				
Number of samples[1]	25	25	25	26	24	26	26
Maximum	27.0	8.0	1,360	858	564	410	50
Minimum	24.0	6.8	318	197	164	67	5
Mean	25.3	7.2	713	426	362	270	7
Standard deviation	.8	.3	243	139	117	101	9
Median	25.0	7.2	686	424	334	280	5
10th percentile	24.0	6.9	385	235	233	112	5
90th percentile	26.2	7.7	1,069	590	540	393	10
			Hydrogeologic unit D				
Number of samples[1]	9	9	9	10	9	10	10
Maximum	26.5	8.2	1,890	1,160	488	400	30
Minimum	25.0	6.9	480	246	259	29	5
Mean	25.7	7.4	825	495	371	219	8
Standard deviation	.6	.4	420	253	95	106	8
Median	26.0	7.4	744	442	371	230	5
10th percentile	25.0	6.9	480	252	259	38	5
90th percentile	26.5	8.2	1,890	1,100	488	391	28
			Surficial aquifer system (all hydrogeologic units combined)				
Number of samples[1]	79	79	79	88	78	88	87
Maximum	29.0	8.2	1,890	1,160	624	450	90
Minimum	23.5	6.8	318	196	157	29	5
Mean	25.5	7.2	631	380	312	253	15
Standard deviation	1.1	.3	244	139	104	81	19
Median	25.5	7.2	585	345	270	250	5
10th percentile	24.0	6.9	394	242	223	149	5
90th percentile	27.0	7.6	889	524	488	380	50

Table 1.--Statistical summary of selected dissolved constituents in ground water from hydrogeologic units--Continued

	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Fluoride
Hydrogeologic unit A							
Number of samples[1]	38	38	38	38	38	38	38
Maximum	140	19	77	6.5	45	110	.5
Minimum	55	1.7	7.4	.2	.1	13	.1
Mean	90	5.6	26.6	2.4	14.6	42	.2
Standard deviation	14	4.2	16.0	1.8	15.4	23	.1
Median	92	4.2	26.5	1.8	6.2	39	.2
10th percentile	72	2.1	8.7	.5	.4	16	.1
90th percentile	110	12.2	50.3	5.9	38	81	.4
Hydrogeologic unit B							
Number of samples[1]	12	12	12	12	12	12	12
Maximum	150	26	[2]100	7.6	40	[2]99	.6
Minimum	10	2.7	7.0	.5	.1	11	.2
Mean	80	9.0	37.2	2.8	8.6	39	.3
Standard deviation	36	6.6	29.0	2.4	11.1	33	.1
Median	77	7.0	24.0	2.0	8	26	.3
10th percentile	18	2.8	7.9	.6	.1	12	.2
90th percentile	138	23.3	90.7	7.4	3.6	99	.6
Hydrogeologic unit C							
Number of samples[1]	26	26	26	26	26	26	26
Maximum	140	32	200	14	77	300	.8
Minimum	12	2.5	23	1.5	.1	13	.2
Mean	83	14.9	62	5.3	15.8	61	.4
Standard deviation	36	.7	42	3.3	18.0	60	.2
Median	88	14.0	50	4.4	10.4	41	.4
10th percentile	30	5.4	28	1.7	.2	15	.2
90th percentile	133	27.5	129	10.0	45.0	139	.6
Hydrogeologic unit D							
Number of samples[1]	10	10	10	10	10	10	10
Maximum	130	34	350	26	53	420	1.6
Minimum	7.0	2.8	25	2.2	2.4	15	.3
Mean	55.0	19.5	101	11.3	18.7	89	.4
Standard deviation	38.5	8.0	101	8.0	15.7	119	.4
Median	43.5	21.0	65	10.1	13	48	.6
10th percentile	8.3	3.8	26	2.3	2.6	16	.3
90th percentile	125.6	33.0	333	25.3	50.9	388	1.5
Surficial aquifer system (all hydrogeologic units combined)							
Number of samples[1]	88	88	88	88	88	88	88
Maximum	150	34	350	26	77	420	1.6
Minimum	7.0	1.7	7.0	.2	.1	11	.1
Mean	83.4	10.6	47.1	4.4	14.3	52	.3
Standard deviation	30.2	8.0	48.6	4.5	15.7	56	.2
Median	88.0	7.8	32.0	2.8	8.6	39	.3
10th percentile	36.9	2.7	9.2	.7	.2	15	.2
90th percentile	120.0	22.0	84.7	9.0	38.0	96	.5

[1] May include replicate samples.

[2] See page 17 for explanation of maximum concentrations of respective constituents.

waters in units A and B in northwestern Dade County generally have calcium-to-sodium ratios no greater than 1:1. In contrast, the mean calcium-to-sodium ratio of water for all wells developed in unit A is 6:1, clearly indicating water in which calcium is the dominant cation. The maximum calcium-to-sodium ratio (15:1) for unit A occurs at site 24 in southern Dade County. The minimum calcium-to-sodium ratio (1:1) for unit A occurs in water from a well at site 11 in northwestern Dade County. The mean, maximum, and minimum calcium-to-sodium ratios for units A and B (and units C and D) are shown in the following table:

	Unit A	Unit B	Unit C	Unit D
	Calcium-to-sodium ratio (milliequivalents per liter)			
Mean	5.8	4.9	2.2	1.4
Maximum	15.0	15.4	5.0	4.4
Minimum	1.1	.2	.2	.04

The similar mean calcium-to-sodium ratios of water from units A and B indicate the similarity of water from these units while establishing the dissimilarity of both to water from units C and D. As plate 2 shows, calcium sodium bicarbonate water in northwestern Dade County at depths less than 100 feet below land surface (units A and B; sites 3, 6, and 11) is similar in composition to water in southern Broward County (site B-2). Calcium sodium bicarbonate water occurs at depths less than 100 feet below land surface throughout much of southern Broward County. Dissolved solids concentrations of this ground water range from 409 to 534 mg/L (Howie, 1987). Dissolved solids concentrations of calcium sodium bicarbonate water from wells at sites 3, 6, and 11 in Dade County range from a minimum of 448 mg/L at site 3 to a maximum of 574 mg/L at site 6. The presence of similar calcium sodium bicarbonate water in the upper part of the surficial aquifer system in northwestern Dade County and southern Broward County suggests that some cation exchange may be occurring in both areas. Cation exchange occurs when calcium or magnesium ions in solution are exchanged for sodium ions. Sediments that have been exposed to seawater may contain a large amount of exchangeable sodium. When calcium already in solution in water encounters these sediments, it may be exchanged for sodium (Hem, 1985). The presence of ground water in northwestern Dade County, similar in composition to that found in Broward County, indicates that similar geochemical processes may be occurring in this part of the surficial aquifer system in Dade and Broward Counties.

Another factor which could contribute to the occurrence of calcium sodium bicarbonate water in northwestern Dade County is the possible southward migration of water from southern Broward County into Dade County. Ground-water movement in the shallow Biscayne aquifer in the conservation areas of Broward County (unit A in Dade County) is generally southward (Fish, 1987). There appears to be a general southward improvement in water quality from southern Broward County into northern Dade County (north of U.S. 41), continuing southward into Everglades National Park in southern Dade County. Dissolved solids concentrations of calcium bicarbonate water and calcium sodium bicarbonate water from wells finished in units A and B in northwestern Dade County range from 298 to 574 mg/L (pl. 2). South of U.S. 41, dissolved solids concentrations of water from wells finished in units A and B in this area produce calcium bicarbonate waters with dissolved solids concentrations of less than 400 mg/L.

The progressive southward freshening of ground water in units A and B and the predominance of calcium bicarbonate water in these units are probably due in part to the presence of permeable limestones of presumably high vertical hydraulic conductivity in Dade County which allows significant recharge of the aquifer. Recharge water enriched with carbon dioxide causes dissolution of carbonate materials, resulting in the occurrence of calcium bicarbonate waters. In contrast, infiltration of freshwater recharge in western Broward County is hindered by the presence of dense limestone and muddy or clayey sand (Fish, 1987). Downward leakage of freshwater recharge apparently has also diluted and displaced seawater which may have been present in units A and B of the surficial aquifer system in Dade County.

Unit C
(Limestone, Sandstone, and Sand Unit of the Tamiami Formation)

Waters associated with unit C are slightly more mineralized than those associated with units A and B. The mean dissolved solids concentration of water in unit C is 426 mg/L, as compared with 333 mg/L in unit A and 330 mg/L in unit B (table 1).

Throughout unit C in Dade County, four water types can be identified: Calcium bicarbonate, sodium bicarbonate, calcium sodium bicarbonate, and sodium chloride.

In unit C, the only area of Dade County where sodium chloride water occurs, other than those areas where unit C is influenced by saltwater intrusion (sites 9, 16, 21, 27, 28, 32, and 33), is in the vicinity of site 3. One well at site 3, finished 150 feet below land surface, produces sodium chloride water similar to that found at the same depth at a site in Broward County, 10.6 miles east-northeast. Howie (1987) states that sodium chloride water in Broward County may result from incomplete flushing of residual seawater.

In northwestern Dade County, unit C consists primarily of gray limestone (Causarás, 1987). Throughout most of northwestern Dade County, unit C contains either calcium sodium bicarbonate water or sodium bicarbonate water (pl. 2). Sodium bicarbonate water is found at sites 6, 12, 13, 19, and 23. Calcium sodium bicarbonate water occurs in Dade County at sites 5, 7, 13, 18, 19, and 23. At sites 5 and 6, water composition in unit C is similar to that in Broward County at the same depths (pl. 2) although slightly lower in dissolved solids and specific conductance. At site 13, calcium sodium bicarbonate water occurs at 73 feet below land surface, whereas sodium bicarbonate water occurs at 130 feet below land surface. At site 19, calcium sodium bicarbonate water occurs at 120 feet below land surface, whereas sodium bicarbonate water occurs at 160 feet below land surface (pl. 2).

In western Dade County at sites 4, 10, 11, 17, 26, and 29, wells finished in unit C produce calcium bicarbonate water (pl. 2). At sites 4 and 10, this water is present throughout the vertical extent of the surficial aquifer system (pl. 2).

Generally, in sodium bicarbonate water or calcium sodium bicarbonate water, the dominant cation in solution is sodium and concentrations of calcium and magnesium are less. The mean sodium concentration of water in unit C (62 mg/L) is higher than that found in unit A (26.6 mg/L); however, the mean calcium concentration in unit C (83 mg/L) is only slightly less than that in unit A (90 mg/L) (table 1). Calcium-to-sodium ratios of this sodium bicarbonate water are low, with a minimum ratio of 0.2:1 (see table on page 20). In those areas of unit C where calcium bicarbonate water does occur, calcium-to-sodium ratios range from 1.7:1 to 5.0:1, typical for this water type.

The predominance of calcium sodium bicarbonate water and sodium bicarbonate water in unit C is probably due in part to ion-exchange processes, involving the exchange of calcium ions for sodium ions through base-exchange reactions. In addition, the lithology of this unit tends to consist of more sand, shell, and sandstone than limestone. Because less carbonate material is present for dissolution, lower ratios of calcium to other cations may result. Calcite that is present in unit C is probably being dissolved, and calcium is entering into a base-exchange reaction with sodium which results in the occurrence of calcium sodium bicarbonate water in this unit. As was evident in units A and B, there appears to be a general southward freshening of ground water in unit C from northern Dade County into central and southern Dade County (pl. 2).

Unit D
(Lower Clastic Unit of the Tamiami Formation)

Unit D contains four water types: Calcium bicarbonate, sodium bicarbonate, calcium sodium bicarbonate, and sodium chloride.

Several sites in northwestern Dade County (sites 3, 5, and 12) produce primarily sodium chloride water, similar to that found in southern Broward County at sites B-1 and B-2 (pl. 2). Sodium chloride water in northern Dade County and southern Broward County probably results from incomplete flushing of residual seawater in zones of low permeability or restricted ground-water circulation.

In western Dade County (sites 4, 10, 17, and 26), unit D contains calcium bicarbonate water or calcium sodium bicarbonate water (pl. 2). In those areas of central and southern Dade County (generally east of the Florida Turnpike and south of U.S. 41) not affected by saltwater intrusion, sodium bicarbonate water is predominant. Water from one well finished in unit D at site 14, located near U.S. 41 and the Florida Turnpike in central Dade County, contains magnesium sodium calcium bicarbonate water. As the Stiff diagram for this well shows, the predominant cation is magnesium and the predominant anion is bicarbonate. The calcium-to-magnesium ratio for water in unit D is 1.9:1. Variations in calcium-to-magnesium ratios are probably affected by local variations in lithology. C.R. Causaras (U.S. Geological Survey, oral commun., 1986) indicates that small amounts of dolomitic rock (containing magnesium carbonates) are present throughout parts of the surficial aquifer system. The presence of high magnesium concentrations in ground water relative to both calcium and sodium (such as occurs at site 14) may indicate the presence and dissolution of dolomitic rock.

Statistical Comparison of Selected Constituents in the Hydrogeologic Units

Further differentiation between water types in the hydrogeologic units was determined by a statistical comparison of selected water-quality constituents by analysis of variance (ANOVA). The constituents analyzed were: (1) Dissolved solids, an indicator of the degree of mineralization of water; (2) calcium and sodium, cations predominant in ground water in Dade County; and (3) chloride and iron, ions relevant in the determination of water potability. Planned contrasts between the four hydrogeologic units and within selected units were tested.

The following table shows the results of the statistical comparison of selected constituents between the four hydrogeologic units:

Constituent[1]	Significant difference exists between units listed below ($\alpha=0.05$)	No significant difference exists between units listed below ($\alpha=0.05$)
Dissolved solids	A and C; A and D	A and B
Calcium	A and D	A and B; A and C
Sodium	A and C; A and D	A and B
Chloride	A and D	A and B; A and C
Iron[2]	A and C	A and B; A and D

The ANOVA indicates that water in units A and B (based on the constituents utilized in the ANOVA) are not significantly different in composition. Stiff diagrams in plate 2 for wells developed in units A and B show that calcium bicarbonate water is predominant throughout most of Dade County in these two units.

Several ground-water constituents in unit A are significantly different from those in units C and D. Mean concentrations of dissolved solids, sodium, and iron are significantly different between units A and C, but mean concentrations of calcium and chloride are not. Plate 2 shows that both calcium bicarbonate and sodium bicarbonate water occurs in unit C. Mean concentrations of dissolved solids, sodium, calcium, and chloride are also significantly different between units A and D.

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[1] All constituents are dissolved.

[2] Values less than detection limit were set to detection limit.

A second ANOVA was performed to determine whether significant differences of mean concentrations of selected ground-water constituents within two of the hydrogeologic units (units A and C) occur between sites in northwestern Dade County and sites in the rest of the county (not including sites influenced by saltwater intrusion). The results of the ANOVA are shown below. (Units B and D were not considered in this analysis due to the limited number of sites in these two units.)

Constituent[1]	Units in which significant differences exist between sites in northwestern Dade County and the rest of the county (α=0.05)	Units in which no significant differences exist between sites in northwestern Dade County and the rest of the county (α=0.05)
Dissolved solids	A; C	--
Calcium	--	A; C
Sodium	A; C	--
Chloride	A; C	--
Iron[2]	--	A; C

The ANOVA indicates that mean concentrations of dissolved solids, sodium, and chloride at sites developed in both units A and C in northwestern Dade County are significantly different than the mean concentrations of these constituents at sites throughout the rest of the county.

It is apparent from the areas and depths at which the various water types occur that the quality of water in the surficial aquifer system in Dade County is largely influenced by the occurrence of residual seawater and to what extent the residual seawater has been diluted or flushed from the aquifer system. In northwestern Dade County, the low permeability silts and sands of unit B, where present, have apparently retarded the infiltration of fresh recharge water from unit A to parts of units B, C, and D. This results in the occurrence of water with high dissolved solids of calcium sodium bicarbonate, sodium bicarbonate, or sodium chloride water types. In those areas where unit B is absent (primarily central Dade County), more complete flushing of residual seawater from units C and D has occurred and dissolved solids are lower. Water in units C and D in these areas is generally a calcium sodium bicarbonate or sodium bicarbonate water type.

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[1] All constituents are dissolved.

[2] Values less than detection limit were set to detection limit.

General Potability of Ground Water in Dade County with Respect to Drinking Water Standards

A comparison of maximum concentrations of selected constituents from the four hydrogeologic units comprising the surficial aquifer system with Primary and Secondary Drinking Water Regulations maximum contaminant levels, established by the Florida Safe Drinking Water Act (Florida Department of Environmental Regulation, 1982), is given in table 2. Also shown in table 2 is the percentage of samples that exceed the maximum contaminant levels. These regulations adopt the National Primary and Secondary Drinking Water Regulations of the Federal Government (U.S. Environmental Protection Agency, 1983), where possible, and otherwise create additional regulations fulfilling State and Federal requirements (Florida Department of Environmental Regulation, 1982). The Primary Drinking Water Regulations establish mandatory limits and apply to the physical and chemical characteristics of water that affect the health of consumers. They are applicable to all public water systems and are enforceable by the U.S. Environmental Protection Agency or the State. The Secondary Drinking Water Regulations establish recommended limits and deal with the esthetic qualities of drinking water. They are not Federally enforceable and are intended as guidelines for regulation by the State. The Florida Department of Environmental Regulation (1982) requires that all potable ground waters shall meet the minimum standards of the Primary and Secondary Drinking Water Regulations standards.

The maximum concentrations of most of these constituents for each hydrogeologic unit are below the maximum contaminant levels of the Florida Primary and Secondary Drinking Water Regulations. However, in some hydrogeologic units, the maximum concentrations of sodium, chloride, color, fluoride, iron, and dissolved solids exceed the respective maximum contaminant levels.

Dissolved Solids

Dissolved solids is a measure of all the dissolved constituents in water. The sum of the concentration, in milligrams per liter, of individual constituents approximates the measured dissolved solids concentration, hence, the degree of mineralization. The dissolved solids concentration of each well developed at the Dade County test sites is shown in plate 2 beside each well's respective Stiff diagram.

Of the four hydrogeologic units comprising the surficial aquifer system in Dade County, unit B had the lowest mean (table 1, 330 mg/L). Dissolved solids concentrations in unit B ranged from 206 to 574 mg/L. The mean dissolved solids concentration of unit A (333 mg/L) was similar to that of unit B. In Dade County, dissolved solids concentrations in both units A and B generally increase to the northwest. A maximum dissolved solids concentration of 574 mg/L, which exceeds the Florida Secondary Drinking Water Regulations standard of 500 mg/L, was found at site 6 in one well developed in unit B in northwestern Dade County. Dissolved solids concentrations in units A and B in northwestern Dade County typically range from 298 to 574 mg/L, indicating the presence of more highly mineralized water in this area.

Table 2.--Comparison of maximum concentrations of dissolved constituents in water from hydrogeologic units with State of Florida drinking water maximum contaminant levels and percentage of samples that exceed maximum contaminant levels[1]

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation; S, surficial aquifer system. mg/L, milligrams per liter; °C, degrees Celsius; Pt-Co, platinum-cobalt; MCLs, maximum contaminant levels for drinking water, established by State of Florida, Department of Environmental Regulation. Table does not include samples of water from wells at sites affected by saltwater intrusion; concentrations shown in micrograms per liter, except where noted.]

	Hydrogeologic unit (see fig. 3)	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Sodium (mg/L)	Nitrate (total as N in mg/L)
Primary drinking water regulations MCLs[1]		50	1,000	10	50	50	2	160	10.0
Maximum	A	2	100	3	10	6	.3	77	3.4
Percentage of samples that exceed MCLs.		0	0	0	0	0	0	0	0
Maximum	B	16	100	1	10	3	.3	[2]300	<.1
Percentage of samples that exceed MCLs.		0	0	0	0	0	0	8	0
Maximum	C	11	100	2	10	4	.6	200	<.1
Percentage of samples that exceed MCLs.		0	0	0	0	0	0	10	0
Maximum	D	3	100	1	10	2	1.5	350	<.1
Percentage of samples that exceed MCLs.		0	0	0	0	0	0	21	0
Maximum	S	16	100	3	10	6	1.5	350	3.4
Percentage of samples that exceed MCLs.		0	0	0	0	0	0	7	0

	Hydrogeologic unit (see fig. 3)	Dissolved solids[3] (residue at 180 °C)	Iron	Manganese	Zinc	Sulfate (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Color (Pt-Co units)
Secondary drinking water regulations MCLs[1]		500	300	50	5,000	250	250	1.4	15
Maximum	A	478	1,900	30	30	45	110	.5	90
Percentage of samples that exceed MCLs.		0	57	0	0	0	0	0	47
Maximum	B	574	2,900	20	50	40	[2]600	.6	80
Percentage of samples that exceed MCLs.		25	42	0	0	0	8	0	17
Maximum	C	858	1,300	10	320	77	300	.8	50
Percentage of samples that exceed MCLs.		16	14	0	0	0	3	0	6
Maximum	D	1,160	830	10	70	53	420	1.6	30
Percentage of samples that exceed MCLs.		29	36	0	0	0	14	7	7
Maximum	S	1,160	2,900	30	320	77	420	1.6	90
Percentage of samples that exceed MCLs.		13	41	0	0	0	4	1	25

[1] See page 25 for explanation of difference between Primary and Secondary Drinking Water Regulations.

[2] See page 17 for explanation of maximum concentrations of respective constituents.

[3] Concentrations may be greater if no other maximum contaminant level is exceeded (Florida Department of Environmental Regulation, 1982).

Water associated with units C and D was slightly more mineralized than water associated with units A and B as indicated by higher mean dissolved solids concentrations (table 1). The mean dissolved solids concentration for unit C was 426 mg/L and for unit D was 495 mg/L (table 1). Maximum dissolved solids concentrations in both unit C (858 mg/L) and unit D (1,160 mg/L) occur at sites in northwestern Dade County and exceed the Florida Secondary Drinking Water Regulations standard of 500 mg/L.(table 2).

Chloride

The potability of uncontaminated ground water is largely determined by the concentrations of major ions in solution. In south Florida, dissolved chloride is usually the limiting ion. Mean chloride concentrations in the four hydrogeologic units (table 1) are less than 100 mg/L and do not exceed the Florida Secondary Drinking Water Regulations standard of 250 mg/L. However, several sites (3, 5, 6, 11, 12, and 17) in northwestern Dade County (fig. 1) have individual chloride concentrations (table 3) which exceed the drinking water standard. Most of these wells are developed in units C and D and are unlikely to be developed as a source of water for drinking water supply. As mentioned previously, ground water in this area of Dade County tends to have higher specific conductance values and higher dissolved solids, chloride, and sodium concentrations than the rest of the county. The occurrence of this more mineralized water probably results from incomplete flushing of residual seawater from the surficial aquifer system in this area and from ion-exchange processes in conjunction with additional calcite solution.

Color

Color in ground water may be partly derived from the leaching of decaying vegetation in the surface environment or from carbonaceous material in an aquifer system. The determination of color is mainly significant in the evaluation of water supplies for potability where color is not desirable (Hem, 1985). The mean color value of the surficial aquifer system (15 Pt-Co [platinum-cobalt] units) slightly exceeds the Florida Secondary Drinking Water Regulations standard of 15 Pt-Co units (table 2); however, the mean color value in unit A (table 1, 24 Pt-Co units) exceeds the drinking water standard to a much greater extent. The highest color values were found in wells beneath the water-conservation areas and The Everglades (except for site 8, table 3) and are probably caused by the leaching of decaying vegetation. Color values were generally much lower (5-10 Pt-Co units) in coastal areas.

In unit B, water from wells at sites 19 and 23 (table 3) near The Everglades had color values that exceeded the Florida Secondary Drinking Water Regulations standard (table 2).

In units C and D, mean color values (table 1) generally did not exceed the Florida Secondary Drinking Water Regulations standard (table 2). Only at site 3 (in unit C) did the color value of 50 Pt-Co units (table 3) exceed the Florida Secondary Drinking Water Regulations standard.

Table 3.--Supplementary water-quality data for wells completed in the surficial aquifer system

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. °C, degrees Celsius; µS/cm, microsiemens per centimeter; CaCO3, calcium bicarbonate; Pt-Co, platinum-cobalt. Table does not include replicate sample data nor are all data in table necessarily included in statistical analyses; temperature, pH, specific conductance, and alkalinity were measured in the field at the time of sampling; wells marked with an asterisk are affected by saltwater; concentrations shown in milligrams per liter, except where noted; -- represents no data were collected.]

Site/ well No.	Hydro- geologic unit	Well depth (feet)	Temper- ature (°C)	pH (units)	Specific conductance (µS/cm)	Dissolved solids residue (at 180 °C)	Alkalinity (as CaCO3)	Hardness (as CaCO3)	Color (Pt-Co units)
B-1	C	60	--	7.0	1,660	964	440	320	0
B-1	C	100	--	7.1	1,650	960	440	330	0
B-1	C	140	--	7.6	1,550	847	364	260	0
B-2	A	39	21.0	--	635	431	284	270	40
B-2	C	99	27.0	7.3	920	526	382	250	10
B-2	C	149	27.0	7.4	1,120	652	385	200	10
B-2	C	179	29.0	7.4	2,880	1,580	402	300	10
D-1	A	70	--	7.2	770	465	266	280	40
D-1	C	110	--	7.1	690	402	243	260	30
D-1	C	150	--	7.1	1,160	--	253	320	10
D-2	A	30	--	7.1	580	336	200	230	0
D-2	A	70	--	7.0	635	365	223	250	0
3A	A	30	23.5	7.3	680	448	296	240	50
3B	C	78	24.0	7.3	686	450	304	240	50
3C	C	150	24.0	7.4	1,360	858	243	320	5
4A	B	20	25.0	7.0	580	330	380	300	5
4B	C	70	25.0	6.9	806	490	528	400	5
4C	C	130	25.5	7.0	838	470	564	410	5
4D	D	220	26.0	7.0	805	480	488	310	5
5	D	191	26.0	7.4	1,890	1,160	456	220	5
5A	A	20	28.5	7.1	628	398	276	270	50
5B	B	56	25.5	7.1	580	298	364	280	5
5C	C	144	26.0	7.1	928	524	453	320	5
6A	A	26	24.5	7.1	670	396	228	250	50
6B	B	67	24.5	7.0	1,027	574	512	300	5
6C	C	90	24.5	7.0	1,280	732	552	330	10
7	D	166	24.5	--	379	330	--	106	5
7A	A	27	23.5	7.2	622	382	624	260	60
7B	A	57	24.0	7.0	606	398	296	250	60
7C	C	117	24.5	7.4	647	368	268	190	10
8*	D	290	25.5	7.2	2,250	2,010	296	580	5
8A	A	50	27.5	7.0	535	331	260	220	10
8B	A	90	26.5	6.9	550	334	276	240	30
8C	C	160	26.5	7.4	1,345	828	288	220	5
9B*	A	36	27.0	7.1	731	478	196	310	10
9C*	A	100	25.0	7.7	7,730	6,110	164	1,300	5
9D	A	60	26.0	7.1	716	430	212	260	10
10	D	173	25.0	6.9	744	420	472	400	5
10A	B	29	25.0	7.2	371	230	248	190	5
10B	C	70	25.0	6.8	678	430	488	380	5
10C	C	130	25.0	7.0	797	450	516	390	5
11A	A	14	24.0	7.3	735	478	292	260	60
11B	C	84	27.0	7.0	808	426	480	340	5
11C	C	123	25.0	7.0	829	456	472	380	5
12	D	182	25.0	--	1,283	743	207	79	10
12A	A	20	25.0	6.9	615	372	328	250	50
12B	B	70	25.0	7.4	700	399	336	220	5
12C	C	130	25.5	7.5	889	529	332	180	5
13	D	186	25.0	7.6	903	564	444	140	5
13A	A	30	23.5	7.4	531	326	244	220	60
13B	C	73	24.0	7.4	650	366	280	200	5
13C	C	130	24.0	7.6	646	406	280	150	5
14	D	177	26.0	7.3	557	426	295	240	5
14A	A	23	25.0	6.8	394	336	269	250	40
14B	A	60	26.5	7.2	482	312	243	250	30
14C	C	120	26.0	6.9	686	484	397	390	5
15	D	215	26.0	7.1	362	218	--	--	1
15A	A	43	26.0	6.9	585	320	--	330	5
15B	C	97	25.5	7.1	556	422	361	330	5
15C	C	63	25.5	7.2	515	344	269	260	10
15D	C	130	25.5	7.2	687	450	364	330	5

Table 3.--Supplementary water-quality data for wells completed in the surficial aquifer system--Continued

Site/ well No.	Hydro- geologic unit	Well depth (feet)	Temper- ature (°C)	pH (units)	Specific conductance (μS/cm)	Dissolved solids residue (at 180 °C)	Alkalinity (as CaCO3)	Hardness (as CaCO3)	Color (Pt-Co units)
16*	D	215	27.5	7.0	12,510	12,400	280	2,500	10
16A	A	33	27.5	7.3	530	312	256	240	5
16B	C	60	26.5	6.8	595	346	285	270	5
16C*	C	87	26.0	8.0	7,410	7,800	239	1,600	5
17	D	170	26.0	7.2	580	360	269	260	5
17A	A	14	26.5	7.1	604	380	256	260	30
17B	B	50	26.5	7.0	2,250	1,600	354	690	5
17C	C	130	26.0	7.2	585	350	289	270	5
18A	A	22	24.0	7.2	500	258	232	190	5
18B	B	59	24.0	7.3	508	272	244	220	5
18C	C	133	24.0	--	319	176	192	88	5
19	D	217	25.0	7.5	480	302	259	120	5
19A	A	23	26.5	7.3	457	294	256	260	30
19B	B	53	25.5	7.3	435	282	249	250	20
19C	C	120	24.0	7.9	412	258	226	140	5
19D	C	160	24.5	8.0	393	242	223	93	5
20A	A	28	25.0	7.8	435	294	285	290	5
20B	A	67	24.5	7.3	415	278	253	250	5
21	D	213	26.0	7.4	435	246	216	--	5
21A	A	27	27.0	7.0	525	340	253	250	5
21B	A	53	26.5	6.9	525	334	239	240	5
21C*	C	110	26.0	6.9	3,690	3,070	223	860	5
23A	A	30	25.5	7.2	525	330	268	230	40
23B	B	64	24.5	7.3	348	240	223	190	80
23C	C	190	25.5	7.7	372	220	248	67	5
24	D	190	25.5	8.2	750	530	289	29	30
24A	A	30	25.5	7.2	485	344	220	290	5
24B	A	70	25.5	7.2	405	332	226	290	5
24C	C	117	26.0	7.5	475	334	256	160	5
25*	D	180	26.5	6.6	12,890	15,500	223	3,700	5
25A	A	30	26.5	6.8	583	386	296	370	5
25B*	A	50	26.0	6.8	1,265	1,010	174	340	5
25C*	C	110	25.5	6.7	14,230	16,000	226	3,700	5
26	D	175	26.5	7.3	720	458	371	290	5
26A	A	20	27.5	7.1	699	444	244	290	90
26B	B	64	26.0	7.0	1,000	554	413	450	5
26C	C	130	25.5	7.2	799	398	335	290	5
27*	D	213	25.0	9.1	4,020	3,710	--	980	5
27A	C	23	24.0	6.8	395	220	240	200	20
27B*	C	90	25.0	7.2	3,930	3,000	190	860	5
27C*	C	150	24.0	7.5	4,050	3,200	156	1,000	5
28*	D	223	24.5	7.4	2,030	1,540	208	510	5
28A	A	23	25.0	7.3	393	222	272	210	10
28B*	B	77	25.0	7.1	1,500	1,380	192	460	50
28C*	C	161	25.0	7.2	1,500	1,814	192	520	--
29	D	240	25.5	--	350	198	--	35	5
29A	A	30	27.0	7.1	450	278	223	220	5
29B	B	81	26.0	8.0	350	206	171	54	5
29C	C	181	26.0	7.7	318	197	164	120	5
30	B	86	25.0	6.9	512	314	223	260	5
30A	A	20	25.0	7.1	446	318	239	260	5
30B	A	50	25.0	7.1	493	316	243	260	5
31A*	A	23	27.0	6.9	2,540	1,760	374	530	60
32*	C	168	27.0	6.7	18,560	22,300	268	4,000	5
32A*	A	18	27.5	6.8	19,590	17,800	352	3,500	30
33*	D*	212	25.5	7.5	6,050	5,440	112	1,400	5
33A	A	30	26.0	7.0	577	332	249	230	10
33B*	C	100	26.0	7.1	2,620	2,510	82	1,300	5
33C*	C	160	25.5	7.8	4,870	4,760	69	1,800	5
34*	D	238	27.0	7.2	1,645	1,410	203	540	5
34A	A	18	29.0	7.2	320	196	157	150	20
34B	A	30	27.5	7.1	456	268	230	210	20
34C*	A	60	26.0	6.9	22,500	22,900	262	4,700	20
34D*	C	90	27.0	7.3	881	624	144	320	5

Table 3.--Supplementary water-quality data for wells completed in the surficial aquifer system--Continued

Site/ well No.	Hydro- geologic unit	Calcium (dis- solved)	Magnesium (dis- solved)	Sodium (dis- solved)	Potassium (dis- solved)	Chloride (dis- solved)	Sulfate (dis- solved)	Fluoride (dis- solved)
B-1	C	80	30	210	14	240	62	0.5
B-1	C	82	30	220	14	250	62	.5
B-1	C	56	28	210	13	240	63	.5
B-2	A	80	16	52	3.4	74	21	.4
B-2	C	70	19	95	7.7	68	16	.4
B-2	C	44	22	160	14	110	34	.5
B-2	C	56	39	470	40	680	68	.7
D-1	A	84	16	60	3.7	87	14	.5
D-1	C	92	7.4	41	2.2	69	13	.4
D-1	C	100	17	110	4.1	190	--	.5
D-2	A	84	5.1	25	4.2	38	29	.3
D-2	A	96	3.1	25	6.4	41	50	.2
3A	C	72	14	65	3.0	95	.6	.4
3B	C	75	13	66	2.8	96	.6	.4
3C	C	71	31	200	14	300	77	.4
4A	B	110	6.8	11	.8	17	.1	.3
4B	C	140	13	42	1.5	37	3.2	.3
4C	C	140	14	43	2.1	40	4.8	.3
4D	D	86	22	72	14	97	4.8	.7
5	D	48	24	350	26	420	53	.6
5A	A	86	12	44	2.3	64	11	.4
5B	B	100	6.5	21	.7	33	0.2	.3
5C	C	92	20	110	7.8	87	11	.4
6A	A	85	8.8	43	1.8	67	1.0	.4
6B	B	76	26	100	7.6	98	11	.5
6C	C	86	26	150	8.5	160	29	.4
7	D	18	15	60	20	39	31	.9
7A	A	96	5.9	27	.6	47	1.0	.3
7B	A	92	5.6	27	.6	45	1.0	.3
7C	C	45	18	64	10	50	6.4	.4
8*	D	110	72	520	14	740	350	.6
8A	A	84	3.1	29	2.0	38	33	.2
8B	A	90	4.0	32	1.1	42	31	.3
8C	C	56	19	210	3.4	250	120	.3
9B	A	120	3.0	37	3.3	100	29	.2
9C*	A	370	84	1,600	16	3,000	250	.2
9D	A	95	4.2	50	3.0	87	38	.2
10	D	130	18	34	4.4	35	2.4	.4
10A	B	73	2.7	10	.5	15	.8	.2
10B	C	130	14	32	1.7	34	7.2	.2
10C	C	130	16	33	2.2	35	3.6	.3
11A	A	72	18	77	4.4	110	28	.5
11B	C	110	15	48	3.2	53	.1	.2
11C	C	120	18	52	4.8	57	.2	.2
12	D	15	10	240	22	290	56	.4
12A	A	90	5.9	36	.8	57	1.2	.2
12B	B	74	7.5	69	1.9	77	11	.3
12C	C	57	9.3	120	7.8	130	15	.4
13	D	20	21	140	18	85	30	.8
13A	A	81	5.2	27	.9	45	.4	.2
13B	C	58	14	64	4.1	46	17	.5
13C	C	32	18	83	10	42	20	.7
14	D	39	34	47	19	50	12	1.6
14A	A	92	4.5	25	.5	43	.1	.3
14B	A	92	4.6	22	.5	38	.8	.2
14C	C	100	32	39	6.6	51	3.2	.4
15	D	74	1.0	6	3.8	8	30	.1
15A	A	98	19	30	2.2	38	.5	.3
15B	C	100	19	30	2.0	37	.1	.3
15C	C	100	2.5	23	4.2	29	34	.2
15D	C	90	25	46	5.6	59	3.2	.3
16*	D	340	390	3,500	96	6,600	640	.5
16A	A	90	2.9	26	2.7	31	22	.3

Table 3.--Supplementary water-quality data for wells completed in the surficial aquifer system--Continued

Site/ well No.	Hydro- geologic unit	Calcium (dis- solved)	Magnesium (dis- solved)	Sodium (dis- solved)	Potassium (dis- solved)	Chloride (dis- solved)	Sulfate (dis- solved)	Fluoride (dis- solved)
16B	C	100	3.5	28	1.6	39	27	0.2
16C*	C	420	130	2,000	26	3,900	270	.1
17	D	83	13	32	2.8	39	21	.3
17A	A	92	7.4	37	1.4	57	.8	.2
17B	B	240	20	300	2.9	600	92	.1
17C	C	86	13	29	2.5	39	7.2	.4
18A	A	70	3.8	20	2.6	33	6.4	.2
18B	B	78	6.6	27	1.2	31	.8	.3
18C	C	25	6.2	34	5.6	11	18	.8
19	D	21	17	70	6.7	15	10	.4
19A	A	94	5.4	15	1.1	22	4.4	.2
19B	B	94	4.7	7	1.1	18	6.4	.2
19C	C	37	11	46	3.7	13	12	.4
19D	C	25	7.3	55	8.7	13	11	.5
20A	A	110	2.6	8	1.8	13	23	.1
20B	A	96	2.8	8	1.2	15	19	.2
21	D	36	22	25	2.2	24	7.6	.5
21A	A	94	2.5	30	4.0	47	25	.2
21B	A	93	2.5	30	3.6	45	24	.1
21C*	C	220	75	730	13	1,500	120	.3
23A	A	81	6.4	30	1.5	40	6.4	.2
23B	B	62	8.9	21	2.2	22	.2	.2
23C	C	12	8.9	60	4.6	13	13	.8
24	D	7	2.8	180	13	47	32	1.0
24A	A	110	3.2	8	6.5	19	43	.2
24B	A	110	3.2	8	6.5	17	45	.1
24C	C	47	11	61	8.9	16	45	.5
25*	D	800	420	4,100	70	8,100	640	.2
25A	A	140	4.1	27	5.9	49	34	.2
25B*	A	120	9.2	170	7.3	350	40	.2
25C*	C	750	450	4,200	80	8,200	680	.2
26	D	80	21	60	7.2	79	14	.3
26A	A	94	12	53	2.4	80	.6	.5
26B	B	150	17	63	2.5	99	11	.4
26C	C	98	11	70	3.4	80	16	.3
27*	D	250	86	880	49	2,000	180	.2
27A	C	75	1.7	7	.2	16	.1	.1
27B*	C	190	92	680	23	1,400	190	.2
27C*	C	250	90	670	14	1,600	160	.2
28*	D	130	45	360	12	750	78	.3
28A	A	82	2.1	9	.3	18	.2	.2
28B*	B	140	27	250	3.4	600	32	.1
28C*	C	150	33	400	7.1	790	81	.5
29	D	12	1.2	61	13	13	15	.7
29A	A	80	4.4	17	1.0	26	4.8	.2
29B	B	10	7.1	53	7.1	11	9.6	.6
29C	C	39	6.2	27	2.1	18	9.8	.4
30	B	100	3.1	19	4.5	29	40	.2
30A	A	100	3.0	19	5.1	29	38	.2
30B	A	100	3.0	19	5.2	29	38	.1
31A*	A	120	56	410	15	750	88	.2
32*	C	290	800	6,150	190	12,000	1,200	.3
32A*	D	290	680	5,000	140	9,400	1,200	.3
33*	D	240	200	1,200	30	2,900	98	.4
33A	A	86	4.6	31	1.6	53	4.8	.2
33B*	C	450	37	230	11	1,200	7.2	.3
33C*	C	420	190	720	26	2,400	37	.3
34*	D	140	44	220	3.8	570	52	.3
34A	A	55	3.0	10	1.4	21	3.0	.2
34B	A	69	8.9	19	2.4	31	6.0	.2
34C*	A	550	800	6,600	170	12,000	1,500	.3
34D*	C	76	30	62	2.2	230	6.2	.4

Nutrients

Mean concentrations of nutrients found in Dade County ground water are shown in table 4. Mean concentrations of nitrate, nitrite, phosphorus, and orthophosphate are low (generally less than 0.10 mg/L), whereas ammonia and organic nitrogen concentrations are higher and show more variability (table 4). None of the well sites had nitrate concentrations that exceeded 10 mg/L, the Florida Primary Drinking Water Regulations standard (table 2).

The highest mean concentrations of organic nitrogen and ammonia occur in units A and B (table 4). In unit A, mean ammonia concentrations in proportion to organic nitrogen concentrations are generally higher in the urbanized eastern and southeastern areas of Dade County (table 5, sites 8, 9, 16). In a study of water quality in selected areas of Dade County serviced by septic tanks, Pitt and others (1975, p. 60) observed similar proportions of ammonia and organic nitrogen in these areas of the county. Wells developed in unit A at sites 18 and 24, located near recreational areas serviced by septic tanks and adjacent to areas of high agricultural activity, had the highest nitrate plus nitrite concentrations (0.98 and 3.40 mg/L, respectively) found in Dade County. Site 18 had approximate equal concentrations of organic nitrogen and nitrate (0.88 and 0.97 mg/L, respectively). Higher concentrations of organic nitrogen in proportion to ammonia were observed in most of western and northern Dade County beneath the water-conservation areas (table 5, sites 3, 7, 11, 18, and 26). The mean concentration of ammonia nitrogen in unit B was similar to that found in unit A (table 4).

Similar trends of nitrogen species composition were found in unit C. Concentrations of organic nitrogen and ammonia nitrogen were highest at sites 3 and 15, respectively. At site 3, adjacent to Water Conservation Area 3B in northwestern Dade County, the concentration of organic nitrogen was 1.1 mg/L, whereas the concentration of ammonia nitrogen was 0.26 mg/L (table 5). At site 15, located in an urbanized area in eastern Dade County, the concentration of ammonia nitrogen was 2.3 mg/L, whereas the concentration of organic nitrogen was 0.20 mg/L (table 5). Nitrate plus nitrite concentrations in this hydrogeologic unit were generally 0.10 mg/L or less.

Mean concentrations of ammonia nitrogen and organic nitrogen were lowest in unit D (table 4). Highest concentrations of ammonia nitrogen and organic nitrogen seem to occur in northwestern Dade County beneath the water conservation areas.

Iron

Much of the ground water in the surficial aquifer system of Dade County has dissolved iron concentrations above 300 μg/L, the Florida Secondary Drinking Water Regulations standard (Florida Department of Environmental Regulation, 1982). However, concentrations vary widely both areally and with depth. The mean iron concentration for the surficial aquifer system is 416 μg/L and ranges from less than 10 to 2,900 μg/L (table 6).

In unit A, iron concentrations ranging from less than 10 to 1,900 μg/L seem to be higher and more variable in the western part of Dade County (those

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Table 4.--Statistical summary of dissolved nutrients in water from hydrogeologic units

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. Means and standard deviations for organic nitrogen, nitrite nitrogen, nitrite + nitrate nitrogen, and orthophosphate were estimated using log-probability regression method, and medians for these same nutrients were estimated using log-normal maximum-likelihood estimation (Helsel and Gilliom, 1985); concentrations shown in milligrams per liter; -- represents no data were collected.]

	Organic nitrogen	Ammonia nitrogen	Nitrite nitrogen	Nitrite + nitrate nitrogen	Phosphorus	Orthophosphate	Organic carbon
Hydrogeologic unit A							
Number of samples[1]	36	36	[2]36	[2]36	36	36	35
Maximum	1.7	1.9	.01	3.4	.07	.05	74
Minimum	.00	.02	<.01	<.01	.01	.01	1
Mean	.53	.47	--	--	.02	.011	11.7
Standard deviation	.49	.45	--	--	.01	.009	14.3
Median	.32	.33	--	--	.02	.01	6.3
10th percentile	.08	.02	--	--	.01	--	1.3
90th percentile	1.42	1.02	--	--	.03	--	23.4
Hydrogeologic unit B							
Number of samples[1]	12	12	[2]12	[3]12	12	[4]12	12
Maximum	.60	1.2	.01	.03	.04	.02	10
Minimum	.02	.07	<.01	<.02	.01	.01	1.2
Mean	.25	.46	--	--	.022	--	4.5
Standard deviation	.22	.40	--	--	.008	--	2.6
Median	.24	.34	--	--	.020	--	4.2
10th percentile	.020	.07	--	--	.010	--	1.4
90th percentile	.585	1.20	--	--	.307	--	9.2
Hydrogeologic unit C							
Number of samples[1]	24	25	[2]25	[2]25	25	24	25
Maximum	1.1	2.3	.01	.10	.06	.03	74
Minimum	.00	.01	<.01	<.01	.01	.01	.6
Mean	.25	.32	--	--	.023	.011	10.0
Standard deviation	.22	.46	--	--	.010	.006	17.4
Median	.25	.23	--	--	.020	.01	5.0
10th percentile	.0	.05	--	--	.010	--	1.0
90th percentile	.47	.72	--	--	.030	--	41.4
Hydrogeologic unit D							
Number of samples[1]	10	10	[3]10	[3]10	10	10	10
Maximum	.33	.38	.01	.07	.04	.04	55
Minimum	.00	.05	<.01	<.02	.01	.01	.7
Mean	.12	.159	--	--	.23	.017	8.1
Standard deviation	.094	.100	--	--	.011	.014	16.5
Median	.105	.135	--	--	.020	.01	3.2
10th percentile	<.01	.053	--	--	.010	--	.8
90th percentile	.32	.365	--	--	.040	--	50.0
Surficial aquifer system (all hydrogeologic units combined)							
Number of samples[1]	82	83	[2] [3]83	[2] [3]83	83	82	82
Maximum	1.7	2.3	.01	3.4	.07	.05	74
Minimum	.00	.01	<.01	<.01	.01	.01	.6
Mean	.36	.39	--	--	.022	.012	9.7
Standard deviation	.39	.43	--	--	.010	.008	14.6
Median	.25	.23	--	--	.020	.01	4.5
10th percentile	.01	.05	--	--	.010	--	1.3
90th percentile	.91	.92	--	--	.030	--	22.1

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[1] May include replicate samples.
[2] Percent of observations less than detection limit exceed 88 percent.
[3] All detected observations have same value.
[4] Detected observations have one of two values.

Table 5.--Supplementary water-quality data for wells completed in the surficial aquifer system

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. Table does not include replicate sample data nor are all data in table necessarily included in statistical analyses; wells marked with an asterisk are affected by saltwater; all constituents are dissolved, except suspended organic carbon; concentrations shown in milligrams per liter; -- represents no data were collected.]

Site/ well No.	Hydro- geologic unit	Organic nitrogen	Ammonia nitrogen	Nitrite nitrogen	Nitrite + nitrate nitrogen	Phosphorus	Ortho- phosphate	Dissolved organic carbon	Suspended organic carbon
3A	A	1.1	0.23	<0.01	<0.02	0.02	0.02	74	0.2
3B	C	1.1	.26	<.01	<.02	.00	.01	74	.2
3C	C	.01	.12	<.01	<.02	.02	.01	51	.1
4A	B	.55	.75	<.01	<.02	.03	.01	6.5	.2
4B	C	.26	.46	<.01	<.02	.03	.01	6.0	.2
4C	C	.18	.46	<.01	<.02	.02	.01	6.0	.3
4D	D	.15	.13	<.01	<.02	.02	.01	4.8	.1
5	D	.10	.38	<.01	<.02	.04	.04	4.2	2.4
5A	A	.92	.98	<.01	.02	.02	.02	19	.3
5B	B	.50	1.2	<.01	<.02	.02	.01	10	.2
5C	C	.25	.23	<.01	<.02	.02	.01	5.0	.2
6A	A	1.0	.60	<.01	<.02	.02	.01	20	.4
6B	B	.26	.34	<.01	.03	.02	.01	5.0	.6
6C	C	.51	.27	<.01	.10	.03	.02	9.0	.4
7	D	.46	.20	<.01	<.02	.02	.01	3.2	.4
7A	A	1.7	.94	<.01	.02	.02	.01	19	.6
7B	A	1.7	.90	<.01	<.02	.03	.01	19	.5
7C	C	.39	.25	<.01	<.02	.06	.03	7.0	.3
8*	D	1.3	.11	<.01	<.02	.01	<.01	2.7	.3
8A	A	.30	1.7	<.01	<.02	.07	.05	7.7	.4
8B	A	.32	.88	<.01	<.02	.03	.02	6.3	.4
8C	C	.04	.08	<.01	<.02	.03	.02	1.5	.2
9B	A	.37	.13	<.01	<.02	.02	.01	5.3	1.4
9C*	A	.10	2.0	<.01	<.02	.02	.01	5.3	.5
9D	A	.32	.28	<.01	<.02	.02	.02	4.7	.5
10	D	.15	.23	<.01	<.02	.02	.01	55	.2
10A	B	.60	1.2	<.01	<.02	.02	.01	7.3	.2
10B	C	.15	.34	<.01	<.02	.03	.01	5.3	.2
10C	C	.43	.32	<.01	<.02	.02	.01	5.3	.2
11A	A	1.7	.23	<.01	<.02	.01	<.01	24	.4
11B	C	.29	.15	<.01	<.02	.01	<.01	2.9	.2
11C	C	--	.01	<.01	<.02	.01	<.01	5.0	.3
12	D	.19	.16	<.01	<.02	.02	.01	3.5	.5
12A	A	--	1.1	<.01	<.02	.03	.01	18	.4
12B	B	.32	.07	<.01	<.02	.02	.01	3.0	.6
12C	C	.28	.09	<.01	.03	.02	.01	4.0	.4
13	D	.33	.21	.01	.07	.04	.04	1.3	.4
13A	A	.84	.76	<.01	<.02	.02	.01	14	.4
13B	C	.14	.23	<.01	<.02	.02	.01	.6	.4
13C	C	.27	.14	<.01	<.02	.01	.01	.6	.4
14	D	.11	.21	.01	<.02	.03	.02	3.3	<.1
14A	A	.73	.47	<.01	<.02	.02	.01	11	.1
14B	A	.67	.53	<.01	<.02	.01	<.01	11	.1
14C	C	.30	.90	<.01	<.02	.02	.01	6.5	.1
15	D	.12	.10	<.01	<.01	.03	.01	--	--
15A	A	--	--	--	--	--	--	--	--
15B	C	.12	.60	<.01	<.02	.02	.01	3.8	.2
15C	C	.20	2.3	<.01	<.02	.02	<.01	3.5	.2
15D	C	.13	.30	<.01	<.02	.02	.01	3.5	.2
16*	D	.60	.80	<.01	<.02	.03	.02	2.0	.1
16A	A	.00	1.9	<.01	<.02	.03	<.01	3.6	.2
16B	C	.25	.23	<.01	<.02	.03	.02	3.5	.1
16C*	C	.65	.65	<.01	<.02	.03	.02	5.2	.1
17	D	.00	.08	<.01	<.02	.02	.01	3.0	.1
17A	A	.76	.74	<.01	<.02	.03	.01	15	.1
17B	B	.13	.30	<.01	<.02	.02	.01	8.1	.4
17C	C	.00	.09	<.01	<.02	.02	.01	5.0	.1

Table 5.--Supplementary water-quality data for wells completed in the surficial aquifer system--Continued

Site/ well No.	Hydro-geologic unit	Organic nitrogen	Ammonia nitrogen	Nitrite nitrogen	Nitrite + nitrate nitrogen	Phosphorus	Ortho-phosphate	Dissolved organic carbon	Suspended organic carbon
18A	A	0.88	0.08	<0.01	0.98	0.02	0.01	9.4	0.6
18B	B	.12	.53	<.01	<.02	.04	.01	2.0	.7
18C	C	.17	.05	<.01	<.02	.02	.02	2.0	.4
19	D	.06	.08	<.01	<.02	.02	.01	2.5	.1
19A	A	.40	.45	<.01	<.02	.01	<.01	8.5	.1
19B	B	.31	.39	<.01	<.02	.02	.01	6.0	.1
19C	C	.02	.07	<.01	<.02	.02	.01	2.3	.1
19D	C	.02	.07	<.01	<.02	.03	.02	2.3	.1
20A	A	.11	.28	<.01	<.02	.02	.01	4.1	.2
20B	A	.14	.16	<.01	<.02	.03	.02	3.3	.1
21	D	.01	.05	.01	.02	.01	.01	.7	.2
21A	A	.22	.02	<.01	.07	.02	.01	1.3	.2
21B	A	.11	.02	<.01	<.01	.02	.01	1.3	.2
21C*	C	.12	.12	<.01	<.02	.02	<.01	2.0	.2
23A	A	.63	.47	.01	<.02	.02	.02	15	.2
23B	B	.03	.33	<.01	<.02	.02	.02	4.0	.2
23C	C	.09	.06	<.01	<.02	.02	.01	35	.2
24	D	.19	.14	<.01	<.02	.02	.02	2.3	.3
24A	A	.10	.02	<.01	3.40	.01	<.01	1.0	.1
24B	A	.17	.02	<.01	3.40	.01	<.01	1.2	.1
24C	C	.35	.05	<.01	.07	.02	.01	1.2	.3
25*	D	.66	.02	.01	.20	.01	<.01	2.4	.2
25A	A	.27	.02	.01	<.02	.01	<.01	1.4	.2
25B*	A	.16	.06	.02	3.60	.01	<.01	1.7	.2
25C*	C	.27	.37	<.01	<.02	.03	.02	3.2	.2
26	D	.08	.08	<.01	<.02	.01	<.01	3.5	.4
26A	A	1.3	.50	<.01	<.02	.02	.01	23	.6
26B	B	.21	.80	<.01	<.02	.03	.01	4.4	.2
26C	C	.00	.07	<.01	<.02	.02	.01	2.5	.2
27*	D	.25	.04	<.01	<.01	<.01	<.01	1.8	.2
27A	C	.05	.24	.01	<.02	.05	.01	45	.2
27B*	C	.02	.15	<.01	<.02	.05	.01	32	.1
27C*	C	.01	.09	<.01	<.02	.05	.01	24	.1
28*	D	<.05	.07	<.01	<.01	.02	.01	3.6	.2
28A	A	.22	.18	<.01	<.01	.02	.01	3.3	.3
28B*	B	.28	.10	.01	<.01	.02	.01	1.0	.3
28C*	C	.13	.07	<.01	<.01	.07	.01	.1	.2
29	D	.12	.07	<.01	<.02	.02	.01	1.7	.2
29A	A	.35	.13	<.01	<.02	.01	<.01	5.4	.2
29B	B	.02	.08	<.01	<.02	.01	<.01	1.2	.2
29C	C	.25	.05	<.01	<.01	.02	.01	2.7	.5
30	B	.02	.35	<.01	<.02	.02	<.01	2.3	.1
30A	A	.12	.20	<.01	<.02	.02	<.01	3.1	.1
30B	A	.27	.18	<.01	<.02	.02	<.01	2.1	<.1
31A*	A	.20	2.8	.01	.02	.03	.03	12	.3
32*	C	.40	.90	.01	<.02	.06	.02	3.5	.2
32A*	A	.30	1.3	.01	<.02	.05	.02	3.2	.2
33*	D	.01	.20	<.01	<.02	.01	.01	.5	.1
33A	A	.26	.51	<.01	<.02	.01	.01	3.8	.1
33B*	C	.08	.15	<.01	<.02	.02	.01	.5	.1
33C*	C	.20	.19	<.01	<.02	.01	.01	.6	.2
34*	D	2.50	.07	<.01	<.02	.01	.01	.8	.2
34A	A	.54	.38	<.01	<.02	.02	.02	4.7	.2
34B	A	.41	.47	<.01	<.02	.02	.01	3.5	.2
34C*	A	.71	.89	.01	<.02	.04	.02	5.6	.1
34D*	C	.03	.09	.01	<.02	.01	.01	.4	.1

areas west of the Florida Turnpike). Parker and others (1955, p. 731) state that iron is naturally high in the Biscayne aquifer (unit A) with concentrations ranging between about 1,000 μg/L and 3,000 to 4,000 μg/L or greater. The highest iron concentration in unit A (1,900 μg/L) was measured in water from a well at site 12 in northwestern Dade County (table 7). Iron concentrations in unit A beneath the water-conservation areas and Everglades National Park generally exceed 300 μg/L. In coastal areas not affected by saltwater intrusion, iron concentrations were generally less although, in some areas (at sites 8, 9, 15, 20, 27, 28, and 34), concentrations still exceed the drinking water standard. The mean iron concentration is slightly higher in unit B (690 μg/L) than in unit A (560 μg/L) (table 6). The highest iron concentration in unit B (2,900 μg/L) was measured in water from a well at site 18.

Mean iron concentrations are lower in unit C (160 μg/L) than in unit A (560 μg/L) and unit B (690 μg/L) (table 6). Iron concentrations generally do not exceed 300 μg/L; however, those that do exceed the drinking water standard are found at sites 15 and 16 (table 7). The mean iron concentration in unit D is 220 μg/L, ranging from less than 10 to 830 μg/L (table 6).

Other Metals

Water samples for other dissolved trace metals including arsenic, barium, cadmium, chromium, lead, manganese, mercury, and zinc were collected from wells at sites in the urbanized eastern parts of Dade County and at sites along major highways. As tables 2 and 7 show, no wells at sites in any of the hydrogeologic units had concentrations of these trace metals that exceeded the Primary or Secondary Drinking Water Regulations standard. Table 6 shows the statistical summary of these constituents. Because a large part of the trace metals data contained concentrations less than detection limits, the mean and standard deviation of each constituent were estimated using the log-probability regression method, whereas the median was estimated using log-normal maximum-likelihood estimation (Helsel and Gilliom, 1985).

SUMMARY AND CONCLUSIONS

The U.S. Geological Survey, in cooperation with the South Florida Water Management District, has undertaken a regional study to define the geologic, hydrologic, and chemical characteristics of the surficial aquifer system.

The overall objectives of the study are to determine the geologic framework and the extent and thickness of the surficial aquifer system, the areal and vertical water-quality distribution and factors that affect the water quality, the hydraulic characteristics of the components of the surficial aquifer system, and to describe ground-water flow in the system. Results of the investigation are being published in a series of reports that provide information for each county as it becomes available. This report presents water-quality data and describes the chemical characteristics of water in the surficial aquifer system in Dade County.

The materials that compose the surficial aquifer system of southeastern Florida have a wide range of permeability and locally may be divided into

Table 6.--Statistical summary of selected dissolved constituents in ground water from hydrogeologic units

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. Means and standard deviations were estimated using log-probability regression method, and medians were estimated using log-normal maximum-likelihood estimation (Helsel and Gilliom, 1985); concentrations shown in micrograms per liter; -- represents no data were collected.]

	Arsenic	Barium	Cadmium	Chromium	Iron	Lead	Manganese	Mercury	Zinc
Hydrogeologic unit A									
Number of samples[1]	20	24	20	[2]20	37	20	37	9	24
Maximum	2	100	3	10	1,900	6	30	.3	30
Minimum	<1	<100	<1	<10	<10	<1	<10	<.1	<10
Mean	1.2	100	1.0	--	560	1.9	9.7	.10	7.5
Standard deviation	.4	--	.7	--	440	1.6	7.3	.08	6.6
Median	1.0	90	1.0	--	520	1.5	9.1	.09	8.0
Hydrogeologic unit B									
Number of samples[1]	12	[2]12	[2]12	[2]12	12	12	12	11	[3]12
Maximum	16	100	1	10	2,900	3	20	.3	50
Minimum	1	<100	<1	<10	10	<1	<1	<.1	<10
Mean	3.3	--	--	--	690	1.3	8.0	.14	--
Standard deviation	5.3	--	--	--	940	1.0	4.8	.09	--
Median	1.0	--	--	--	180	1.0	9.3	.10	--
Hydrogeolgic unit C									
Number of samples[1]	19	21	[2]19	[2]19	25	19	[2]25	17	21
Maximum	11	100	2	10	1,300	4	10	.6	320
Minimum	<1	<100	<1	<10	<10	<1	<1	<.1	<3
Mean	2.2	100	--	--	160	1.0	--	.06	26.5
Standard deviation	4.1	.0003	--	--	280	1.2	--	.10	70.4
Median	1.0	100	--	--	50	.8	--	.05	5.3
Hydrogeologic unit D									
Number of samples[1]	7	[2]8	[2]7	7	10	[2]7	[2]10	[4]6	8
Maximum	3	100	1	10	830	2	10	1.5	70
Minimum	<1	<100	<1	<10	<10	<1	<1	<.1	<10
Mean	1.7	--	--	--	220	--	--	--	16.7
Standard deviation	.8	--	--	--	250	--	--	--	23.5
Median	2.0	--	--	--	140	--	--	--	9.5
Surficial aquifer system (all hydrogeologic units combined)									
Number of samples[1]	58	65	58	58	84	58	84	53	65
Maximum	16	100	3	10	2,900	6	30	1.5	320
Minimum	<1	<100	<1	<10	<10	<1	<1	<.1	<3
Mean	2.0	30	.8	3.3	416	1.4	7.7	.1	14
Standard deviation	3.4	44	.5	4.1	528	1.3	5.8	.09	42
Median	1.0	100	1.0	1.0	220	1.0	8.2	.09	5.8

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[1] May include replicate samples.

[2] All detected observations have same value.

[3] Only one detected observation is above detection limit.

[4] Percent of observations less than detection limit exceed 80 percent.

Table 7.--Supplementary water-quality data for wells completed in the surficial aquifer system

[Hydrogeologic units: A, Biscayne aquifer; B, upper clastic unit of the Tamiami Formation; C, limestone, sandstone, and sand unit of the Tamiami Formation; D, lower clastic unit of the Tamiami Formation. Table does not include replicate sample data nor are all data in table necessarily included in statistical analyses; wells marked with an asterisk are affected by saltwater; all constituents are dissolved; concentrations shown in micrograms per liter; -- represents no data were collected.]

Site/ well No.	Hydro- geologic unit	Arsenic	Barium	Cadmium	Chromium	Lead	Iron	Manganese	Mercury	Strontium	Zinc
3A	A	1	100	<1	10	<1	270	<10	<0.1	980	10
3B	C	1	<100	<1	10	<1	300	<10	<.1	990	70
3C	C	1	100	<1	10	<1	30	<10	<.1	15,400	20
4A	B	2	100	1	<10	<1	1,900	10	.1	990	<10
4B	C	1	100	1	<10	1	50	<10	<.1	1,500	<10
4C	C	1	100	1	<10	<1	40	<10	.1	1,500	<10
4D	D	1	<100	1	<10	<1	40	<10	.1	1,600	<10
5	D	2	100	1	<10	1	220	<10	.3	880	10
5A	A	1	100	1	<10	1	50	10	.1	910	<10
5B	B	13	<100	1	<10	1	1,300	<10	.1	1,300	10
5C	C	1	<100	1	<10	1	20	<10	.1	2,600	320
6A	A	1	<100	1	10	<1	1,100	20	<.1	750	<10
6B	B	1	<100	1	10	1	20	10	.2	4,100	10
6C	C	16	<100	<1	10	<1	120	10	<.1	3,800	10
7	D	5	46	<1	10	1	12	<1	<.1	--	<3
7A	A	1	38	<1	<10	3	780	17	<.1	780	6
7B	A	1	37	<1	<10	2	1,000	15	<.1	760	13
7C	C	1	32	<1	<10	<1	220	4	<.1	1,200	8
8*	D	2	100	3	10	2	540	10	.3	4,400	10
8A	A	1	<100	2	10	4	620	<10	<.1	740	<10
8B	A	1	<100	3	10	2	1,100	10	.2	890	10
8C	C	3	<100	2	10	2	130	<10	.6	440	10
9B	A	3	<100	1	<10	1	210	10	<.1	1,200	<10
9C*	A	<1	100	1	20	2	2,100	30	2.3	4,400	10
9D	A	1	<100	2	<10	3	520	10	.2	850	<10
10	D	2	<100	<1	<10	<1	830	<10	<.1	2,800	30
10A	B	2	<100	<1	<10	<1	1,200	10	<.1	440	50
10B	C	11	<100	1	<10	<1	140	<10	<.1	1,900	70
10C	C	1	100	1	<10	<1	30	10	.4	2,600	<10
11A	A	2	100	1	<10	2	650	20	<.1	1,300	<10
11B	C	1	100	1	<10	4	240	<10	<.1	2,000	<10
11C	C	1	100	1	<10	2	20	10	<.1	2,300	<10
12	D	2	<100	1	<10	1	10	<10	1.5	700	10
12A	A	2	--	1	<10	1	1,900	30	<.1	610	--
12B	B	<1	<100	<1	<10	1	30	10	<.1	1,800	<10
12C	C	1	28	<1	10	<1	15	1	<.1	1,200	5
13	D	1	17	<1	<10	1	44	2	<.1	410	13
13A	A	1	37	<1	<10	1	820	13	<.1	570	4
13B	C	<1	19	<1	<10	2	24	2	<.1	1,400	<3
13C	C	1	19	<1	10	<1	21	<1	<.1	640	<3
14	D	--	<100	--	--	--	210	<10	--	680	<10
14A	A	--	<100	--	--	--	1,000	<10	--	670	<10
14B	A	--	<100	--	--	--	670	<10	--	680	<10
14C	C	--	100	--	--	--	60	<10	--	3,200	<10
15	D	--	--	--	--	--	190	10	--	520	--
15A	A	--	--	--	--	--	540	10	--	3,100	--
15B	C	--	--	--	--	--	1,300	10	--	2,800	--
15C	C	--	--	--	--	--	660	<10	--	810	--
15D	C	--	--	--	--	--	150	<10	--	2,700	--
16*	D	--	300	--	--	--	710	30	--	9,400	20
16A	A	--	<100	--	--	--	230	<10	--	890	<10
16B	C	--	100	--	--	--	320	<10	--	980	<10
16C*	C	--	500	--	--	--	230	30	--	4,600	<10
17	D	2	100	1	<10	1	330	10	<.1	1,700	<10
17A	A	1	<100	1	<10	1	1,100	30	.2	760	<10
17B	B	1	200	1	10	1	290	10	--	5,200	<10
17C	C	1	<100	1	10	1	10	<10	--	1,500	<10

Table 7.--Supplementary water-quality data for wells completed in the surficial aquifer system--Continued

Site/ well No.	Hydro- geologic unit	Arsenic	Barium	Cadmium	Chromium	Lead	Iron	Manganese	Mercury	Strontium	Zinc
18A	A	1	<100	<1	<10	2	630	20	0.1	790	20
18B	B	16	<100	<1	10	3	2,900	20	.1	1,100	<10
18C	C	2	<100	<1	<10	2	10	<10	.2	500	<10
19	D	<1	<100	<1	<10	1	20	10	<.1	350	<10
19A	A	1	<100	1	<10	1	650	<10	.1	66	<10
19B	B	1	<100	1	<10	1	540	<10	.3	700	<10
19C	C	<1	<100	<1	10	3	20	10	.3	650	<10
19D	C	1	<100	<1	<10	4	<10	<10	.2	630	<10
20A	A	--	<100	--	--	--	400	<10	--	650	10
20B	A	--	<100	--	--	--	550	<10	--	620	<10
21	D	--	--	--	--	--	10	<10	--	1,300	--
21A	A	--	--	--	--	--	<10	<10	--	1,100	--
21B	A	--	--	--	--	--	40	<10	--	1,100	--
21C*	C	--	--	--	--	--	660	10	--	3,000	--
23A	A	2	<100	1	<10	<1	1,700	10	<.1	640	<10
23B	B	2	100	1	<10	<1	10	<10	.1	930	<10
23C	C	1	100	1	<10	<1	10	<10	<.1	280	10
24	D	--	--	--	--	--	70	10	--	190	--
24A	A	--	--	--	--	--	<10	<10	--	900	--
24B	A	--	--	--	--	--	<10	<10	--	840	--
24C	C	--	--	--	--	--	170	<10	--	1,500	--
25*	D	--	--	--	--	--	70	30	--	12,000	--
25A	A	--	--	--	--	--	<10	<10	--	1,700	--
25B*	A	--	--	--	--	--	<10	<10	--	1,800	--
25C*	C	--	--	--	--	--	70	30	--	1,200	--
26	D	3	<100	1	<10	<1	380	10	--	2,500	70
26A	A	1	100	1	<10	<1	870	20	--	1,000	30
26B	B	1	<100	1	<10	1	190	<10	--	--	<10
26C	C	1	100	1	<10	1	50	<10	--	1,700	10
27*	D	<1	100	<1	<10	<1	30	10	.2	4,700	20
27A	C	1	100	1	10	<1	470	10	.1	610	<10
27B*	C	1	100	1	<10	1	30	<10	<.1	4,400	10
27C*	C	1	<100	1	20	1	40	10	.2	5,400	20
28*	D	--	--	--	--	--	170	<10	--	3,100	--
28A	A	--	--	--	--	--	340	<10	--	720	--
28B*	B	--	--	--	--	--	130	<10	--	3,000	--
28C*	C	--	--	--	--	--	70	<10	--	4,100	--
29	D	2	<100	<1	10	1	<10	<10	.1	300	<10
29A	A	2	<100	1	10	2	150	10	.1	630	10
29B	B	<1	<100	<1	<10	1	10	<10	.2	250	<10
29C	C	<1	<100	<1	<10	<1	10	<10	<.1	1,000	30
30	B	1	<100	<1	<10	3	170	<10	.1	940	<10
30A	A	1	<100	<1	10	6	150	<10	.3	970	10
30B	A	1	<100	<1	<10	5	170	<10	.1	940	<10
31A*	A	--	--	--	--	--	40	60	--	1,400	--
32*	C	23	200	1	40	<1	1,600	50	1.4	15,800	30
32A*	A	1	200	<1	30	<1	200	120	--	16,200	20
33*	D	--	--	--	--	--	40	20	--	6,200	--
33A	A	--	--	--	--	--	380	10	--	840	--
33B*	C	--	--	--	--	--	30	20	--	12,000	--
33C*	C	--	--	--	--	--	40	30	--	11,000	--
34*	D	--	--	--	--	--	2,000	40	--	5,600	--
34A	A	--	--	--	--	--	420	10	--	580	--
34B	A	--	--	--	--	--	320	<10	--	730	--
34C*	A	--	--	--	--	--	4,200	80	--	--	--
34D*	C	--	--	--	--	--	40	<10	--	3,600	--

aquifers and semiconfining layers. In ground-water systems, such as the surficial aquifer system where large permeability differences occur, water composition can vary considerably with depth at any site because of differences between the mineral composition of the strata through which the water moves; of equal importance are the effects of diluted seawater, recent saltwater intrusion, and urban and industrial contamination.

Some sites within the coastal areas of Dade County and in southern Dade County are affected by saltwater intrusion, either throughout the vertical extent of the surficial aquifer system or in specific zones. In central Dade County, sites located farther inland, generally between the coastal areas and the eastern part of The Everglades, have water with low specific conductance from land surface to the base of the surficial aquifer system.

In central Dade County, the upper 100 feet of the surficial aquifer system (unit A, unit B, and the upper part of unit C) probably have been flushed of residual seawater, and ground water in these units is suitable for most uses throughout most of the county. Calcium bicarbonate is the chemical composition of water generally associated with these units.

In the zones of low permeability in the lower part of unit C and unit D (between about 150 and 230 feet below land surface), calcium sodium bicarbonate type water or sodium bicarbonate water is primarily found; this indicates that ion exchange probably is occurring.

Beneath the water-conservation areas in northwestern Dade County, more highly mineralized water occurs in the surficial aquifer system than elsewhere in the county (except in areas where saltwater intrusion occurs). Calcium bicarbonate water and calcium sodium bicarbonate water occur in this part of the surficial aquifer system at depths from about 20 to 60 feet below land surface. Water in this part of the surficial aquifer system probably is an extension of highly mineralized water found in western Broward County that has been diluted by less mineralized recharge water. Beneath these depths, however, restriction of recharge by low permeability materials results in the occurrence of sodium bicarbonate water and calcium sodium bicarbonate water that are similar in chemical composition to that in Broward County. Also, the presence of base-exchange materials at these depths may also contribute to the occurrence of sodium bicarbonate water by ion-exchange processes.

In general, ground water in the four hydrogeologic units of the surficial aquifer system of Dade County is suitable for most purposes. However, maximum concentrations of sodium, chloride, color, fluoride, iron, and dissolved solids in some parts of Dade County exceed maximum contaminant levels set by the Florida Primary and Secondary Drinking Water Regulations.

Maximum concentrations of chloride, sodium, and dissolved solids that exceed the Florida Secondary Drinking Water Regulations standard generally occur in units B, C, and D in northwestern Dade County.

Dissolved iron concentrations in water of the surficial aquifer system commonly exceed the Florida Secondary Drinking Water Regulations standard; in general, the highest maximum and mean concentrations occur in units A and B, although concentrations vary widely both areally and with depth.

Maximum values of color in ground water in the four hydrogeologic units commonly exceed the Florida Secondary Drinking Water Regulations standard. The highest color values in ground water generally are found beneath the water-conservation areas and The Everglades. This probably is caused by leaching of decaying vegetation and the presence of organic-rich silts and sands found throughout the surficial aquifer system in this area.

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