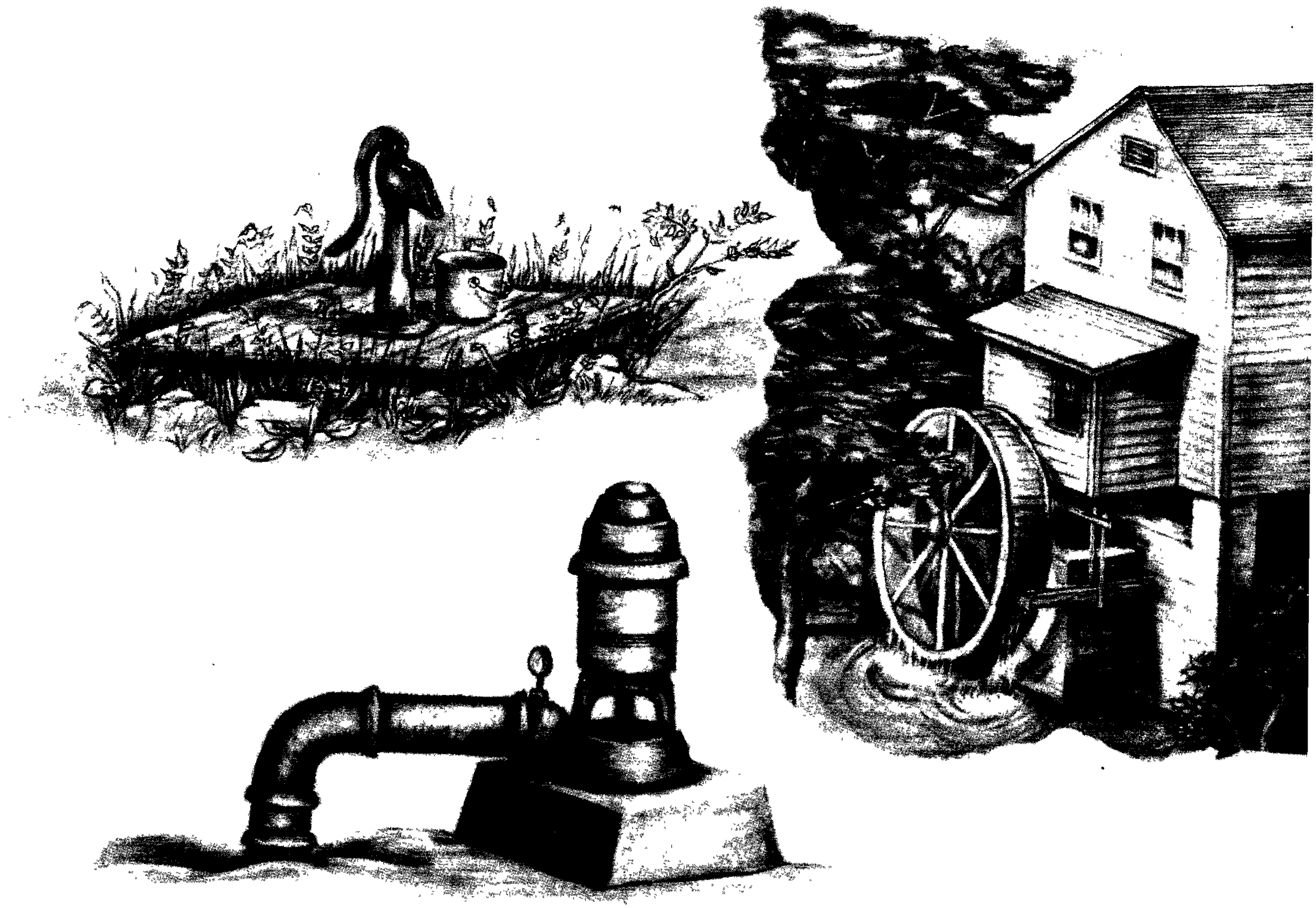
WATER-RESOURCES INVESTIGATIONS REPORT 83-4039

PRELIMINARY
DELINEATION AND DESCRIPTION OF THE REGIONAL AQUIFERS OF TENNESSEE--
THE CRETACEOUS AQUIFER SYSTEM OF WEST TENNESSEE



Prepared by
U.S. GEOLOGICAL SURVEY
in cooperation with the
U.S. ENVIRONMENTAL PROTECTION AGENCY

PRELIMINARY DELINEATION AND DESCRIPTION OF THE REGIONAL AQUIFERS OF TENNESSEE--THE CRETACEOUS AQUIFER SYSTEM OF WEST TENNESSEE

By J.V. Brahana, Dolores Mulderink, and Michael W. Bradley

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UNITED STATES DEPARTMENT OF THE INTERIOR

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For the convenience of readers who may want to use International System of Units (SI), the data may be converted by using the following factors:

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in the text of this report.

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ABSTRACT

The Cretaceous aquifer system in western Tennessee is composed of sand, gravel, and clay. The aquifer system is under confined conditions except in the outcrop area. Ground water is recharged by precipitation on the outcrop area and through some overlying permeable deposits. The hydraulic gradient in the confined aquifers is about 1 foot per mile generally toward the west. The Cretaceous aquifer system unconformably overlies the consolidated Paleozoic formations and is overlain and confined by the Porters Creek Clay.

The Cretaceous aquifer system is used as a source of water supply primarily in the outcrop area. West of the outcrop of this aquifer system, ground water can be obtained at shallower depths and with better water quality. The water of the Cretaceous aquifers generally have very good quality in the outcrop area. The dissolved solids increase down gradient to more than 1,000 milligrams per liter in parts of Shelby County. High iron concentrations are present in some areas.

INTRODUCTION

The Safe Drinking Water Act (P.L.93-523) includes provisions for the protection of underground sources of drinking water. Specifically, Part C of the Act authorizes the Environmental Protection Agency (EPA) to establish regulations to insure that underground injection of contaminants will not endanger existing or potential sources of drinking water. As set forth by EPA, the regulations require that all underground sources of ground water with less than 10,000 milligrams per liter (mg/L) dissolved solids be designated for protection whether or not they are currently being used as a source of drinking water.

The geologic formations of Tennessee (Miller, 1974) have been grouped into eight major regional aquifers. Each aquifer is characterized by a unique set of hydrologic conditions, as well as a distinguishing water quality.

The purpose of this report is to describe the formations that comprise the Cretaceous aquifer system of West Tennessee (fig. 1) and to delineate zones within this aquifer that are current or potential drinking-water sources.

This report on the Cretaceous aquifer system provides generalized information on the (1) areal and stratigraphic occurrence, (2) occurrence and movement of ground water, (3) dissolved-solids concentration of the ground water, (4) area of use and potential use,

(5) areas of known ground-water contamination, and (6) known locations of current and potential hydrocarbon, mineral, and geothermal resources in the geologic formations of Cretaceous age.

GEOLOGY

The Cretaceous aquifer system consists of unconsolidated sediments of Late Cretaceous age. These sediments are composed primarily of sands and gravels, with interbedded clays and marls. The sands and gravels have a high primary (intergranular) porosity and permeability. The Cretaceous deposits crop out as part of the Coastal Plain in West Tennessee, and in the western valley of the Tennessee River. They dip to the west beneath the Porters Creek Clay and occur in the subsurface throughout western Tennessee. The geologic and hydrologic character of the formations that comprise the Cretaceous aquifer system is given in table 1.

The Cretaceous formations were deposited in the Mississippi Embayment, a structural trough which has its axis approximately coincident with the Mississippi River. The Cretaceous aquifer system is thicker at the western edge of the state and toward the south down the axis of the embayment (Boswell and others, 1965). The aquifer system is thinner toward the north because the older Cretaceous formations are progressively absent. The contours on the top and bottom of the aquifer and the locations of cross sections constructed for this report are shown in figures 2 and 3. The cross sections are shown in figures 4 through 7. These figures show the hydrogeologic sequence of aquifers and confining units and the generalized quality of the water in the Cretaceous aquifer system.

The Cretaceous formations lie unconformably on Paleozoic limestones, dolomites, and cherts that range in age from Mississippian to Cambrian (Freeman, 1953). The eroded upper surface of the Paleozoic rocks slopes toward the axis of the embayment at about 35 ft/mi, and progressively older rocks directly underlie Cretaceous sediments toward the west. The Paleozoic rocks are, for the most part, much more dense and nonporous than the overlying sediments.

The geology of Cretaceous deposits is described in detail in a number of reports, including: Glenn (1904); Glenn (1906); Wells (1933); Stearns and Armstrong (1955); Milhous (1959); Marcher and Stearns (1962); Cushing and others (1964); Boswell and others (1965); Wilson and Criner (1969); and Russell and Parks (1975).

HYDROLOGY

The Cretaceous aquifer system is a highly permeable ground-water reservoir in which confined, intergranular flow predominates. The porous and permeable formations are recharged in the outcrop area, which is limited roughly to the area east of the outcrop of the Porters Creek Clay and west of the Tennessee River (fig. 8). Outcrops east of the river in Hardin and Wayne Counties do not contribute recharge to the regional aquifer system, although they do serve as a source of local ground water. Any westward flow from these outcrops follows a shallow path and is discharged by springs or into tributaries and is intercepted by the Tennessee River, which acts as a drain.

The recharge west of the Tennessee River follows one of two paths. Most ground water moves along a fairly shallow flow system and is discharged as the base flow contribution of the streams that drain the outcrop area (fig. 9). A small percentage of the recharge moves westward at a hydraulic gradient of about 1 ft/mi and becomes part of the deep circulation pattern of the regional aquifer system (fig. 9).

Confining beds above and within the aquifer play an important role in the hydrology. The Porters Creek Clay is the upper confining unit for the regional aquifer. The Coon Creek, Demopolis, and Sardis Formations occur approximately in the middle of the aquifer and separate the McNairy Sand and Coffee Sand aquifers. Clays in the Eutaw and Tuscaloosa Formations restrict vertical movement of ground water and, to varying degrees, isolate the sands from each other. Lateral flow components of this aquifer system predominate, with only minor vertical flow between the different formations. Leakage into the Cretaceous sediments from the underlying Paleozoic aquifers occurs at some locations, but is not areally significant (Boswell and others, 1965).

Water levels vary seasonally in response to changes in natural recharge and discharge in the outcrop area. Natural discharge also occurs in the subsurface as underflow to the west, out of Tennessee into Arkansas and Missouri (figs. 8 and 9).

The detailed hydrology of the formations of the Cretaceous aquifer system is described in a number of published reports. The following were used to compile this atlas: Glenn (1906); Wells (1933); Cushing and others (1964); Boswell and others (1965); Cushing (1966); Rima (1966); Wilson and Criner (1969); and Zurawski (1978).

WATER QUALITY

Chemical analyses of water from the Cretaceous aquifer system indicate generally good quality water in the outcrop area and in the upper part of the aquifer, with more mineralized water in the lower formations in the confined part of the aquifer to the west. In the southwest part of Shelby County, the aquifer contains water with more than 1,000 mg/L dissolved solids. The areal distribution of dissolved-solids concentrations in the Cretaceous aquifer system are shown in figure 10. The variation by depth and formation is shown in table 2. General water quality is also shown on the cross sections (fig. 4-7).

Water quality along the cross sections is based on work by Cushing (1966), who obtained much of his data from geophysical logs. The apparent zonation on the cross sections commonly occurs at lithologic and formational boundaries, and is believed to be due to two major factors: (1) confining beds above and within this aquifer system effectively retard vertical leakage of the fresher water from the shallower formations, and (2) flow velocities are relatively slow, even though the flow system is dynamic; therefore, flushing action by the fresher water from shallower formations is slow.

Another possibility for the water-quality zonation is that the Paleozoic formations that underlie the Cretaceous aquifer may discharge water with high dissolved-solids concentrations into the basal part of the aquifer system. Boswell and others (1965) report high chloride concentration in a well in the Coffee Sand in Henderson County, Tenn. Water from that well is almost identical in composition to water from a Paleozoic source 5-1/2 miles to the east. The hydrologic conditions for this to occur are known to exist at other locations.

The general water quality for the four major water-bearing formations of the Cretaceous aquifer system is:

McNairy Sand - Calcium bicarbonate water type, may have high iron; low dissolved solids in outcrop area, increasing downdip, less than 1,000 mg/L throughout area except for southwest Shelby County.

Coffee Sand - Calcium bicarbonate water type, may be hard, may have high iron. Higher sulfate and lower chloride than Eutaw. Low dissolved solids in outcrop area. Dissolved solids increase downdip.

Eutaw Formation - Sodium bicarbonate water type, dissolved solids generally low in outcrop area, increase downdip.

Tuscaloosa Formation - Sodium or calcium bicarbonate water type, low dissolved solids in outcrop area, high iron concentration.

In addition to unpublished data, the following reports were used to compile information for this water-quality section: Glenn (1906); Wells (1933); Lanphere (1955); Boswell and others (1965); Cushing (1966); Wilson and Criner (1969); Cushing and others (1970); and Brown (1971).

DRINKING-WATER SUPPLIES

Use of the Cretaceous aquifer system as a source of drinking water has been restricted primarily to the outcrop area of the Cretaceous formations. West of the outcrop of the Porters Creek Clay, few municipal or domestic wells are drilled into the Cretaceous aquifer system because water of excellent quality generally can be found at shallower depths. A summary of public water supplies that derive water from the Cretaceous aquifer system is presented in table 3 and figure 11. The Cretaceous aquifer system can yield enough water for most municipal needs in West Tennessee and, as such, represents a valuable unused resource. The area of present use and potential use is shown in figure 11.

Most of the data for drinking-water supplies comes from unpublished sources, primarily the Tennessee Department of Health and Environment. Historic use of water from this aquifer are documented in Lanphere (1955), Boswell and others (1965), and Cushing and others (1970).

HYDROCARBON, MINERAL, AND GEOTHERMAL RESOURCES

Formations in the Cretaceous aquifer system are being mined for their mineral resources in the outcrop area (fig. 12). Foundation sand is actively mined from the McNairy Formation throughout the outcrop area. Sand with more than 95 percent quartz is being mined for glass production in Benton County. There are known reserves of heavy mineral sands in Henderson County. The heavy sand primarily consists of ilmenite and zircon. No hydrocarbon or geothermal resources are known to be present in the formations of the Cretaceous aquifer system.

SUMMARY

The Cretaceous aquifer system is composed of unconsolidated sand and gravel separated by formations of clay and marl. The sand and gravel have high intergranular permeability. The aquifers are unconfined in the outcrop area and are confined by the Porters Creek Clay in the subsurface.

Water in the Cretaceous aquifer system generally contains less than 300 mg/L dissolved solids. The dissolved-solids concentrations increase with depth and down gradient. The McNairy Sand in southwest Shelby County produces water with more than 1,000 mg/L dissolved solids. High iron concentrations occur in some areas.

The Cretaceous aquifer system is used for domestic and public water supplies throughout the outcrop area. West of the Porters Creek Clay, the Cretaceous aquifer system is only slightly used because of the availability of water in the overlying Tertiary aquifer system.

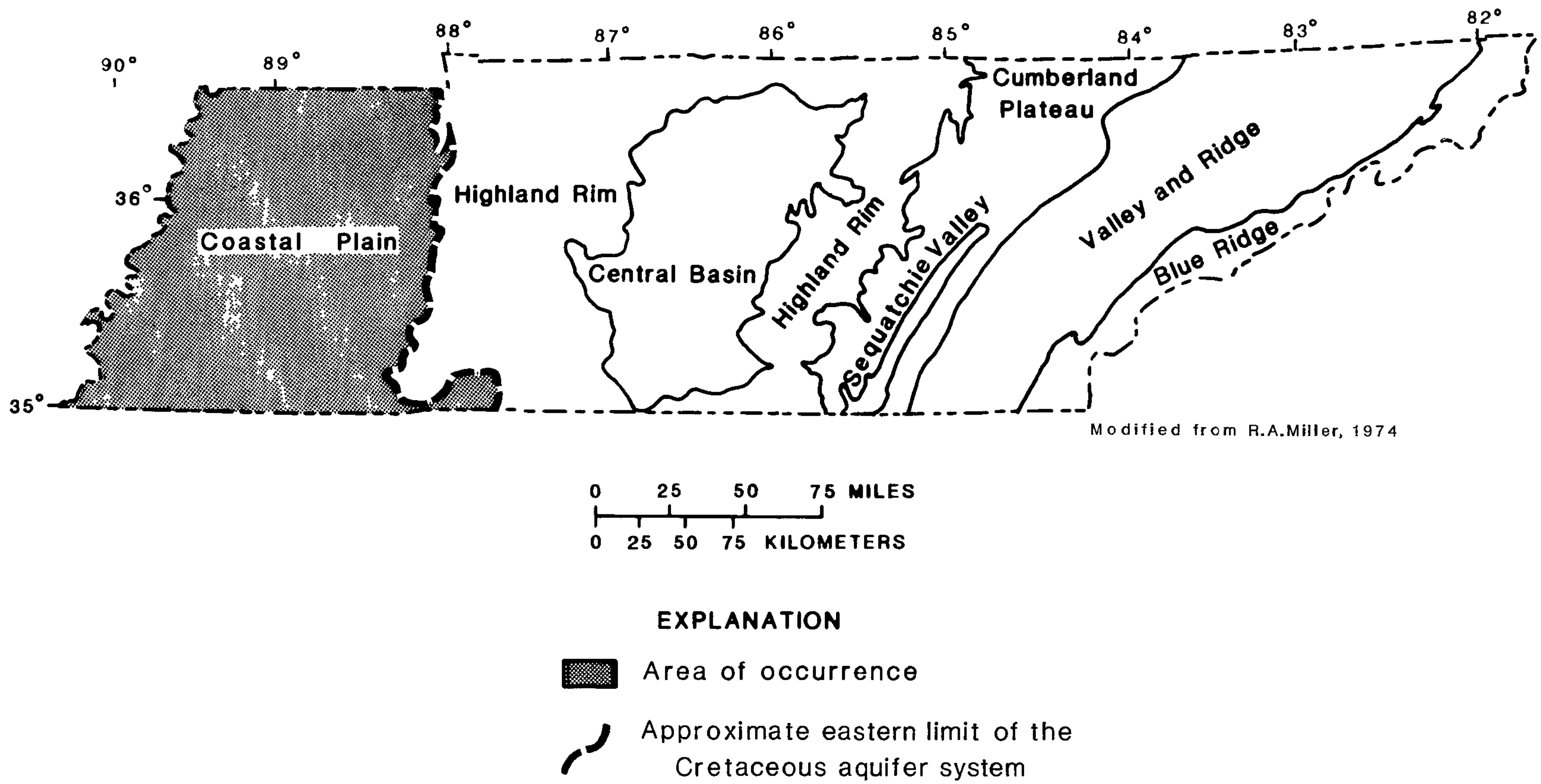

Figure 1.-- Areal occurrence of the Cretaceous aquifer system and physiographic provinces in Tennessee.

Table 1.--Geohydrology of the formations comprising the Cretaceous aquifer system

[Sources: Wells (1933), Cushing and others (1964), Boswell and others (1965), Hardeman (1966), and Miller (1974)]

SYSTEM	Stratigraphic unit	Geologic description	Hydrologic significance		
			Occurrence in Tennessee	Hydrologic classification and character	Yield
TERTIARY	Porters Creek Clay	Clay, medium-gray to brownish-gray, massive, locally contains glauconitic sand. Thickness 45 to 400 feet. In some areas it is cut by sand dikes which range in width from a fraction of an inch to 22 feet.	Present throughout the western three-fourths of West Tennessee in the subsurface, outcropping in a narrow band 1 to 5 miles wide.	Due to its fine texture and clay composition, the Porters Creek retards the vertical movement of water and serves as the upper confining unit for the Cretaceous aquifer system. Its continuity, homogeneity, and thickness distinguish it as an effective confining unit.	No data exist for yields, but at best they would be suitable only for domestic supplies.
	Clayton Formation	Sand, clay, and limestone. Locally contains marine fossils. Thickness 0 to 80 feet.	Outcrop mapped in Hardeman and McNairy Counties. Occurs in subsurface in the western part of West Tennessee.	Generally acts as a confining unit although fine sands locally supply small quantities of water for domestic supplies.	Yields suitable for small domestic supplies.
CRETACEOUS	Owl Creek Formation	Sand, fine-grained, and clay, micaceous; commonly contains glauconite and marine fossils. Thickness 0 to 35 feet.	Outcrop in Tennessee limited to Hardeman and McNairy Counties. Occurs in the subsurface in the western part of West Tennessee.	Confining unit. Fine texture confines downward movement of water.	Yields little or no water to wells.
	McNairy Sand	Sand with interbedded clay and locally some lignite. Fine sand at base contains heavy minerals. Thickness 300 to 400 feet.	Crops out in the western valley of the Tennessee River. Occurs in subsurface throughout western part of West Tennessee.	High permeability sands are capable of transmitting large quantities for public supplies.	Yields range from several gallons a minute to more than several hundred gallons per minute depending on thickness.
	Coon Creek Formation	Sand and clay; glauconitic, fossiliferous, and micaceous. Thickness 50 to 180 feet.	Outcrop varies from 3 to 4 miles wide.	Fine-grained sands may locally supply small capacity domestic wells.	Yields little or no water to wells.
	Demopolis Formation	Marl, chalky marl, and calcareous clay; light-gray, very thickbedded, silty, sandy, glauconitic, and fossiliferous. Thickness 0 to 300 feet.	Formation thickens toward the south.	Significant confining unit. Fine-grained material inhibits vertical movement of ground water. Basal units may supply local domestic supplies.	Yields little or no water to wells.
	Sardis Formation	Sand, quartz and glauconite, with with clay; locally fossiliferous; grades upward into calcareous clays. Thickness 0 to more than 40 feet.	Crops out mainly in Henderson County.	Confining unit. Fine-grained texture inhibits vertical movement of ground water.	Yields little or no water to wells.
	Coffee Sand	Sand with lenses of brown clay. Upper sands are commonly cross-bedded. Basal beds contain fine chert pebbles. Thickness 0 to more than 200 feet.	Outcrops mainly in Henderson and Decatur Counties. Present throughout the western	High intergranular porosity and permeability in sands.	Yields range from several gallons a minute to more than 100 gallons per minute.
	Eutaw Formation	Glauconitic and micaceous sand locally interbedded with lenses of gray clay. Basal beds contain chert gravel. Thickness 0 to 180 feet.	Occurrence limited mainly to outcrops in Hardin and Wayne Counties. Formation is absent at various locations.	High intergranular porosity and permeability in sands. basal confining unit of the "1,400-foot sand." The "1,400-foot sand" is a high permeability aquifer.	Yields range from several gallons a minute to more than 100 gallongs per minute.
	Tuscaloosa Formation	Chert gravel, clay, silt, and sand. Gravel contains lenses of quartz sand and thin-bedded clay. Thickness 0 to 140 feet.	Crops out mostly in Hardin and Wayne Counties, east of the Tennessee River. Thin or absent in subsurface west of the Tennessee River.	High intergranular porosity and permeability in gravels. Coarse gravels provide water supplied locally. Direct hydraulic connection with underlying formations.	Yields range from several gallons per minute to more than 10 gallons per minute.
CAMBRIAN TO MISSISSIPPIAN UNDIFFERENTIATED	Paleozoic Carbonates	Carbonate rocks and chert, with minor amounts of shale. Rocks extend several thousand feet to Precambrian crystalline rocks.	Occurs throughout West Tennessee beneath the Cretaceous deposits.	The porosity decrease at the Cretaceous-Paleozoic boundary effectively retards vertical leakage of water. Hydrologic interchange occurs at some locations.	Used as an aquifer only where Cretaceous deposits are too thin to yield water, in the eastern part of the Cretaceous aquifer system. Yields generally low.

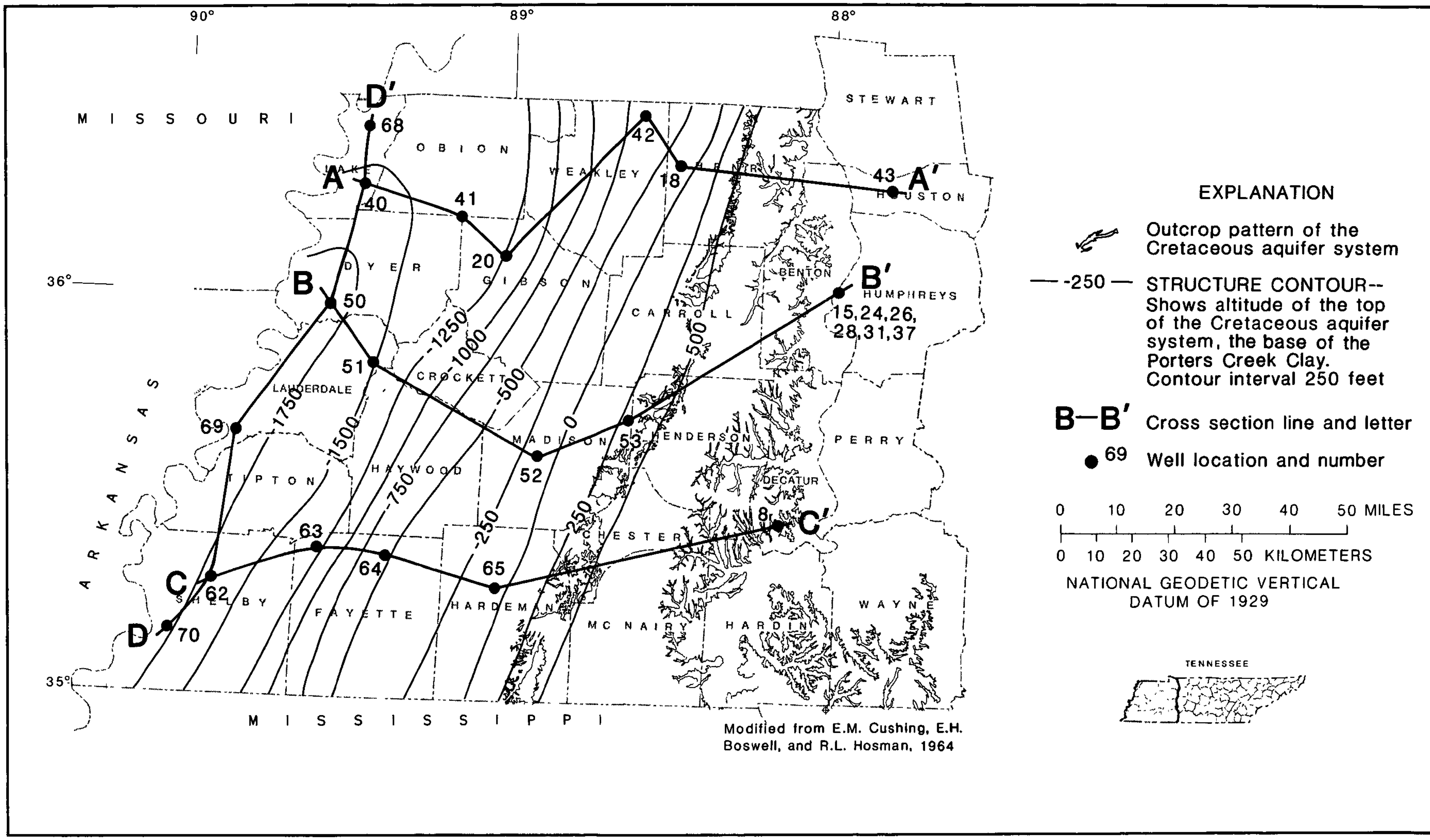

Figure 2.-- Structure contours on the top of the Cretaceous aquifer system.

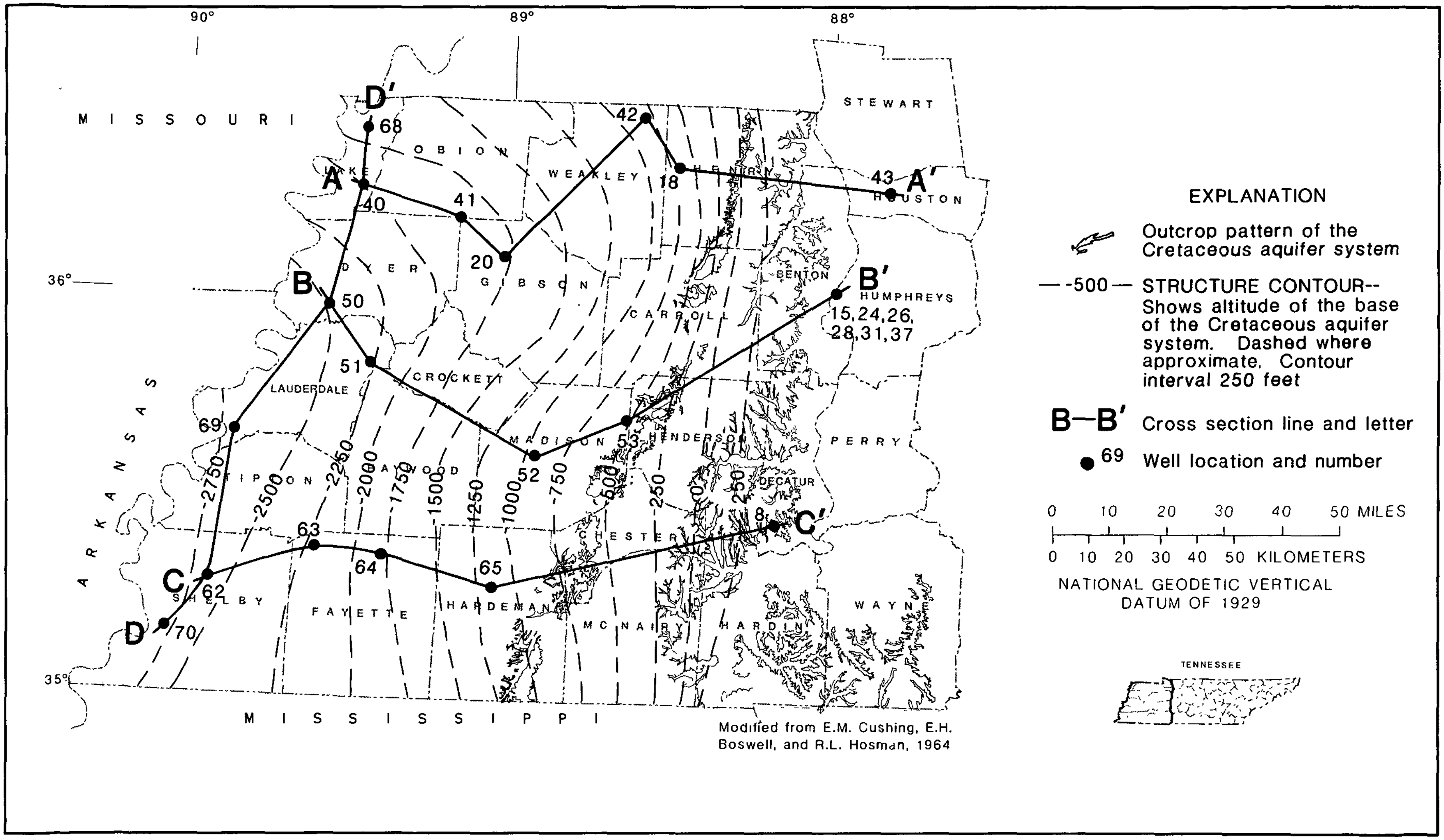

Figure 3.-- Structure contours on the base of the Cretaceous aquifer system.

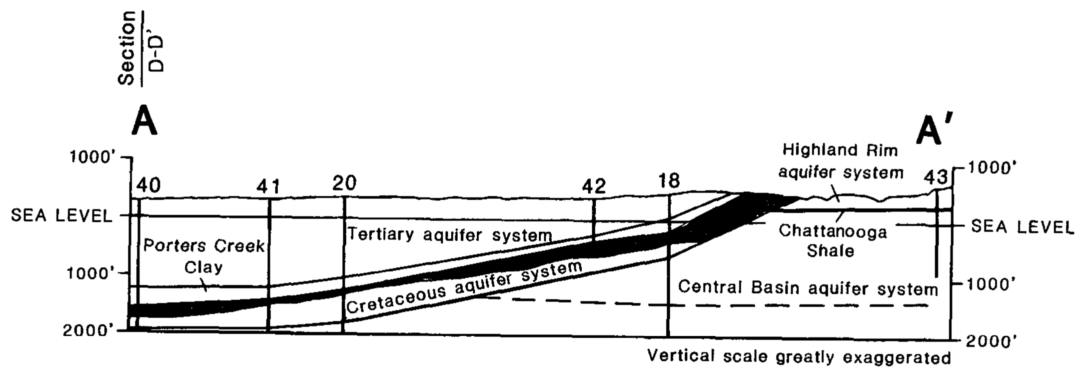

Figure 4.-- Geohydrologic section showing water quality in the Cretaceous aquifer system along line A-A'.

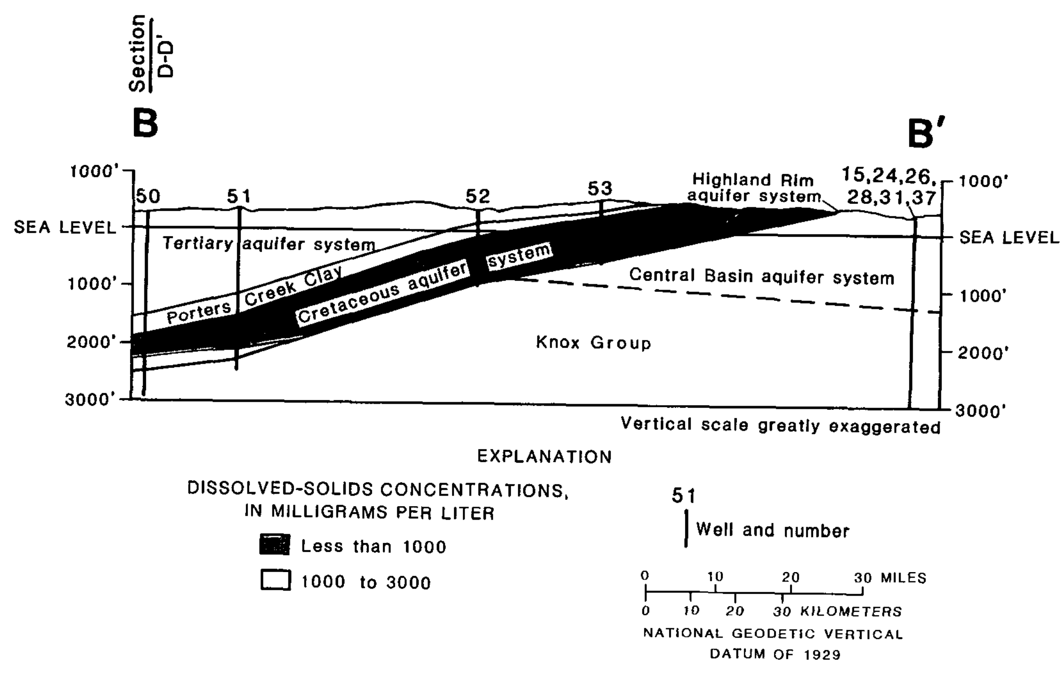

Figure 5.-- Geohydrologic section showing water quality in the Cretaceous aquifer system along line B-B'.

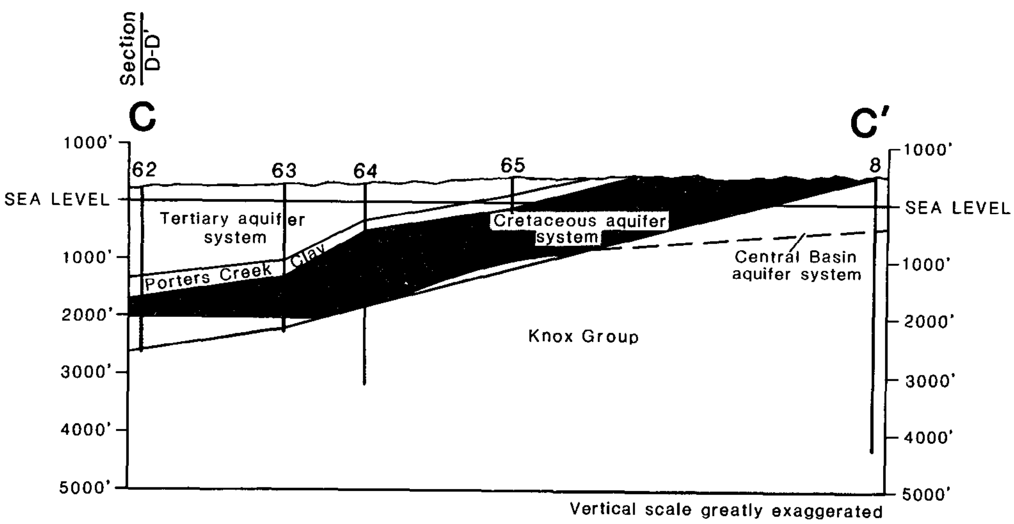

Figure 6.-- Geohydrologic section showing water quality in the Cretaceous aquifer system along line C-C'.

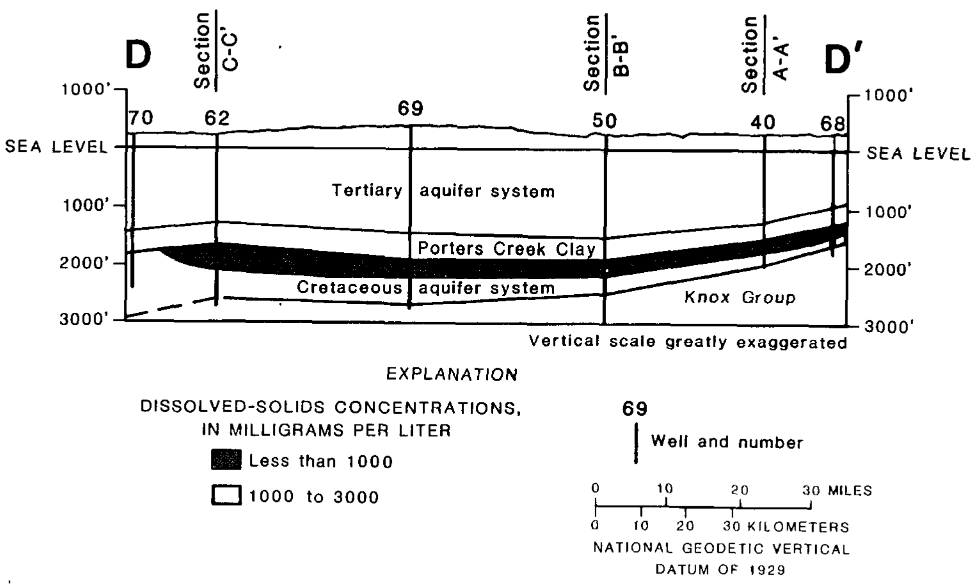

Figure 7.-- Geohydrologic section showing water quality in the Cretaceous aquifer system along line D-D'.

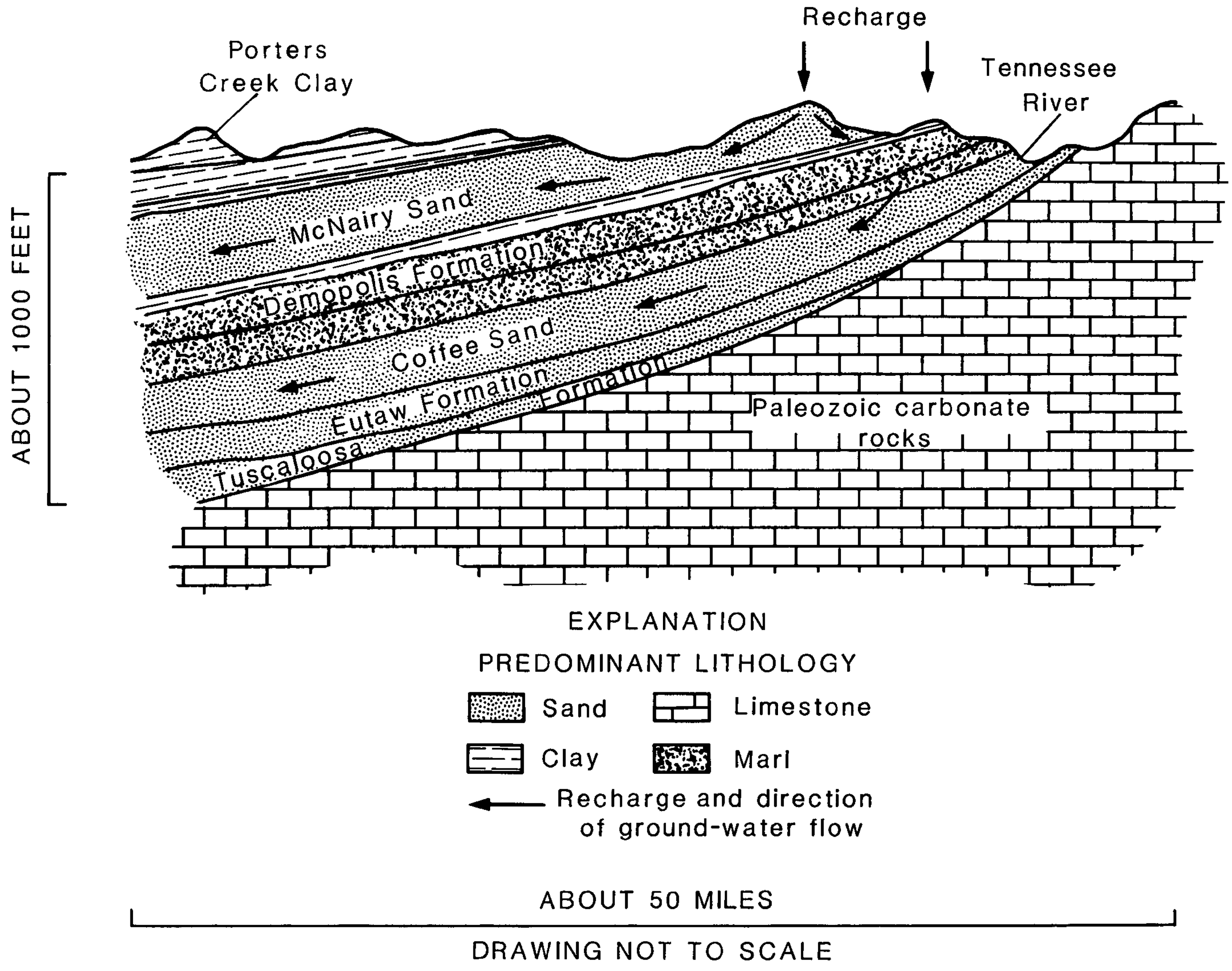

Figure 8.-- Conceptual model of hydrogeology of the Cretaceous aquifer system.

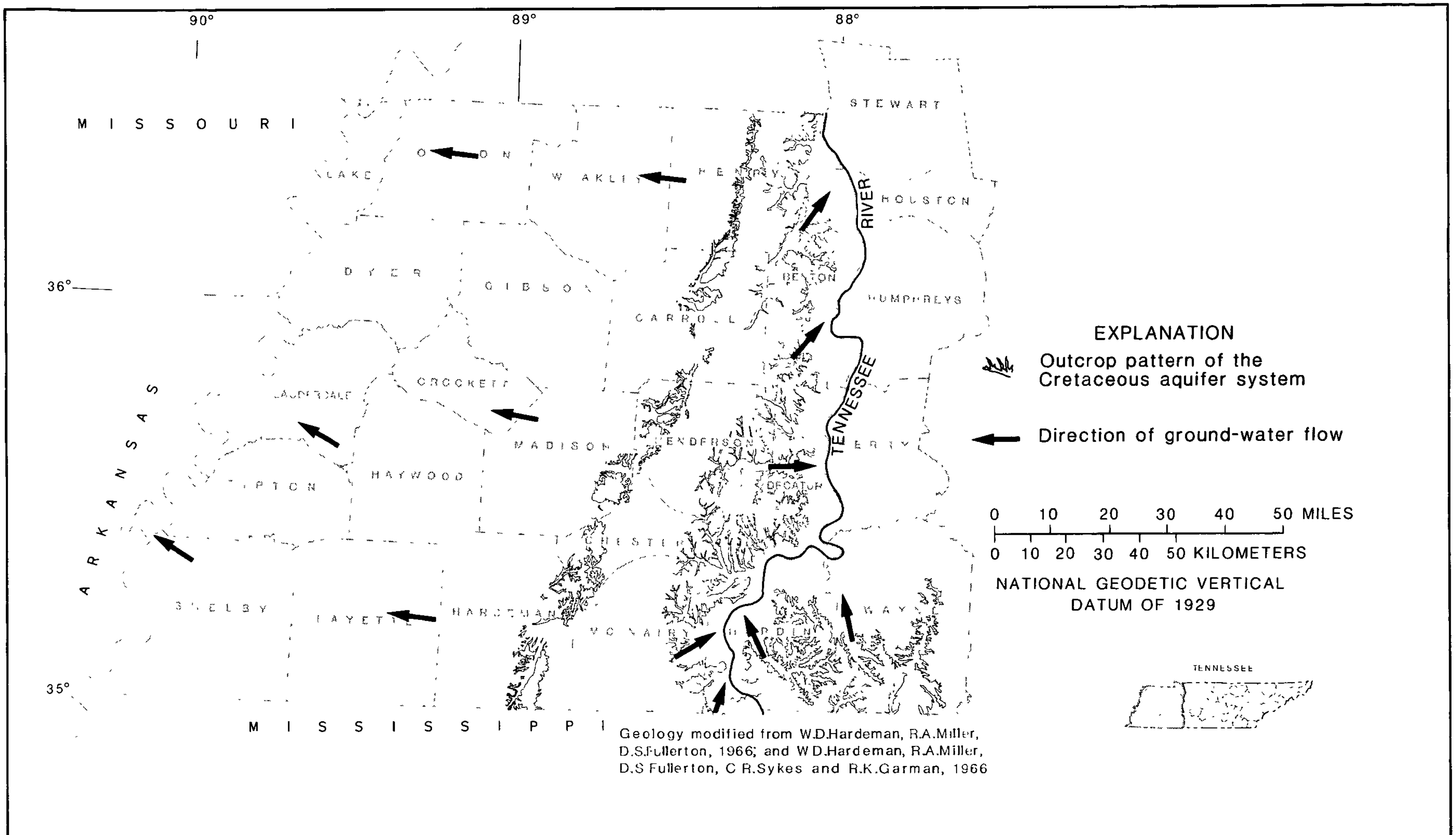

Figure 9.-- Ground-water flow in the Cretaceous aquifer system.

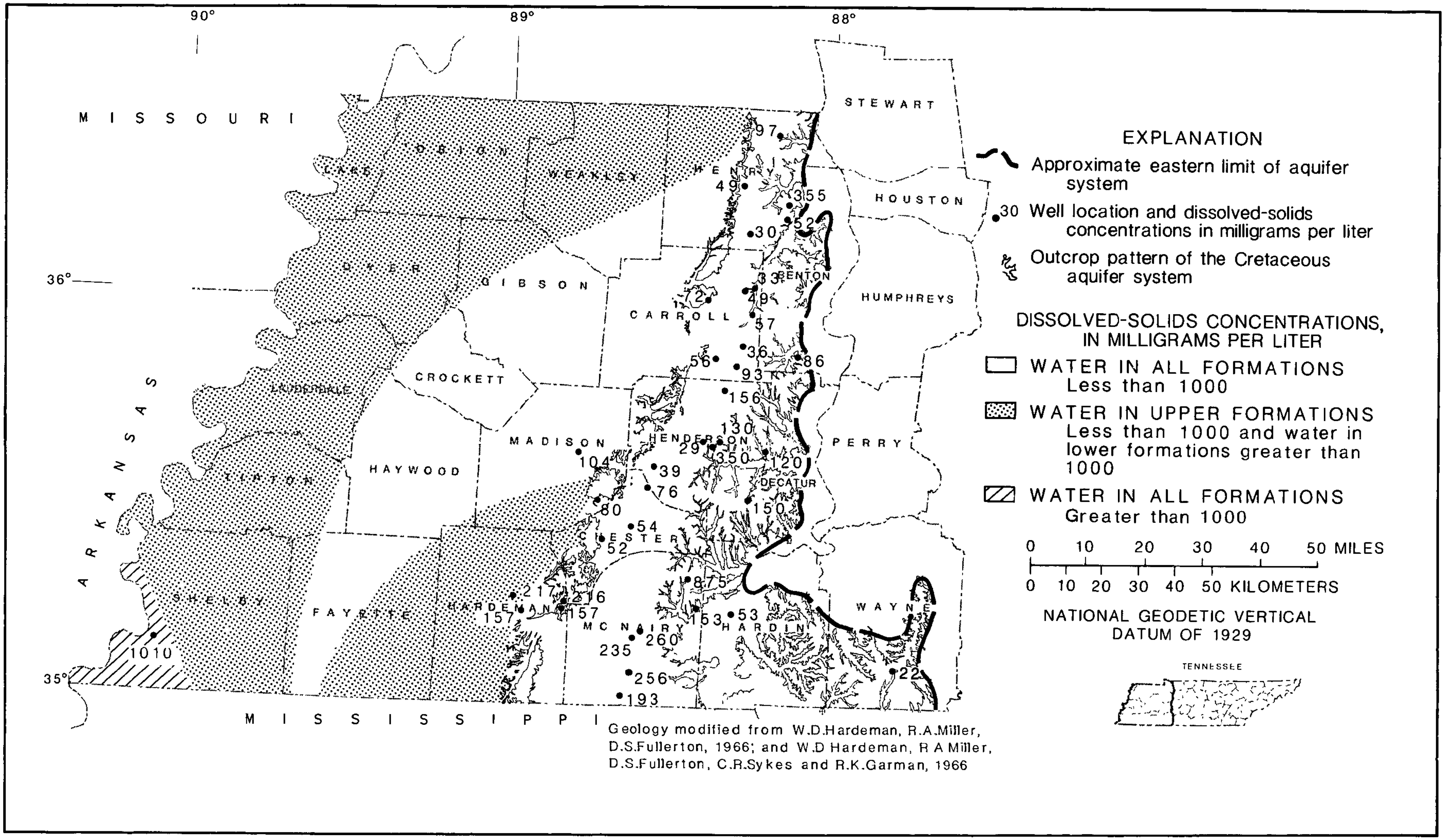

Figure 10.--Dissolved-solids concentrations in the Cretaceous aquifer system.

Table 2.--Dissolved-solids concentrations from selected wells in the Cretaceous aquifer system

[Data sources: 1, Wells (1933); 2, Lanphere (1955); 3, Boswell & others (1965); 4, Theis (1936); 5, Unpublished USGS files]

County	Location	Depth, in feet	Water-bearing formation	Dissolved solids, in milligrams per liter	Data source
Benton	Holladay	35	Coffee	86	1
Carroll	Bruceton	120	McNairy	33	2
	Buena Vista	144	..do..	57	1
	Clarksburg	120	..do..	56	1
	Hollow Rock	82	..do..	49	2
	Huntingdon	213	..do..	72	1
	Westport	61	..do..	36	1
	Yuma	18	..do..	93	1
Chester	Henderson	103	McNairy	54	1
	Mifflin	33	..do..	76	1
	Montezuma	277	..do..	52	1
Hardeman	Bolivar	230	McNairy	217	1
	Bolivar	585	..do..	157	1
	Hornsby	142	..do..	216	1
	Hornsby	140	..do..	157	1
Hardin	Crump	65	Eutaw	53	1
Henderson	Darden	103	Coffee	120	1
	Lexington	114	McNairy	130	1
	Lexington	153	..do..	29	2
	Lexington	496	Eutaw	350	2
	Luray	145	McNairy	39	1
	Scotts Hill	218	Coffee	150	3,5
	Wildersville	30	McNairy	156	1
Henry	Buchanan	36	McNairy	97	1
	Manleyville	80	..do..	52	1
	Mansfield	84	..do..	30	1
	Paris	377	..do..	49	1
	Springville	35	..do..	355	1
McNairy	Adamsville	296	Eutaw	153	2
	Chewalla	310	Coffee	193	1
	Leapwood	330	..do..	875	1
	Ramer	300	..do..	256	1
	Selmer	400	..do..	260	1
	Selmer	589	Eutaw	235	2

Table 2.--Dissolved-solids concentrations from selected wells in the Cretaceous aquifer system--Continued

County	Location	Depth, feet	Water-bearing formation	Dissolved solids, in milligrams per liter	Data source
Madison	Jackson	480	McNairy	104	1
	Pinson, 1.2 mi W	325	..do..	80	1
Shelby	Mallory well field, Memphis	2656	McNairy	1010	3,5
Wayne	Cypress Inn	Spring	Tusculoosa	22	4

Table 3.--Summary of public-supply systems using water from the Cretaceous aquifer system

[Data sources: 1, Reported - Tennessee Division of Water Resources; 2, Reported - Tennessee Division of Water Quality Control; 3, Tennessee comprehensive joint water and related land resources planning, Tennessee Department of Conservation]

Location No.	System	County	Data source
1	Bethel Springs	McNairy	2,3
2	Big Sandy	Benton	1,2,3
3	Bolivar	Hardeman	1,2,3
4	Bruceton	Carroll	1,2,3
5	Cedar Grove Utility District	...do..	1,2,3
6	Clarksburg Utility District	...do..	1,2,3
7	East Paris Utility District	Henry	1,3
8	Eastview Utility District	McNairy	1,2
9	Henderson	Chester	1,2,3
10	Hollow Rock	Carroll	1,2,3
11	Huntingdon	...do..	1,2,3
12	Lexington	Henderson	1,3
13	Michie	McNairy	1,2,3
14	Middleton	Hardeman	1,2,3
15	Paris	Henry	1,2,3
16	Ramer	McNairy	2,3
17	Sardis	Henderson	1,2,3
18	Scotts Hill	...do..	1,2,3
19	Second TriCounty Utility District	McNairy	2
20	Selmer	...do..	1,2,3
21	West Tennessee Water Co.	Henry	1,2,3

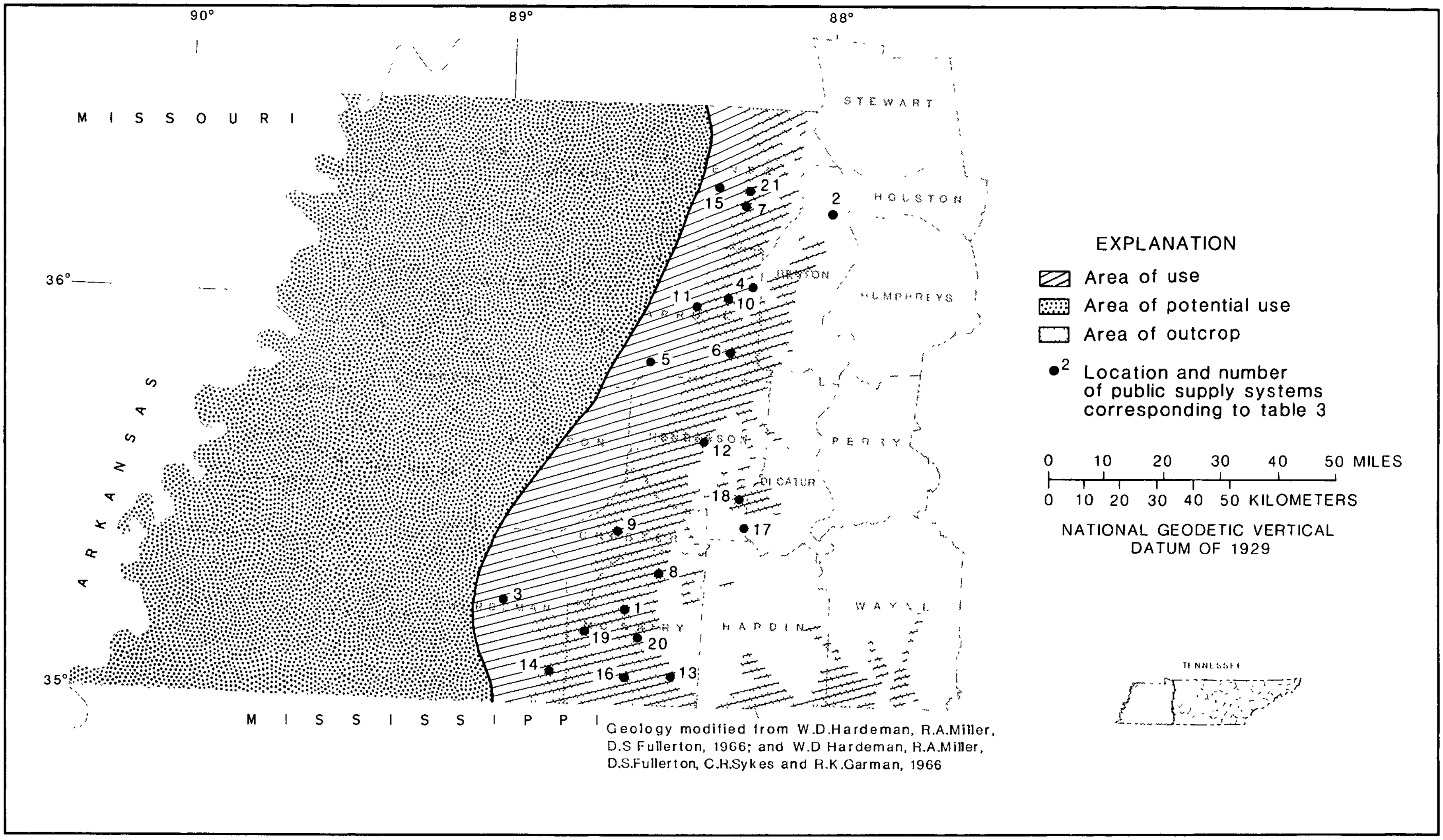

Figure 11.-- Public water-supply systems and areas of use of the Cretaceous aquifer system for drinking water supplies.

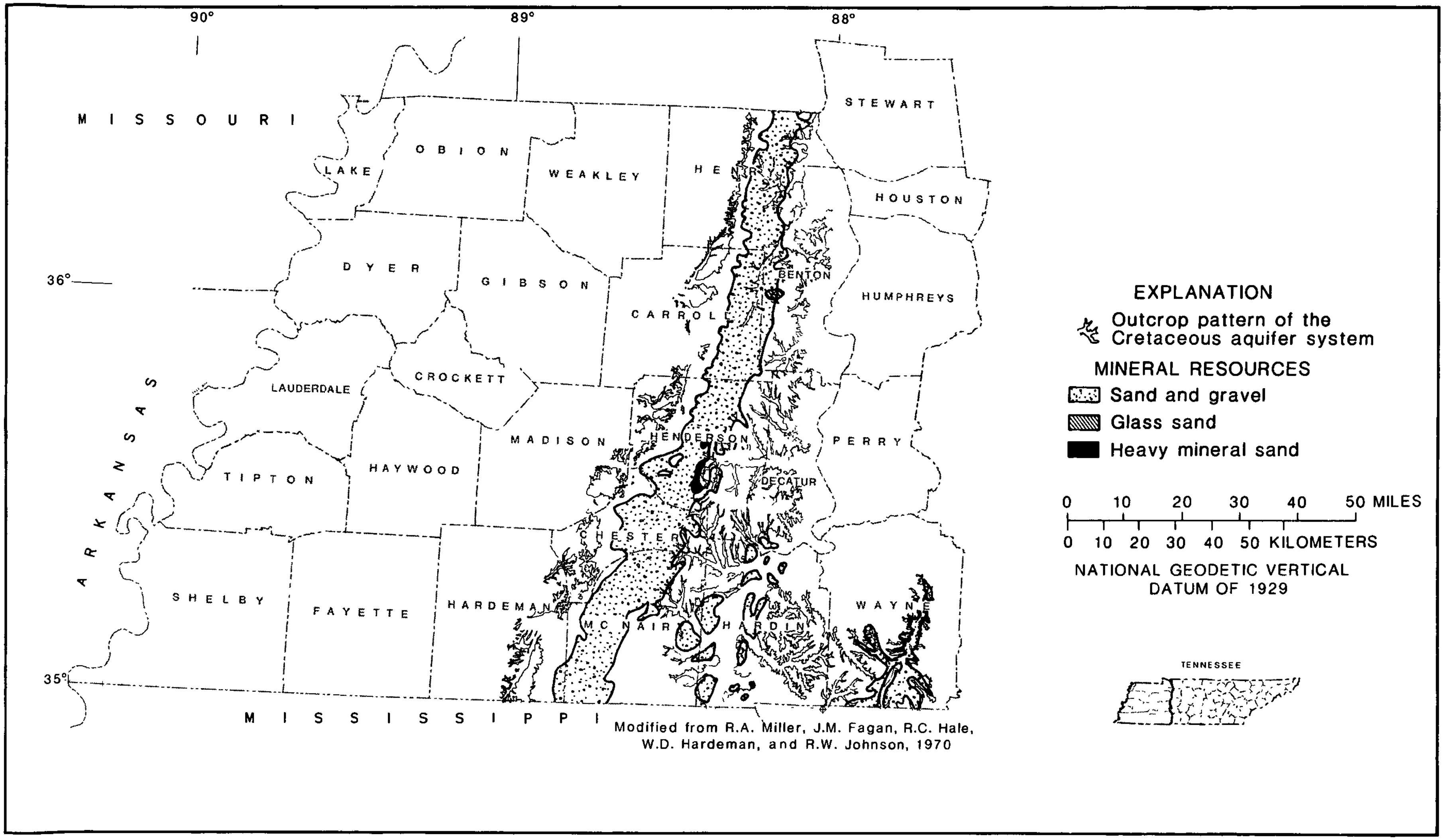

Figure 12.-- Mineral resources of the Cretaceous aquifer system.

REFERENCES

Boswell, E.H., Moore, G.K., MacCary, L.M., and others, 1965, Cretaceous aquifers in the Mississippi Embayment with discussions of Quality of the water by H.G. Jeffery: U.S. Geological Survey Professional Paper 448-C, 37 p.

Brown, D.L., 1971, Techniques for quality of water interpretations from calibrated geophysical logs, Atlantic Coastal Area: Ground Water, v. 9, no. 4, 14 p.

Cushing, E.M., 1966, Map showing altitude of the base of fresh water in coastal plain aquifers of the Mississippi embayment: U.S. Geological Survey Hydrologic Investigation Atlas HA-221.

Cushing, E.M., Boswell, E.H., and Hosman, R.L., 1964, General geology of the Mississippi embayment: U.S. Geological Survey Professional Paper 448-B, 28 p.

Cushing, E.M., Boswell, E.H., Speer, P.R., Hosman, R.L., and others, 1970, Availability of water in the Mississippi embayment: U.S. Geological Survey Professional Paper 448-A, 13 p.

Freeman, L.B., 1953, Regional subsurface stratigraphy of the Cambrian and Ordovician in Kentucky and vicinity: Kentucky Geological Survey Series IX, Bulletin 12, 352 p.

Glenn, L.C., 1904, (Notes on the wells, springs, and general water resources of certain Eastern and Central States) Tennessee: U.S. Geological Survey Water-Supply Paper 102, p. 358-367.

------ 1906, Underground waters of Tennessee and Kentucky west of Tennessee River and of an adjacent area in Illinois: U.S. Geological Survey Water-Supply Paper 164, 173 p.

Hardeman, W.D., Miller, R.A., Fullerton, D.S., Sykes, C.R., and Garman, R.K., 1966, Geologic Map of Tennessee, west and west-central sheets: Tennessee Division of Geology, scale 1:250,000.

Lanphere, C.R., 1955, Geologic source and chemical quality of public ground-water supplies in western Tennessee: Tennessee Division of Geology Report of Investigations no. 1, 69 p.

Marcher, M.V., and Stearns, R.G., 1962, Tuscaloosa formation in Tennessee: Geologic Society of America Bulletin, v. 73, p. 1365-1386.

Milhous, H.C., 1959, Well logs in Tennessee: Tennessee Division of Geology Bulletin 62, 606 p.

Miller, R.A., 1974, The geologic history of Tennessee: Tennessee Division of Geology Bulletin 74, 63 p.

Rima, D.R., 1966, Natural buried reservoirs in western Kentucky and Tennessee: Journal of the American Water Works Association, v. 58, no. 5, p. 573-579.

Russell, E.E., and Parks, W.S., 1975, Stratigraphy of the outcropping Upper Cretaceous, Paleocene, and Lower Eocene in Western Tennessee (including descriptions of younger fluvial deposits): Tennessee Division of Geology Bulletin 75, 53 p.

Stearns, R.G., and Armstrong, C.A., 1955, Post-Paleozoic stratigraphy of western Tennessee and adjacent portions of the upper Mississippi Embayment: Tennessee Division of Geology Report of Investigations No. 2, 29 p.

Wells, F.G., 1933, Ground-water resources of western Tennessee, with a discussion of Chemical character of the water by F.G. Wells and M.D. Foster: U.S. Geological Survey Water-Supply Paper 656, 319 p.

Wilson, J.M., and Criner, J.H., 1969, Geohydrology of Henry and Weakley Counties, Tennessee: Tennessee Divison of Water Resources, Water Resources Series 7, 49 p.

Zurawski, Ann, 1978, Summary appraisals of the Nation's ground-water resources--Tennessee Region: U.S. Geological Survey Professional Paper 813-L, 35 p.

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