

INTRODUCTION

The Gulf Coast Regional Aquifer-System Analysis (Gulf Coast RASA) is a study of regional aquifers composed of sediments of mostly Cenozoic age that underlie about 230,000 mi² of the Gulf Coastal Plain in parts of Alabama, Arkansas, Florida, Illinois, Kentucky, Mississippi, Missouri, Tennessee, Texas, and all of Louisiana (fig. 1). The study also includes about 60,000 mi² of the Continental Shelf (Grubb, 1984). These regional aquifers, named the Gulf coast aquifer systems, are part of three aquifer systems: the Mississippi embayment aquifer system, the Texas coastal uplands aquifer system, and the coastal lowlands aquifer system (fig. 2). The Gulf coast aquifer systems have been divided into 10 water-yielding units based on geologic and hydraulic factors (Weiss and Williamson, 1985; Pettijohn and others, 1988; Hoeman and Weiss, 1991; Weiss, 1992).

The middle Wilcox aquifer is in sediments of Eocene age and is part of both the Mississippi embayment and the Texas coastal uplands aquifer systems. Relation of the aquifer to overlying and underlying units is shown in figure 3. The middle Wilcox is composed chiefly of interbedded sand, silt, and clay. Sand content is greater than 40 percent throughout most of Texas and in several isolated areas in the Mississippi embayment. Sand content is less than 20 percent in several isolated areas of northern, east-central, and southeastern Mississippi. The areas with less than 20 percent sand also extend into adjacent parts of Tennessee, Louisiana, and Alabama (Hoeman and Weiss, 1991). The average thickness of the aquifer is about 1,200 ft. It dips from the outcrop in southern Illinois along the Mississippi River to southwestern Mississippi at about 40 to 50 ft/mi. It dips at about 110 to 150 ft/mi from southeastern Mississippi to the southern edge of the aquifer in Louisiana and from updip to downdip in southern Texas. Ground-water pumpage from the middle Wilcox aquifer during 1985 was about 120 Mgal/d (Mezko and others, 1990).

The Gulf Coast RASA is part of the U.S. Geological Survey's Regional Aquifer-System Analysis program. The program began in 1978 and is designed to provide an understanding and assessment of the Nation's ground-water resources on a regional basis (Bennett, 1979). A summary of progress in the RASA program through 1984 was given by Sun (1986), and progress on the Gulf Coast RASA was reported by Grubb (1987) and Williamson and others (1990).

Purpose and Scope

This report describes the water chemistry of the middle Wilcox aquifer. Maps in this report show the areal distribution of the concentration of dissolved solids, temperature, the primary water types, pH, and the concentrations of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and silica. Also included are five maps showing milliequivalent ratios of (1) magnesium to calcium, (2) magnesium plus calcium to bicarbonate, (3) magnesium plus calcium to sodium plus potassium, (4) bicarbonate to sulfate, and (5) bicarbonate to chloride. The maps of constituent ratios are included for comparing with the same constituent ratios commonly reported for sea water and for water used for specific purposes such as industry and public supply. The ratios also have been used to show trends that may indicate major controls on the chemistry of the ground water.

Compilation of Maps

The maps in this report are based primarily on data from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and data from the Texas Department of Water Resources (Pettijohn, 1988). The data were screened as explained by Pettijohn (1986) and values were plotted on maps in each 100-square-mile area where data exist. The 100-square-mile areas are the same as those illustrated by Grubb (1987, p. 115) and used for simulation of ground-water flow by Williamson (1987) and Williamson and others (1990).

These maps show regional trends in chemical properties. The concentrations of dissolved solids and major ions, pH, and temperature vary with depth within the aquifer. Point values can be smaller or larger than the values shown on the map, depending on whether the point is at the top or bottom of the aquifer. Because there are clusters of sampling sites at some locations, the median value of a property or constituent in each 100-square-mile area was used for constructing maps. The density of sampling sites in each 100-square-mile area is shown as an inset on each of the maps of the respective property or constituent. The number of sampling sites per interval is indicated on the bar graph included with each map. The number of 100-square-mile areas and a summary of median values for each constituent, property, and ratio are shown in table 1.

The maximum values in table 1 are usually larger than the maximum line of equal concentration shown on the corresponding map. In some instances the maximum value in the table is much larger than the maximum line shown on the map because the values in the table are for only one 100-square-mile area and there are not enough data of equal magnitude to justify adding additional intervals.

The concentrations of major ions and the pH are based on median values of all samples within each 100-square-mile area. The dissolved-solids concentrations greater than 10,000 mg/L and temperature are based on depth-averaged values from geophysical well logs (Pettijohn and others, 1988). The water type was computed from the cation and the anion that composed the largest percentage of milliequivalents per liter of the dissolved solids in a ground-water sample. Although water type was computed for each sampling site, only the most frequently observed water type (mode) in each 100-square-mile area is shown on the map. More detailed discussions of how the data were analyzed, processed, and mapped are given by Pettijohn (1986, 1988), Weiss (1987), and Pettijohn and others (1988).

Superimposed on selected maps are locations of geologic structures that are used as reference points in describing the chemistry of the ground water from east to west. Updip, mid-dip, and downdip are used as reference areas in describing the chemistry of the ground water from north to south. Uplift areas include outcrop along the updip limit of the aquifer and subcrop areas; mid-dip refers to areas about midway between the updip limit and the downdip limit of the aquifer; and downdip refers to areas adjacent to the downdip limit of the aquifer. The large outcrop area along the Texas-Louisiana border, which overlies the Sabine uplift near mid-dip, will be referred to as "Sabine uplift" and used as a reference area in describing the chemistry of the ground water. A map showing the location of salt domes and boundaries of salt dome basins (Beckman and Williamson, 1990) is included for the purpose of relating salt structures to constituent concentrations (fig. 4).

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Quantity	By	To obtain
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
mile (mi)	1.609	kilometer
million gallons		cubic meters per second
per day (Mgal/d)	0.04381	
square mile (mi ²)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentrations and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L). Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$^{\circ}\text{F} = 1.8(^{\circ}\text{C}) + 32$$

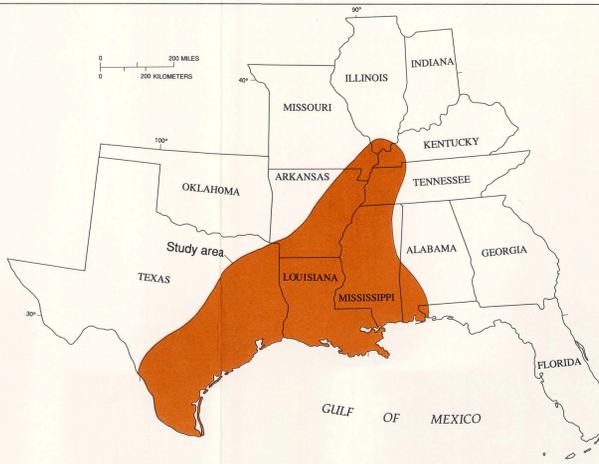


Figure 1.—Location of study area.

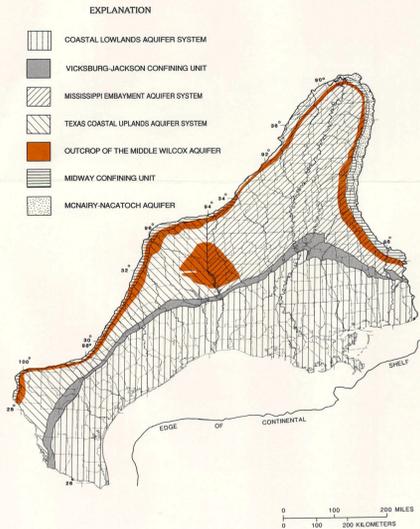


Figure 2.—Generalized outcrop of major aquifer systems and confining units in the Gulf Coast Regional Aquifer-System Analysis study area. Outcrop of the middle Wilcox aquifer superimposed.

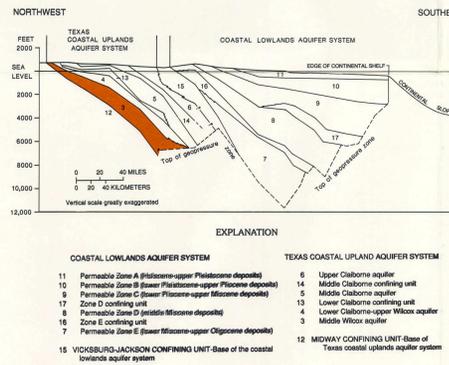


Figure 3.—Diagrammatic geologic cross-section through southwest part of study area.

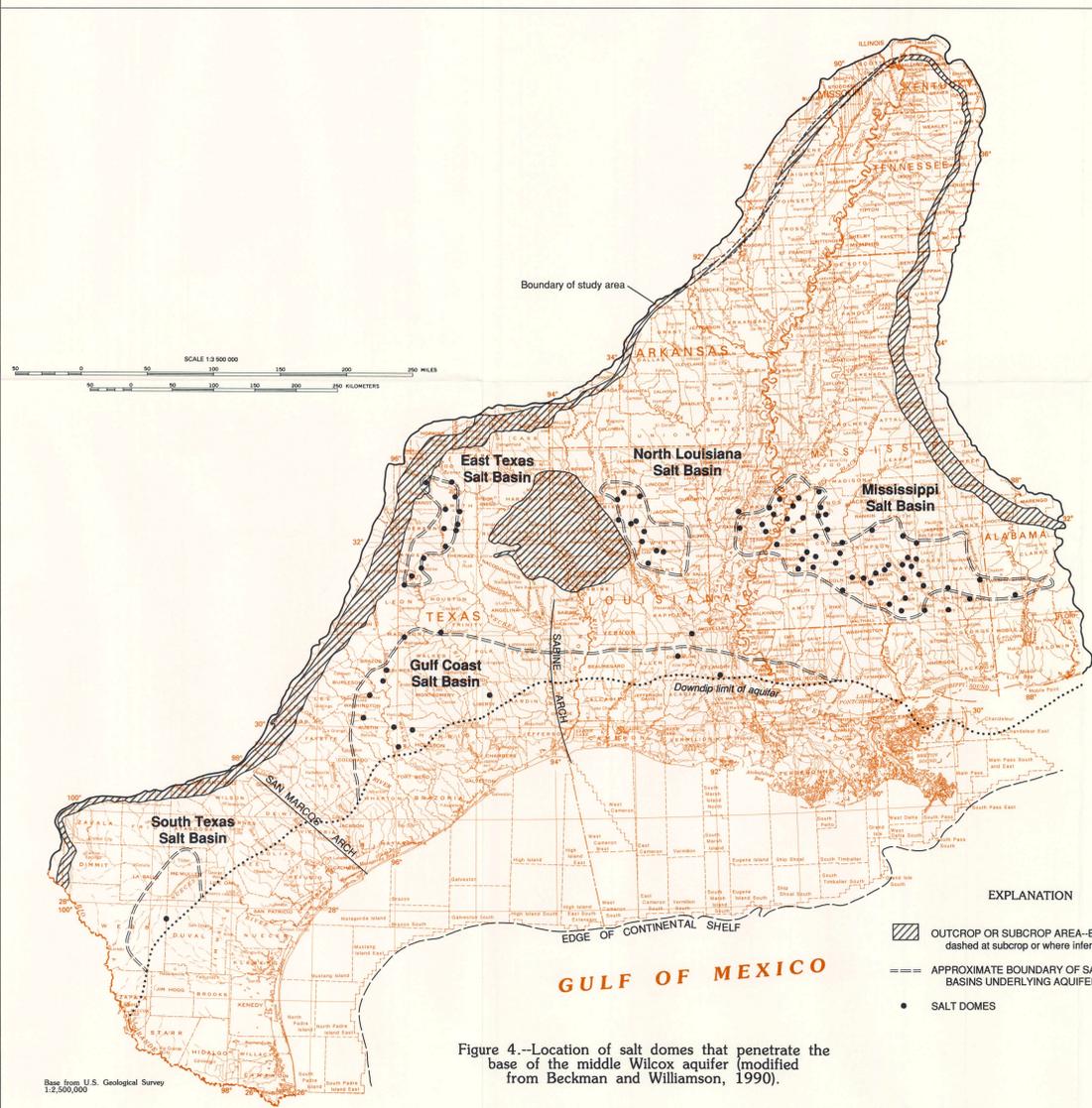


Figure 4.—Location of salt domes that penetrate the base of the middle Wilcox aquifer (modified from Beckman and Williamson, 1990).

SUMMARY AND CONCLUSIONS

The water chemistry of the middle Wilcox aquifer, which is part of the Mississippi embayment aquifer system and the Texas coastal uplands aquifer system, is presented by a series of maps. These maps show the areal distribution of (1) the concentration of dissolved solids and temperature, (2) the primary water types and pH, (3) the concentrations of major ions and silica, and (4) the milliequivalent ratios of selected ions. Dissolved constituents, pH, temperature, and ratios are based on the median values of all samples in each 100-square-mile area.

The concentration of dissolved solids in water from the middle Wilcox aquifer, based on the median values in each 100-square-mile area, ranges from 26 mg/L in the northern part of the Mississippi embayment aquifer system area to 25,400 mg/L in a downdip area in southeastern Texas. About one-third of the aquifer area has concentrations of dissolved solids that are less than 500 mg/L. The increase in concentration of dissolved solids in a downdip direction is attributed to mineral-water interaction such as dissolution of silicates in outcrop areas and dissolution of evaporites comprising salt domes downdip in the deeper parts of the aquifer. The temperature, based on median values per each 100-square-mile area, ranges from 15 degrees Celsius in the outcrop in the northern part of the Mississippi embayment aquifer system area to 117 degrees Celsius in a downdip area in southern Texas.

The primary water types in the middle Wilcox aquifer, which are based on the most frequently observed type (mode) in each 100-square-mile area, are calcium bicarbonate in the outcrop in Missouri, Kentucky, Mississippi, and southern Texas; sodium bicarbonate in the remaining outcrop areas and all areas from outcrop to mid-dip; and sodium chloride in all downdip areas. The pH, based on median values per each 100-square-mile area, ranges from 4.8 in the outcrop area of south-central Arkansas to 9.0 in eastern Texas.

The concentrations of major ions in water from the middle Wilcox aquifer, based on median values of all samples in each 100-square-mile area, generally increase from the outcrop area to the downdip limit of the aquifer. The concentration of dissolved calcium ranges from 0.4 mg/L in central Mississippi to 12,000 mg/L in south-central Arkansas. The concentration of dissolved magnesium ranges from 0.1 mg/L in central Mississippi to 1,490 mg/L in a downdip area in southeastern Texas. The concentration of dissolved sodium ranges from 0.8 mg/L in western Tennessee to 76,000 mg/L in a downdip area in southeastern Mississippi. The concentration of dissolved potassium ranges from 0.1 in western Kentucky, western Tennessee, and northern Mississippi to 10,200 mg/L in a downdip area in southeastern Texas. The concentration of dissolved bicarbonate ranges from 3 mg/L in the outcrop in central Arkansas to 2,960 mg/L in a downdip area in southern Texas. The concentration of dissolved sulfate ranges from 0.1 in several parts of the Mississippi embayment aquifer system area to 39,700 mg/L in a downdip area in southern Texas. The concentration of dissolved chloride ranges from 0.1 in northern Mississippi and western Tennessee to 119,000 mg/L in a downdip area in southeastern Mississippi. The concentration of silica ranges from 1 to 100 mg/L and there appears to be no areal trend in concentration across the aquifer.

The milliequivalent ratio maps of selected ions in water from the middle Wilcox aquifer, constructed from the median milliequivalent ratio for each 100-square-mile area, indicate some trends. The milliequivalent ratio of magnesium to calcium ranges from 0.03 to 12.8 and shows no areal trend. The milliequivalent ratio of magnesium plus calcium to bicarbonate ranges from less than 0.01 to 158 and generally decreases from outcrop to mid-dip and increases from mid-dip to the downdip limit of the aquifer. The milliequivalent ratio of magnesium plus calcium to sodium plus potassium ranges from less than 0.01 to 162 and generally decreases from the outcrop area to the downdip limit of the aquifer. The milliequivalent ratio of bicarbonate to sulfate ranges from 0.03 to 520 and there appears to be no areal trend across the aquifer area. The milliequivalent ratio of bicarbonate to chloride ranges from less than 0.01 to 15; generally increases from the outcrop to mid-dip and decreases from mid-dip to the downdip limit of the aquifer. The data in the area from the Sabine uplift southwestward to the Rio Grande. From the Sabine uplift eastward to southwestern Alabama the ratio of bicarbonate to chloride generally decreases from outcrop to downdip in the area west of the Mississippi River and shows localized trends east of the Mississippi River.

SELECTED REFERENCES

Beckman, J.D., and Williamson, A.K., 1990, Salt-dome locations in the Gulf Coastal Plain, south-central United States, U.S. Geological Survey Water-Resources Investigations Report 90-400, 44 p.

Bennett, G.D., 1979, Regional ground water systems analysis: U.S. Army Corps of Engineers Water Spectrum, v. 11, no. 4, p. 36-42.

Grubb, H.F., 1984, Planning report for the Gulf Coast Regional Aquifer-System Analysis in the Gulf of Mexico Coastal Plain, United States: U.S. Geological Survey Water-Resources Investigations Report 84-4219, 30 p.

1986, Gulf Coast Regional Aquifer-System Analysis Program of the U.S. Geological Survey—Summary of progress, 1978-84: U.S. Geological Survey Circular 1082, p. 152-161.

1987, Overview of the Gulf Coast Regional Aquifer-System Analysis, south-central United States, in Vecchioli, John, and Johnson, A.L., eds., Regional aquifer systems of the United States, Aquifers of the Atlantic and Gulf Coastal Plain, American Water Resources Association Monograph 9, p. 101-118.

Hoeman, R.L., and Weiss, J.S., 1991, Geologic units of the Mississippi embayment and Texas coastal uplands aquifer systems, south-central United States: U.S. Geological Survey Professional Paper 1416-B, 19 p.

Mezko, T.O., Williams, T.A., Ackerman, D.J., and Williamson, A.K., 1990, Ground-water pumpage from the Gulf coast aquifer systems, 1960-85, south-central United States: U.S. Geological Survey Water-Resources Investigations Report 89-418, 177 p.

Pettijohn, R.A., 1986, Processing water-chemistry data, Gulf coast aquifer systems, south-central United States, with summary of dissolved-solids concentrations and water types: U.S. Geological Survey Water-Resources Investigations Report 86-4186, 42 p.

Pettijohn, R.A., 1988, Dissolved-solids concentrations and primary water types, Gulf coast aquifer systems, south-central United States: U.S. Geological Survey Hydrologic Investigations Atlas HA-706, 2 sheets, scale 1:5,000,000.

Pettijohn, R.A., Weiss, J.S., and Williamson, A.K., 1980, Distribution of dissolved-solids concentrations and temperature in ground water of the Gulf coast aquifer systems, south-central United States: U.S. Geological Survey Water Resources Investigations Report 80-4082, 5 sheets, scale 1:3,500,000.

Sun, R.J., ed., 1986, Regional Aquifer-System Analysis Program of the U.S. Geological Survey, Summary of Progress 1978-84: U.S. Geological Survey Circular 1082, 264 p.

Weiss, J.S., 1987, Determining dissolved-solids concentrations in highly mineralized ground water of the Gulf coast aquifer systems using electric logs, in Vecchioli, John, and Johnson, A.L., eds., Regional aquifer systems of the United States, Aquifers of the Atlantic and Gulf Coastal Plain: American Water Resources Association Monograph 9, p. 139-158.

1992, Geologic units of the coastal lowlands aquifer system, south-central United States: U.S. Geological Survey Professional Paper 1416-C, 32 p.

Weiss, J.S., and Williamson, A.K., 1985, Subdivision of thick sedimentary units into model layers for simulation of ground-water flow: Ground Water, v. 23, no. 6, p. 767-774.

Williamson, A.K., 1987, Preliminary simulation of ground-water flow in the Gulf coast aquifer systems, south-central United States, in Vecchioli, John, and Johnson, A.L., eds., Regional aquifer systems of the United States, Aquifers of the Atlantic and Gulf Coastal Plain: American Water Resources Association Monograph 9, p. 119-137.

Williamson, A.K., Grubb, H.F., and Weiss, J.S., 1990, Ground-water flow in the Gulf coast aquifer systems, south-central United States—a preliminary analysis: U.S. Geological Survey Water-Resources Investigations Report 89-4071, 124 p.

Wilson, T.A., and Hoeman, R.L., 1988, Geophysical well-log data base for the Gulf coast aquifer systems, south-central United States: U.S. Geological Survey Open-File Report 87-677, 213 p.

TABLE 1.—Summary of median values in 100-square-mile areas for selected properties and chemical constituents in ground water from the middle Wilcox aquifer

[All dissolved ion concentrations are in milligrams per liter. All dissolved ion concentrations used to calculate ratios, for example Ca/Mg, are in milliequivalents per liter. Temperatures are in degrees Celsius. pH is in standard units. Chemical symbols: Ca, calcium; Mg, magnesium; Na, sodium; K, potassium; HCO₃, bicarbonate; SO₄, sulfate; Cl, chloride; <, less than]

Property or constituent	Statistics for median values of 100-square-mile areas			Number of 100-square-mile areas
	Median	Minimum	Maximum	
pH	7.6	4.8	9.0	528
Temperature	29.6	15.0	117	693
Dissolved-solids	625	26.0	125,500	675
Calcium	10.0	0.4	12,000	509
Magnesium	3.0	0.1	1,490	501
Sodium	99	0.8	76,000	509
Potassium	2.4	0.1	10,200	378
Bicarbonate	250	3.0	2,960	532
Sulfate	20.0	0.1	39,700	492
Chloride	29.0	0.1	119,000	545
Silica	16.0	1.0	100	462
Ratio Mg:Ca	0.47	0.03	12.8	500
Ratio Mg+Ca:HCO ₃	0.50	<0.01	158	491
Ratio Mg+Ca:SO ₄	0.44	<0.01	2	272
Ratio HCO ₃ :SO ₄	7.9	0.03	9,520	487
Ratio HCO ₃ :Cl	4.2	<0.01	135	531

PROPERTIES AND CHEMICAL CONSTITUENTS IN GROUND WATER FROM THE MIDDLE WILCOX AQUIFER, GULF COAST REGIONAL AQUIFER SYSTEMS, SOUTH-CENTRAL UNITED STATES

by

ROBERT A. PETTIJOHN, JOHN F. BUSBY, AND JEFFERY D. BECKMAN

1993