U.S. Department of the Interior
U.S. Geological Survey

Estimated Rate of Recharge in Outcrops of the Chicot and Evangeline Aquifers near Houston, Texas

In cooperation with the Harris-Galveston Coastal Subsidence District

During 1989–90, the U.S. Geological Survey (USGS), in cooperation with the Harris-Galveston Coastal Subsidence District, conducted a field study to determine the depth to the water table and to estimate the rate of recharge in outcrops of the Chicot and Evangeline aquifers near Houston, Texas. The study area (fig. 1) comprises about 2,000 square miles of outcrops of the Chicot and Evangeline aquifers in northwestern Harris County, Montgomery County, and southern Walker County. The depth to the water table was estimated using seismic refraction, and an estimated rate of recharge in the aquifer outcrops was computed using the tritium-interface method (Andres and Egger, 1985) in which environmental tritium is the ground-water tracer. The water table generally ranges in depth between 10 and 30 feet in the study area, and the average total recharge rate was estimated to be not larger than 6 inches per year. The rate is total recharge to the saturated zone, rather than net recharge to the deep regional flow system. The total recharge can be reduced by evapotranspiration and by local discharge, mainly to streams. These results are published in USGS Water-Resources Investigations Report 96–4018 (Noble and others, 1996).

A second study of environmental tritium in the same area as the 1989–90 study, also in cooperation with the Harris-Galveston Coastal Subsidence District, was done in 1996 to confirm the results of the original study. This fact sheet documents the estimation of an upper limit on the average total recharge rate on the basis of the vertical movement of tritium in ground water during 1953–89 and during 1953–95.

The USGS acknowledges assistance in the study by personnel from Harris and Montgomery Counties and the Texas Water Development Board.

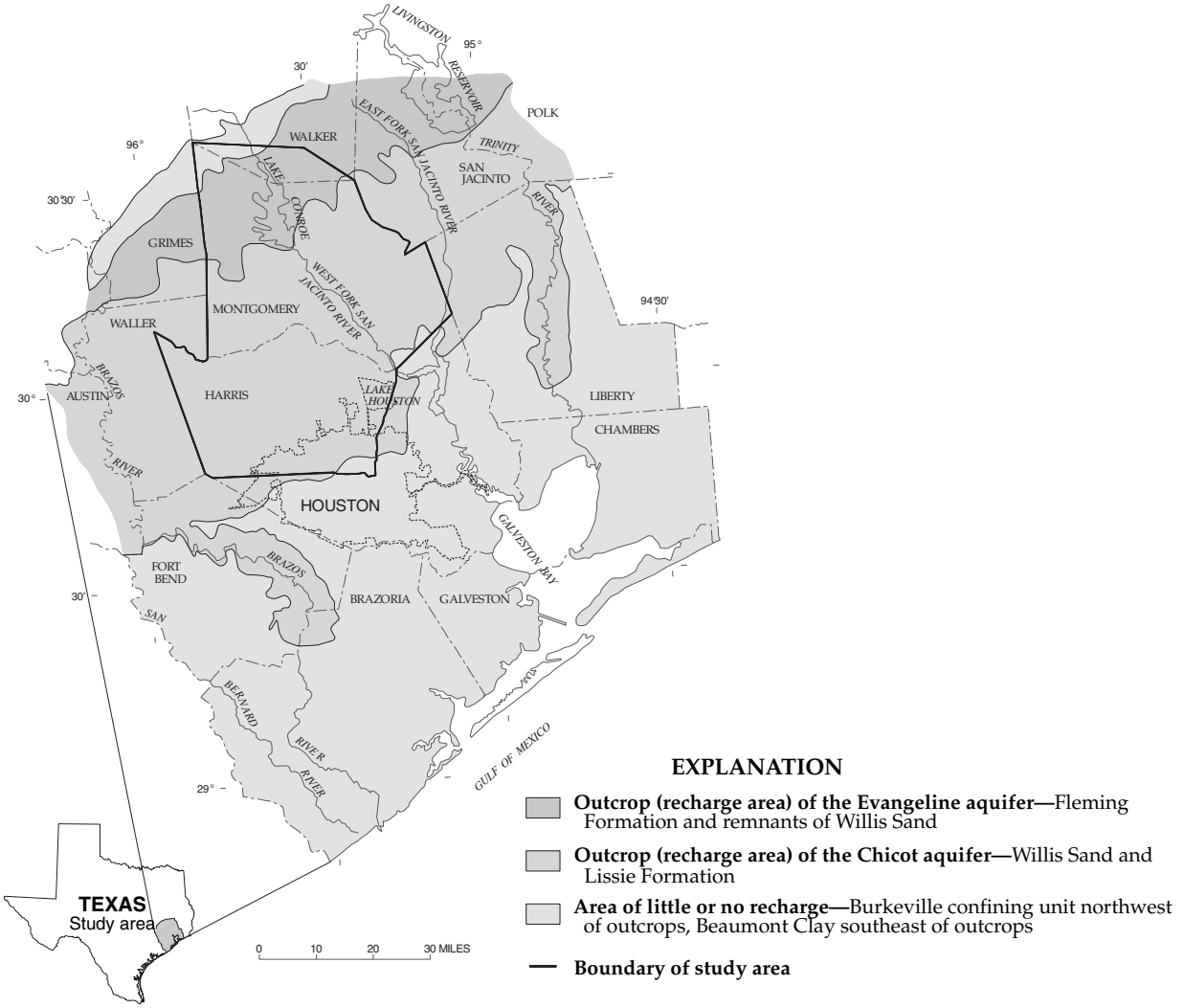

Figure 1. Location of the study area and outcrops of the Chicot and Evangeline aquifers near Houston, Texas (modified from Gabrysch, 1977, fig. 1).

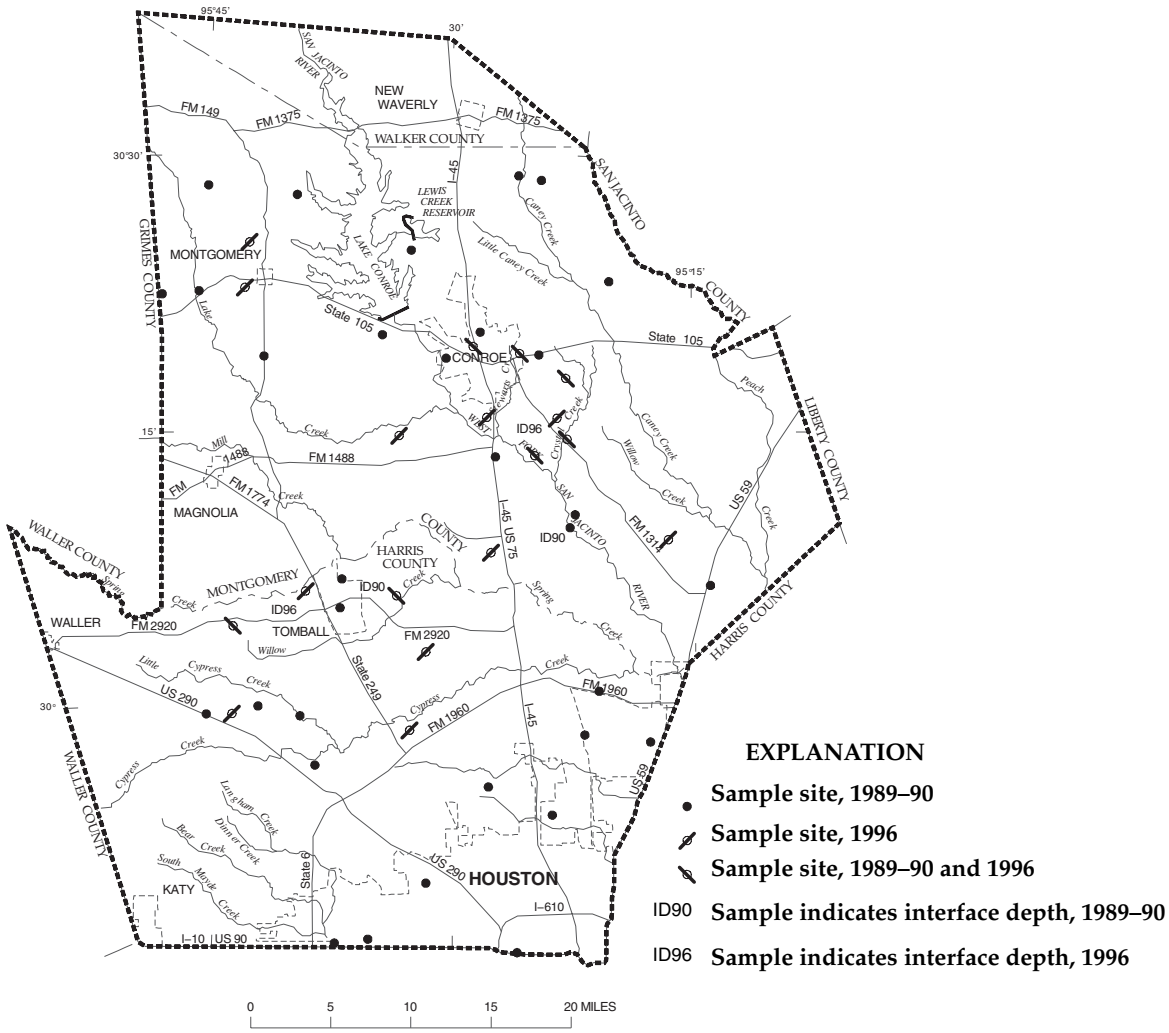

Figure 2. Locations of tritium sampling sites, 1989–90 and 1996 studies, Chicot and Evangeline aquifers near Houston, Texas.

Tritium, a radioactive isotope of hydrogen with an atomic mass of 3, is used as a tracer for studying ground-water processes that occur on a scale of less than 100 years (Plummer and others, 1993, p. 257). Tritium is particularly suited for recharge studies because it enters the hydrologic cycle as part of the water molecules in precipitation, it has a half-life (the time required for a radioactive element to lose one-half of its radioactivity) of 12.43 years, and its concentrations in precipitation were increased substantially by atmospheric nuclear testing during 1953–62.

Before atmospheric nuclear testing, the amount of tritium in the environment was very small. Concentrations in precipitation before 1953 are not well known. Payne (1972) estimates a range of 2 to 25 tritium units (TU) (1 TU equals 3.24 picocuries per liter). In 1953 when atmospheric thermonuclear testing began, the concentrations of tritium in precipitation began to rise, peaking at about 2,000 TU in May 1962 at Waco, Tex., the USGS tritium sampling station nearest to Houston.

Because of radioactive decay, ground water recharged exclusively from precipitation that fell before 1953 would have maximum tritium concentrations of about 0.2 to 0.8 TU by the early 1990s (Plummer and others, 1993, p. 260). If ground water has larger tritium concentrations, some fraction of the water must have come from precipitation that fell after 1953. Thus, tritium can be a marker for recharge that occurred after 1953. The greatest depth below the water table at which postnuclear-testing tritium concentrations are found can be used to estimate a maximum rate for recharge that has occurred since 1953.

Method of Estimating Recharge Rate Using Environmental Tritium

The method of estimating recharge rate using environmental tritium in this and the previous study is called the interface method (Andres and Egger, 1985). "Interface" refers to the deepest point below the water table to which tritium at postnuclear-testing concentrations has traveled. The basis for the method is that the vertical distance downward from the water table that the tritium has traveled is equal to the rate of travel multiplied by the time of travel (time difference between sampling year and 1953). Expressed as an equation,

$$\text{distance (depth)} = \text{rate} \times \text{time}. \quad (1)$$

Application of the interface method in the 1989–90 and 1996 environmental-tritium studies was based on the following assumptions: The ground-water flow in the study area is mainly vertical and downward. The water table demonstrates no

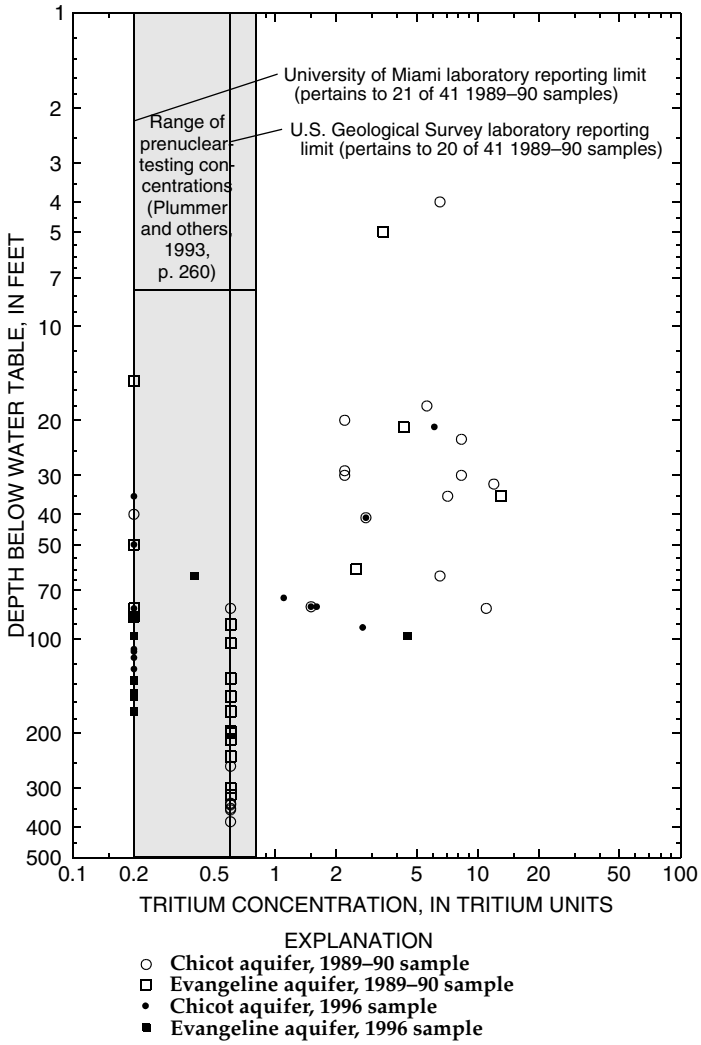

Figure 3. Depth below water table of environmental tritium concentrations in samples from selected wells, 1989–90 and 1996 studies, Chicot and Evangeline aquifers near Houston, Texas.

long-term trends from 1953 to the time of sampling, and 1989–90 and 1996 water levels are the same. Tritium moves in the aquifer at a rate equal to the average interstitial velocity of ground-water flow. The volume of water per unit area that entered the saturated zone during the period between the tritium sampling year and 1953 divided by the length of the period (average specific discharge during the period) is equal to the average recharge rate during the period.

Given these assumptions and that in ground-water flow,

$$\frac{\text{specific discharge}}{\text{effective porosity}} = \text{average interstitial velocity}, \qquad (2)$$

(Lohman and others, 1972, p. 13), an equation for recharge rate is developed from equations 1 and 2 as follows:

$$\text{depth} = \text{average interstitial velocity} \times \text{time}, \qquad (3)$$

$$\text{depth} = \frac{\text{specific discharge} \times \text{time}}{\text{effective porosity}}, \qquad (4)$$

$$\text{depth} = \frac{\text{recharge rate} \times \text{time}}{\text{effective porosity}}, \qquad (5)$$

and finally,

$$\text{recharge rate} = \frac{\text{depth} \times \text{effective porosity}}{\text{time}}. \qquad (6)$$

Because the recharge rate computed from equation 6 (commonly expressed in inches per year) is based on the deepest penetration below the water table of postnuclear-testing tritium concentrations, it represents an upper bound on the average recharge rate during the time between the tritium sampling year and 1953.

Field Application of the Method and Estimation of Recharge Rate

In this and the 1989–90 study, shallow water wells were selected for tritium sampling on the basis of location and screened interval. In the 1989–90 study, the selection objectives were to obtain samples from locations throughout the study area and from as many depths as possible. Forty-one wells (fig. 2) were sampled in that study. In the 1996 study the selection objectives were to obtain tritium samples from depths less than 175 feet below the water table, selectively resample wells used in the 1989–90 study, and establish new sample locations in the study area. Approximately one-half of the wells selected for resampling from the 1989–90 study were not sampled because they had been deepened beyond the zone of interest, destroyed, or were dry. Consequently, only 6 of the 28 wells of the 1989–90 study with sample depths less than 175 ft could be resampled in the 1996 study, necessitating sampling of more new locations than expected.

For the 1996 study, 23 wells were sampled at 18 locations (fig. 2). For both studies at least three volumes of casing water were pumped from each well before sampling to ensure that samples were representative of water from the screened intervals. Samples from the 1989–90 study were analyzed by the USGS laboratory in Reston, Va., where the detection limit at the time was 0.6 TU, and the University of Miami (Fla.) laboratory, where the detection limit was 0.2 TU. Samples from the 1996 study were analyzed at the University of Miami laboratory; the detection limit was unchanged.

The results of tritium analyses from 1989–90 indicate that tritium concentrations range from less than the detection limits to 13 TU (table 1). Results from the 1996 study indicate that tritium concentrations range from less than the detection limits to 6.1 TU. The distribution of tritium concentrations in the Chicot and Evangeline aquifers did not support estimating separate recharge rates for the two aquifers.

To determine the subsurface location of the tritium interface, the sample-collection depth below the water table was graphed as a function of tritium concentration (fig. 3). The graph shows that the deepest penetration below the water table of tritium concentrations is approximately 80 feet in the 1989–90 study, and approximately of 95 feet in the 1996 study.

Noble and others (1996, p. 17) estimated that effective porosity in the outcrop area of the Chicot and Evangeline aquifers likely ranges from 20 to 25 percent. Accordingly, a mid-range estimated effective porosity of 23 percent was used to estimate

Table 1. Environmental tritium concentrations in samples from selected wells, 1989–90 and 1996 studies, Chicot and Evangeline aquifers near Houston, Texas

[<, less than]

Well number or location	Sample depth below water table (feet)	Tritium (sample) concentration (tritium units)	Year sampled
Chicot aquifer			
LJ–65–02–311	4	6.5	1990
TS–60–44–610	18	5.6	1990
LJ–65–12–734	20	2.2	1990
TS–60–45–414	21	4.3	1990
TS–60–45–414	21	6.1	1996
LJ–65–06–111	23	8.3	1990
LJ–65–12–725	29	2.2	1990
LJ–60–60–111	30	2.2	1990
LJ–65–05–930	30	8.3	1990
LJ–65–13–839	32	12	1990
TS–60–53–720	35	<.2	1996
TS–60–53–316A	35	<.2	1996
TS–60–53–316B	35	<.2	1996
TS–60–53–316	35	7.1	1990
LJ–65–12–303	40	<.2	1990
LJ–60–59–403	41	<.2	1996
LJ–60–59–403	41	2.8	1990
TS–60–44–806	50	<.2	1996
LJ–65–03–620	63	6.5	1990
TS–60–45–413	74	1.1	1996
LJ–60–60–206	79	1.6	1990
LJ–60–60–206	79	1.5	1996
TS–60–63–110	80	<.6	1990
LJ–65–02–313	80	<.2	1996
TS–60–54–702	80	11	1989
LJ–60–60–206B	83	1.6	1996
LJ–60–59–326	92	2.7	1996
TS–60–45–706	108	<.2	1996
TS–60–54–806	110	<.2	1996
12250 Cutten Rd.	115	<.2	1996
19035 Doerre Rd.	125	<.2	1996
Evangeline aquifer			
TS–60–37–203	5	3.4	1990
TS–60–34–301	15	<.2	1990
TS–60–37–309	35	13	1990
TS–60–34–904	50	<.2	1990
TS–60–38–704	60	2.5	1990
TS–60–35–504	63	<.8	1996
TS–60–44–214	80	<.2	1990
TS–60–46–406	85	<.2	1990
TS–60–46–406	85	<.2	1996
TS–60–35–204	90	<.6	1989
TS–60–35–503	98	<.2	1996
TS–60–45–905	98	4.5	1996
TS–60–45–114	103	<.6	1989
TS–60–42–202	134	<.6	1989
TS–66–44–805	136	<.2	1996
TS–60–35–705	150	<.2	1996
TS–60–45–513	153	<.6	1989
TS–60–45–513	153	<.2	1996
TS–60–53–315	171	<.6	1989
TS–60–53–315	171	<.2	1996

the average recharge rate in the 1989–90 and 1996 recharge studies.

On the basis of a maximum tritium depth of 80 feet from the 1989–90 study, the upper limit on the average recharge rate during the 37 years 1953–89 was estimated to be 6 inches per year (Noble and others, 1996, p. 17). On the basis of a maximum tritium depth of 95 feet from the 1996 study, the upper limit on the average recharge rate during the 43 years 1953–95 also is estimated to be 6 inches per year. As previously noted, the estimated average recharge rate represents total recharge to the saturated zone, rather than net recharge to the deep regional flow system, because the total recharge can be reduced by evapotranspiration and local discharge. Estimation of the difference between total recharge and net recharge was beyond the scope of this study.

References Cited

Andres, Gerhard, and Egger, Richard, 1985, A new tritium interface method for determining the recharge rate of deep groundwater in the Bavarian Molasse Basin: Journal of Hydrology, v. 82, no. 1/2, p. 27–38.

Gabrysch, R.K., 1977, Approximate areas of recharge to the Chicot and Evangeline aquifer systems in the Houston-Galveston area, Texas: U.S. Geological Survey Open-File Report 77–754, 1 sheet.

Lohman, S.W., and others, 1972, Definitions of selected groundwater terms—revisions and conceptual refinements: U.S. Geological Survey Water-Supply Paper 1988, 21 p.

Noble, J.E., Bush, P.W., Kasmarek, M.C., and Barbie, D.L, 1996, Estimated depth to the water table and estimated rate of recharge in outcrops of the Chicot and Evangeline aquifers near Houston, Texas: U.S. Geological Survey Water-Resources Investigations Report 96–4018, 19 p.

Payne, B.R., 1972, Isotope hydrology: Advanced Hydroscience, v. 8, p. 95–138.

Plummer, L.N., Michel, R.L., Thurman, E.M., and Glynn, P.D., 1993, Environmental tracers for age dating young ground water, *in* Alley, W.M., Regional ground-water quality: New York, Van Nostrand Reinhold, 634 p.

—John E. Noble

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

For more information, please contact:

Subdistrict Chief
U.S. Geological Survey
2320 La Branch Street
Houston, TX 77004

Phone: (713) 717–3655
FAX: (713) 718–3661
World Wide Web: http://txwww.cr.usgs.gov