INDICATIONS OF DOWNWARD LEAKAGE FROM THE WATER-TABLE AQUIFERS TO THE PRINCIPAL ARTESIAN AQUIFER AT MEMPHIS, TENNESSEE

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Artesian aquifers have served as reliable sources of water in the Memphis area for 100 years. Since 1886, more than 3.3 trillion gallons of water have been withdrawn from the Eocene Memphis Sand ("500-foot" sand) and the deeper Paleocene and Eocene Fort Pillow Sand ("1400-foot" sand). Currently (1987), these aquifers serve as the only major source of water for municipal and industrial use. Although withdrawals in 1984 averaged about 190 millions gallons per day and are likely to increase to meet the demands of an expanding metropolitan area, no serious problems of ground-water availability are anticipated through at least the next half century. However, the discovery that several abandoned dumps in the Memphis urban area contain unknown quantities of hazardous wastes has focused public awareness on a significant potential problem--the unresolved question of the vulnerability of the ground-water resource to contamination. The presence of these dumps has intensified the need for a more complete understanding of the freshwater aquifer system of the Memphis area.

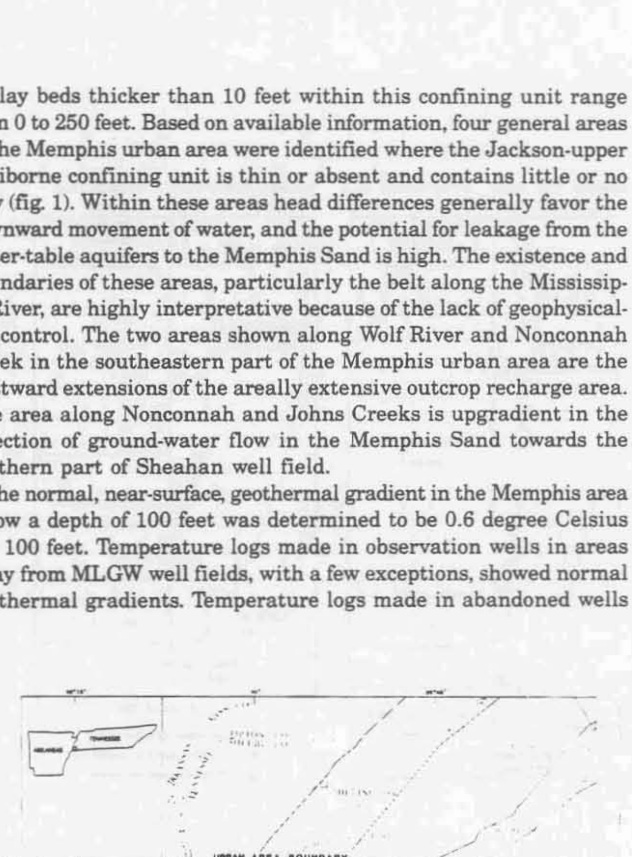
In order to better assess the potential for interaquifer exchange of ground water, the U. S. Geological Survey, in cooperation with the Tennessee Department of Health and Environment, Office of Water Management, and the City of Memphis, Memphis Light, Gas and Water Division (MLGW), initiated an investigation in 1984 to determine the potential for leakage among the principal aquifers in the Memphis area. This investigation consisted primarily of the following elements:

1. geologic information was compiled from geophysical logs, and maps were prepared to show the thickness of the confining beds and the aggregate thickness of clay beds within the confining beds;
2. temperature data were collected using geophysical methods to determine the normal geothermal gradient and deviations from the normal gradient;
3. ground-water level data were collected, and potentiometric maps and derivative head difference maps were prepared to show the potential for vertical movement of water; and
4. water samples were collected and analyzed for selected isotopes of carbon and hydrogen to determine the relative ages of the water.

The results of the investigation were published in a report by Graham and Parks (1986). The present paper summarizes the indications that were found of downward vertical leakage from the water-table aquifers–the alluvium and fluvial (terrace) deposits–to the principal artesian aquifer–the Memphis Sand.

The Jackson-upper Claiborne confining unit in the Eocene Jackson and underlying Claiborne Groups separates the water-table aquifers from the Memphis Sand. In the Memphis urban area, this confining unit ranges from 0 to 360 feet in thickness. Aggregate thicknesses of clay beds thicker than 10 feet within this confining unit range from 0 to 250 feet. Based on available information, four general areas in the Memphis urban area were identified where the Jackson-upper Claiborne confining unit is thin or absent and contains little or no clay (fig. 1). Within these areas head differences generally favor the downward movement of water, and the potential for leakage from the water-table aquifers to the Memphis Sand is high. The existence and boundaries of these areas, particularly the belt along the Mississippi River, are highly interpretative because of the lack of geophysical-log control. The two areas shown along Wolf River and Nonconnah Creek in the southeastern part of the Memphis urban area are the westward extensions of the areally extensive outcrop recharge area. The area along Nonconnah and Johns Creeks is upgradient in the direction of ground-water flow in the Memphis Sand towards the southern part of Sheahan well field.

The normal, near-surface, geothermal gradient in the Memphis area below a depth of 100 feet was determined to be 0.6 degree Celsius per 100 feet. Temperature logs made in observation wells in areas away from MLGW well fields, with a few exceptions, showed normal geothermal gradients. Temperature logs made in abandoned wells



"Figure 1 Areas where the Jackson-upper Claiborne confining unit is thin or absent and the potential for downward leakage from the water-table aquifers to the Memphis Sand is high (from Graham and Parks, 1986)."

and observation wells in MLGW well fields generally showed a pronounced distortion in the geothermal field (fig 2). The geothermal gradients for wells in areas affected by pumping from the Memphis Sand are less than normal gradient for the Memphis area, indicating recharge by downward vertical leakage. If no leakage had occurred, the depth to the coolest water would be at a depth of about 100 feet. However, the depth to the coolest temperature ranged from 100 to 400 feet below land surface in the Memphis area (fig. 3). The areal distribution of the depth to coolest temperature is similar to the potentiometric surface in major cone of depression in the Memphis Sand (fig. 4), indicating a general component of downward vertical leakage in the area of intense pumping from the Memphis Sand in the Memphis urban area.

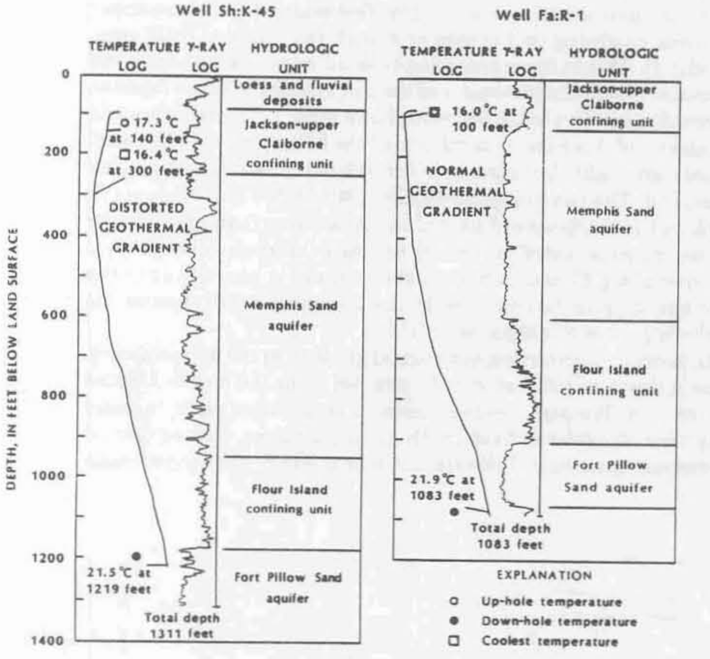


Figure 2 Temperature and gamma-ray logs of wells Sh:K-45 and FA:R-1 showing the normal and distorted geothermal gradients as related to depth and hydrologic unit (from Graham and Parks, 1986). See figure 3 for well locations.

Head differences between the water-table aquifers and the Memphis Sand range from 0 to 130 feet in the Memphis urban area. Areally, the total hydraulic head in the water-table aquifers, as related to sea level, equals or is greater than the total hydraulic head in the Memphis Sand. Therefore, throughout the entire Memphis urban area, the vertical hydraulic gradient favors downward movement of water from the water-table aquifers to the Memphis Sand.

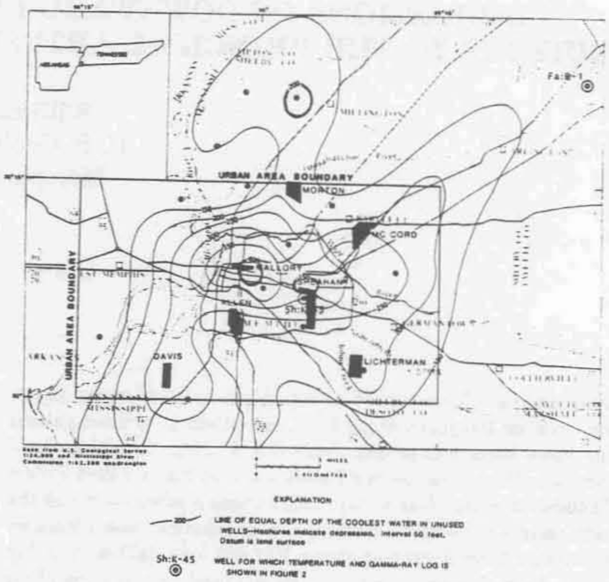


Figure 3 Depth below land surface of the coolest temperature recorded in the wells logged in the Memphis area (modified from Graham and Parks, 1986).

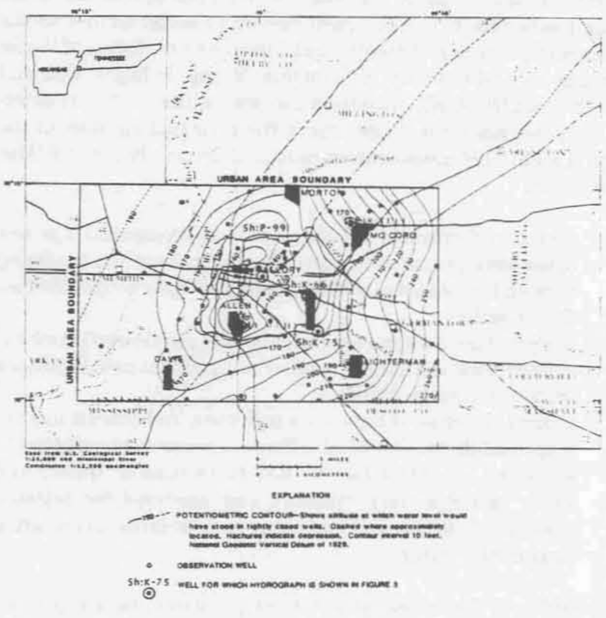


Figure 4 Altitude of the potentiometric surface in the Memphis Sand in the Memphis urban area, fall 1984 (modified from Graham and Parks, 1986).

A depression in the water-table surface was recognized in the southern part of Sheahan well field. This depression was inferred mostly from the record of water levels in observation well Sh:K-75 in the water- table aquifer (fluvial deposits). The hydrograph of Sh:K-75 shows a long-term decline of the water level that is similar to the decline of the water level in Sh:K-66 in the Memphis Sand (fig. 5). The depression in the water-table surface and the water-level

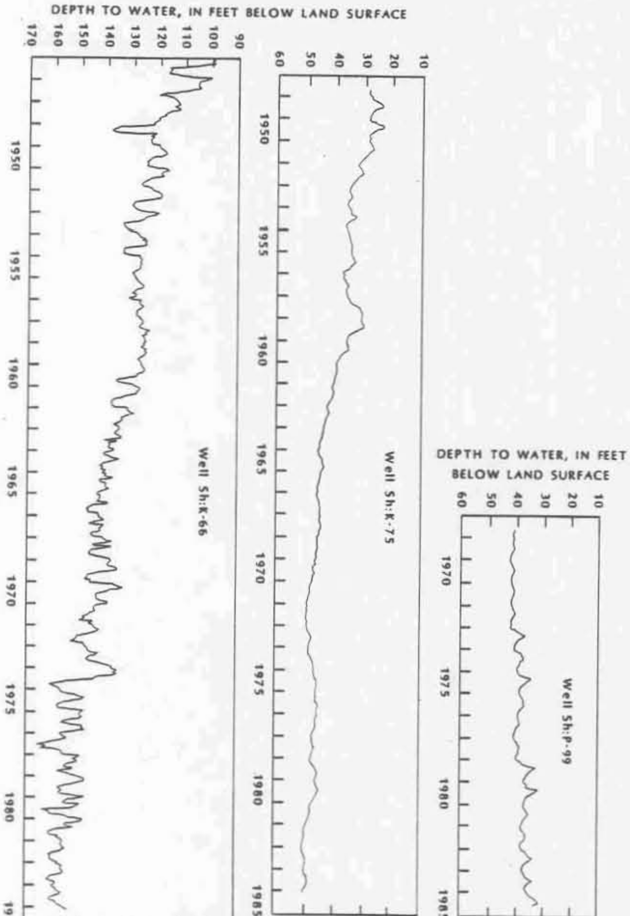


Figure 5 Hydrographs of observation wells Sh:P-99 and Sh:K-75 in the fluvial deposits (water-table aquifer) and Sh:K-66 in the Memphis Sand (from Graham and Parks, 1986). See figure 4 for location of wells.

decline indicate that pumping stress in the Memphis Sand has lowered water levels in the overlying water-table aquifers in the southern part of Sheahan well field. Well Sh:P-99 is located near the center of the major cone of depression in the potentiometric surface of the Memphis Sand (fig. 4), an area where the Jackson-upper Claiborne confining unit is thick and contains much clay. The hydrograph for Sh:P-99 (fig. 5) shows no water-level decline but rather a rise in water levels beginning in 1973 due to recharge from several years of above normal precipitation.

The vertical distribution of carbon-14 data from one of the water-table aquifers (fluvial deposits), the Memphis Sand, and the Fort Pillow Sand shows an increase in the relative age of the water with depth. The areal distribution of carbon-14 data for water from the upper part of the Memphis Sand show a pronounced northwestward deflection of the 75 percent modern contour (fig. 6). This deflection indicates that relatively recent water has been brought into the major

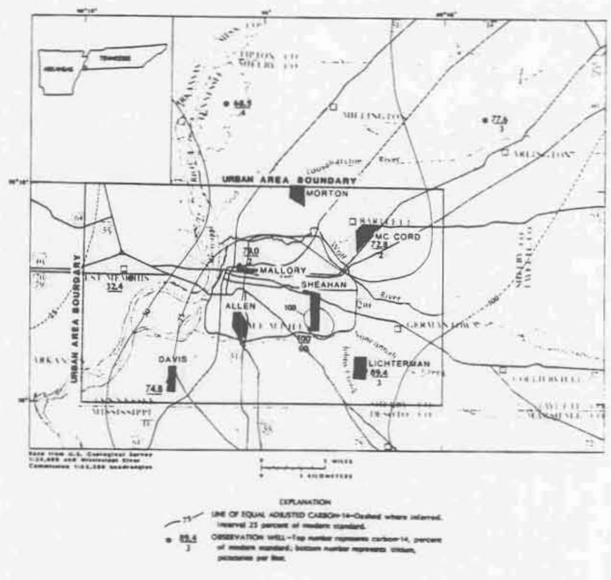


Figure 6.–Distribution of adjusted carbon-14 and tritium in water from the upper part of the Memphis Sand in the Memphis area (from Graham and Parks, 1986).

cone of depression at Memphis (fig. 4), either by horizontal movement through the aquifer from the outcrop recharge area in the southeastern part of the Memphis urban area or by downward vertical leakage from the water-table aquifers. The values of 100 percent of the modern standard for adjusted carbon-14 and 60 picocuries per liter for tritium isotope concentration (fig. 6) indicate that some water from relatively recent precipitation has entered the Memphis Sand in the southern part of Sheahan well field.

In conclusion, the results of this investigation indicate that downward vertical leakage from the water- table aquifers to the Memphis Sand is occurring in the Memphis urban area. This vertical leakage occurs by downward movement of water from the water-table aquifers through the Jackson-upper Claiborne confining unit into the Memphis Sand, or where the confining unit is absent, directly into the Memphis Sand. The downward vertical leakage probably has been greatest in areas where the Jackson-upper Claiborne confining unit is thin or absent and in MLGW well fields where this leakage has been induced by pumping stress in the Memphis Sand.

The southern part of Sheahan well field provides an example of an area where much information is known that indicates vertical leakage is occurring from the water-table aquifers to the Memphis Sand. This information includes: (1) an adjacent area where the confining unit is thin or absent and contains little or no clay, (2) head differences generally favoring the downward movement of water, (3) a distortion in the geothermal gradient with the coolest temperature at a depth of about 230 feet, (4) a depression in the water-table surface and long-term water-level declines in the water-table aquifer (fluvial deposits), and (5) carbon and hydrogen isotope data that indicate the presence of relatively recent water in the Memphis Sand.

REFERENCE

1. Graham, D. D., and Parks, W. S., 1986, **Potential for leakage among principal aquifers in the Memphis area, Tennessee,** U. S. Geological Survey Water Resources Investigations Report 85-4295, 46 p.