In cooperation with the San Antonio Water System

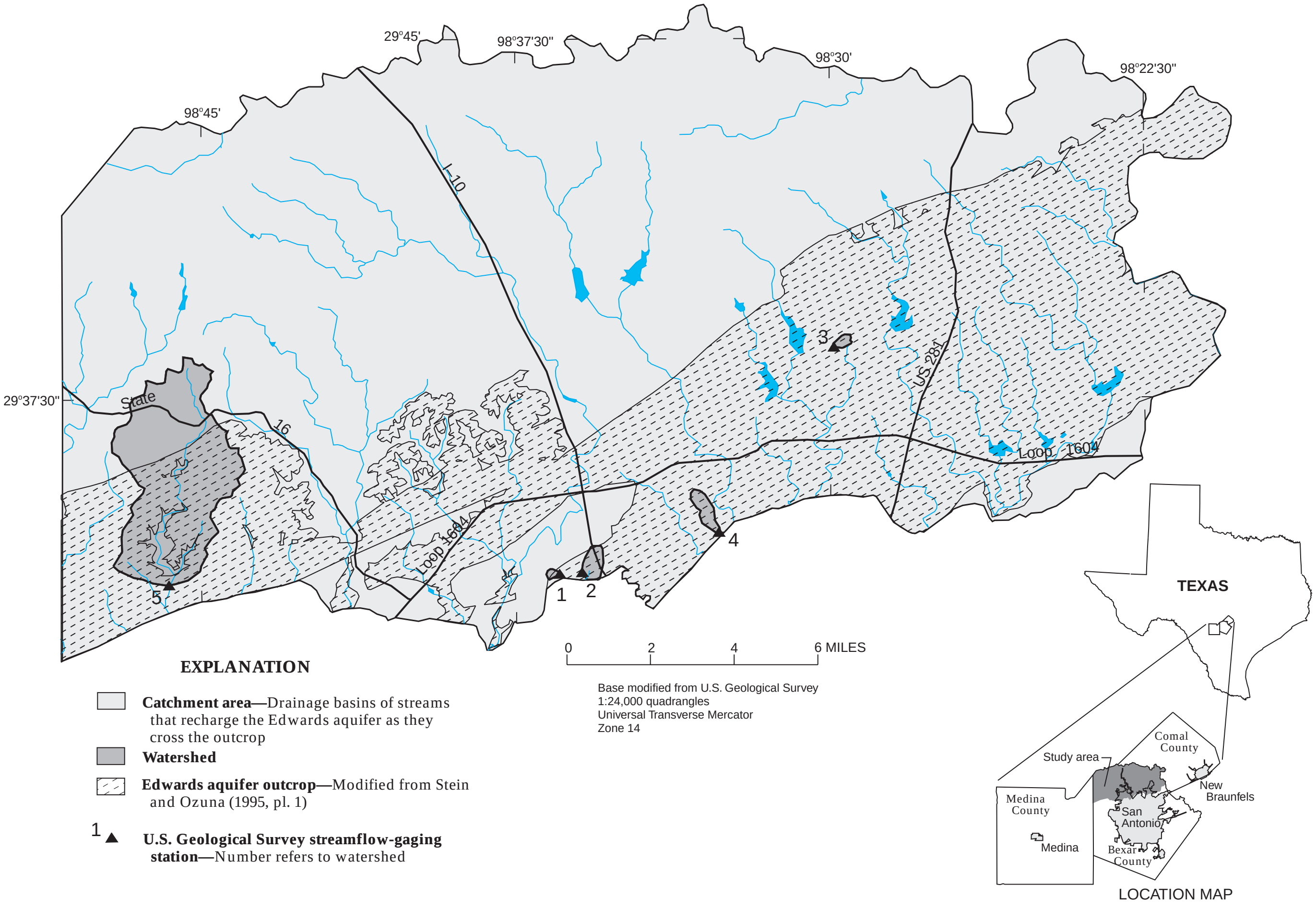
Stormwater Runoff for Selected Watersheds in the Edwards Aquifer Recharge Zone, Bexar County, Texas, 1996–98

The Edwards aquifer is one of the most productive carbonate aquifers in the Nation. The dissolution-modified, faulted limestone aquifer is the sole source of public water supply for San Antonio, Texas (fig. 1) and is the major source of water for Bexar County. In addition to providing public water supply to more than 1 million people, the Edwards aquifer supplies large quantities of water for agriculture, industry, and military installations. Major springs discharging from the aquifer support recreational activities and businesses, provide water to downstream users, and provide habitat for several threatened or endangered species.

The Edwards aquifer recharge zone is approximately coincident with the stratigraphic units that constitute the Edwards aquifer outcrop; however, the recharge zone includes outcrops of other stratigraphic units in proximity to the units of the Edwards aquifer outcrop where caves, sinkholes, faults, fractures, or other permeable features create a potential for recharge. For this report, areas that are immediately adjacent to the Edwards aquifer outcrop and that drain to the outcrop are considered to be in the recharge zone.

In Bexar County, the area of the Edwards aquifer outcrop is about 119 square miles (mi^2). Most of the land (about 72 percent) on the outcrop is undeveloped (fig. 2). Residential use is about 10 percent of the outcrop land use.

Residential and commercial development on the Edwards aquifer recharge zone in Bexar County is increasing. Urban development can have an appreciable influence on water quality. Impervious cover in developed areas can result in increased stormwater runoff, conveying contaminants from nonpoint sources to local streams or geologic features such as



Base modified from U.S. Geological Survey 1:24,000 quadrangles Universal Transverse Mercator Zone 14

Figure 1. Location of selected watersheds and streamflow-gaging stations in the Edwards aquifer recharge zone, Bexar County, Texas.

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

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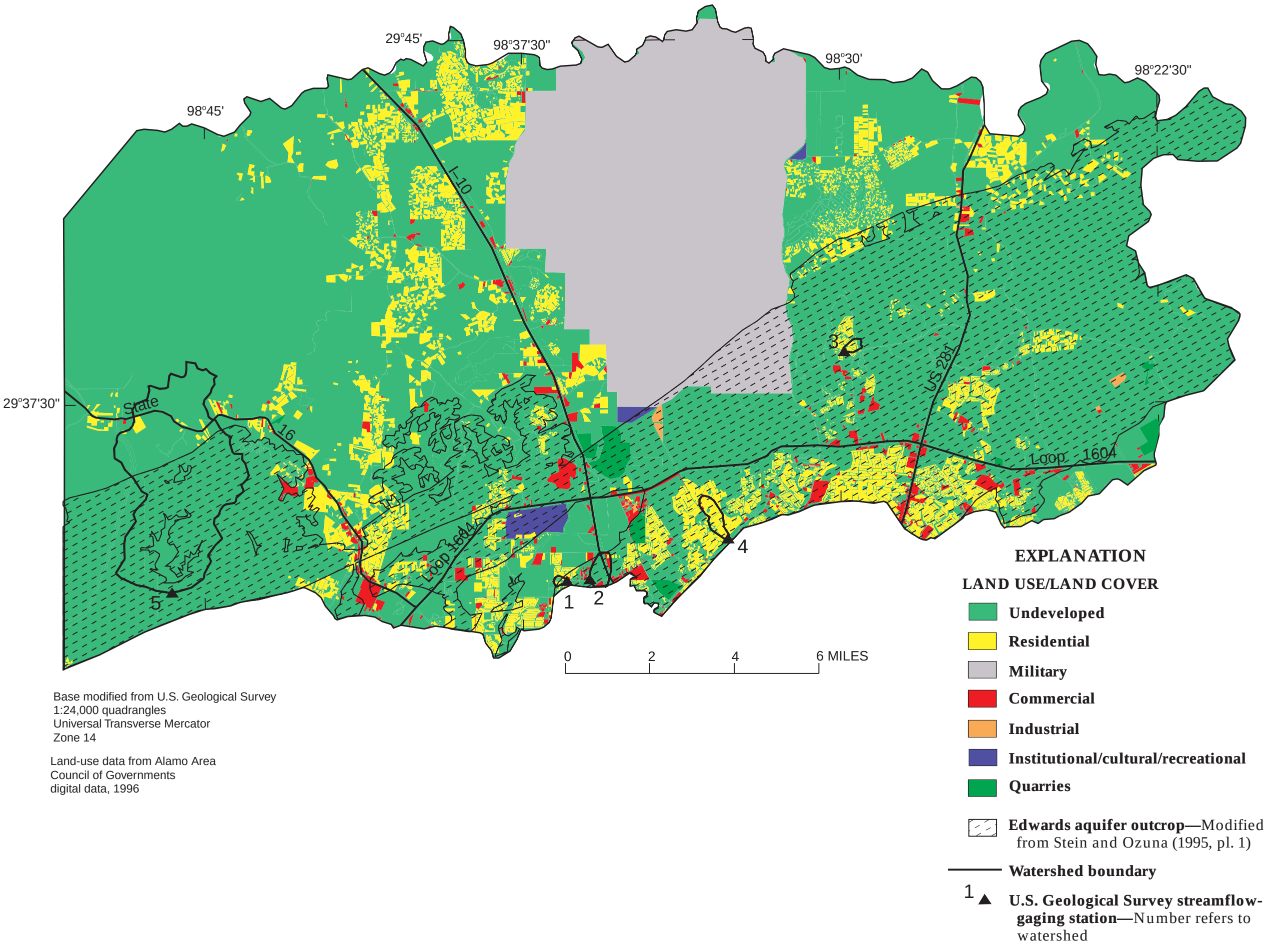

Base modified from U.S. Geological Survey
1:24,000 quadrangles
Universal Transverse Mercator
Zone 14

Land-use data from Alamo Area
Council of Governments
digital data, 1996

Figure 2. Land use/land cover in the Edwards aquifer recharge zone, Bexar County, Texas, 1996.

caves and fractures where infiltration into the aquifer can occur.

In 1996, the U.S. Geological Survey (USGS), in cooperation with the San Antonio Water System, began a study to monitor the quality and quantity of stormwater runoff of five selected watersheds in the Edwards aquifer recharge zone. The purpose of the study is to further the understanding of relations between stormwater and land use and to help resource managers assess the effects of development on the Edwards aquifer recharge zone. Land use is relatively commercial in two of the watersheds and predominantly residential in two of the watersheds; one watershed is largely undeveloped (table 1). This fact sheet provides an overview of the data-collection methods and selected results of analysis.

Data Collection and Analysis

Rainfall and runoff data and stormwater samples were collected during June 1996–October 1998 from streamflow-gaging stations at the outlets of the five selected watersheds in the Edwards aquifer recharge zone. At each station, rainfall and gage height (stream water level) were measured during storm-runoff events. A computer recorded instrument readings, calculated stream discharges (and runoff), and activated automatic water samplers on the basis of calculated runoff. During each storm-runoff event, the autosamplers were programmed to collect numerous

Table 1. Characteristics of selected watersheds in the Edwards aquifer recharge zone, Bexar County, Texas, 1996–98

[<, less than]

Watershed (fig. 1)	Drainage area (acres)	Impervious cover (percent)	Land use/ land cover	Remarks
1	19	50	Commercial	No stormwater-control structures.
2	315	45–65	Commercial	Watershed includes section of I–10; stormwater-control structures required for businesses; ongoing construction during study period.
3	75	40–50	Residential	Medium density, single-family homes.
4	250	<5	Residential	3- to 5-acre lots; septic tanks.
5	6,880	<2	Undeveloped	Upper 2,450 acres of watershed is upstream of recharge zone; runoff events are rare.

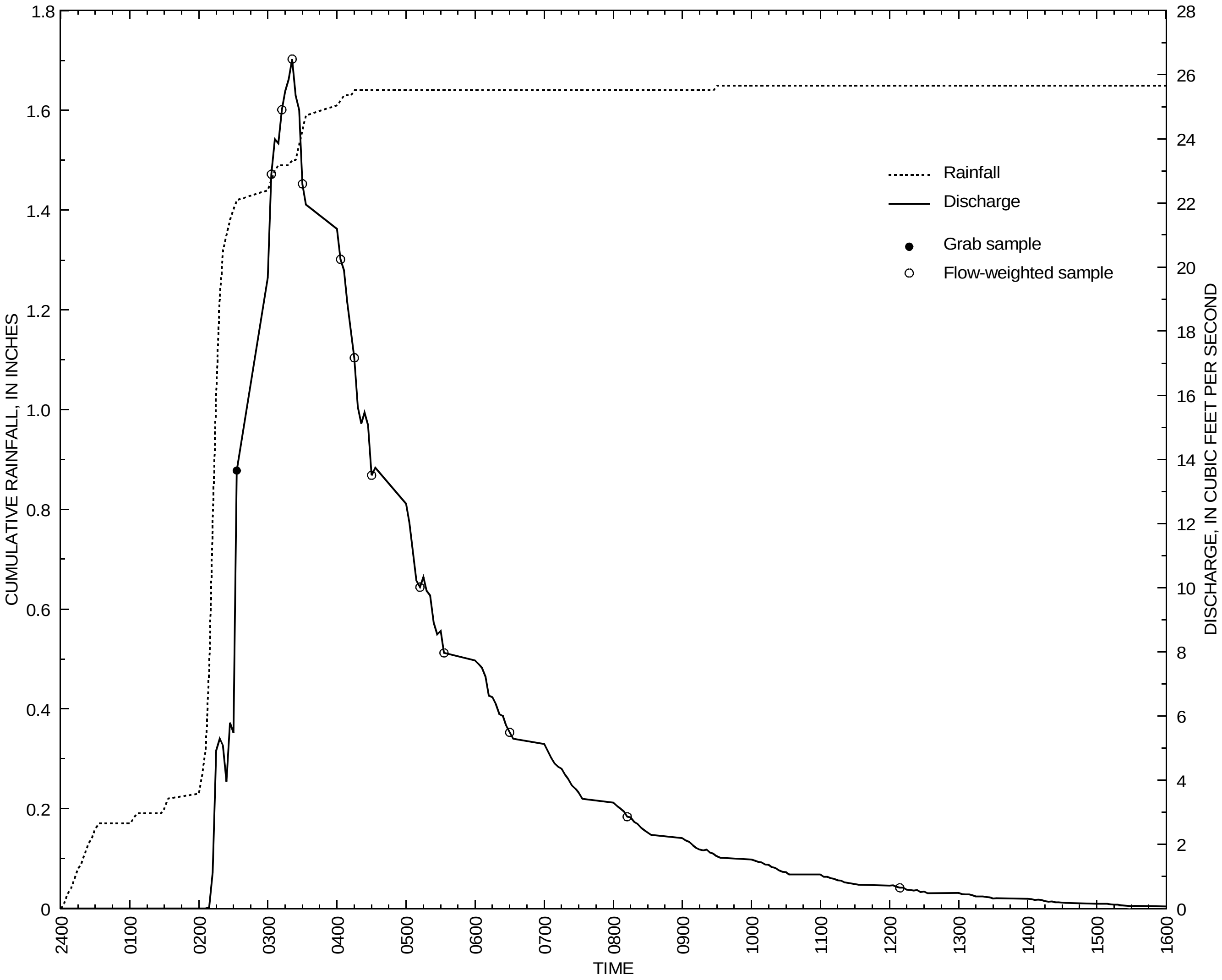

Figure 3. Rainfall, discharge, and times of flow-weighted and grab sample collection during a storm-runoff event at watershed 4, Bexar County, Texas, March 16, 1998.

flow-weighted samples. At the end of a storm-runoff event, the samples were composited, packaged, and shipped to the USGS National Water Quality Laboratory in Arvada, Colo., for analysis. The composite samples were analyzed for common inorganic constituents, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nutrients, trace elements, selected organic compounds, and pesticides.

Analyses of the composite samples yielded event-mean concentrations (EMC), which represent average water-quality conditions during a runoff event. EMCs are useful for comparing concentrations from different sites or from different runoff events at the same site, and for estimating the mass of a chemical constituent exiting the watershed during an event. The mass of a constituent exiting the watershed in runoff can be estimated by multiplying the EMC by the runoff (and appropriate conversion factor).

Discrete grab samples also were collected during each storm-runoff event and analyzed for specific conductance, pH, fecal coliform and fecal streptococcus bacteria, cyanide, phenols, oil and grease, and volatile organic compounds (VOC). Generally, grab samples are collected during the early stages of a runoff event and indicate the presence of constituents in the “first flush” of a runoff. As the constituent concentrations might not represent the average concentrations during a runoff event, estimates of mass of these constituents are uncertain. Rainfall, discharge, and times of flow-weighted and grab sample collection for an example storm-runoff event at watershed 4 on March 16, 1998, are graphed in figure 3.

Selected Water-Quality Property and Constituent Concentrations

Thirty-two composite storm-runoff samples (representing 32 storm-runoff events) were collected at the five selected watersheds during June 1996–October 1998. The watersheds with the larger percentages of impervious cover (1 and 2, table 1) yielded more runoff per acre than the less developed watersheds (4 and 5, table 1). More samples were collected from the watersheds with more impervious cover (1 and 2) because runoff occurred with as little as 0.05 inch (in.) of rainfall in the watershed, whereas runoff in watersheds 4 and 5 occurred only during intense rainfall with totals of at least 1.5 in. The median EMCs of selected constituents for each watershed are listed in table 2.

Boxplots were constructed to show example comparisons of concentrations

Table 2. Median event-mean concentrations of selected properties and constituents by watershed, Bexar County, Texas, 1996–98

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; cols./100 mL, colonies per 100 milliliters; $CaCO_3$, calcium carbonate; <, less than; µg/L, micrograms per liter; --, insufficient data]

Property or constituent	Watershed (fig. 1)				
	1	2	3	4	5
Number of composite storm-runoff samples collected	10	2	12	4	4
Specific conductance (µS/cm)	91	106	88	114	200
Chemical oxygen demand (mg/L)	38	39	31	27	30
Fecal coliforms (cols./100 mL)	10,000	27,000	13,000	4,900	4,300
Fecal streptococci (cols./100 mL)	5,600	64,000	38,000	67,000	5,180
Calcium, dissolved (mg/L)	12	13	11	16	35
Magnesium, dissolved (mg/L)	.4	4.0	.4	.8	2.1
Sodium, dissolved (mg/L)	2.2	1.3	1.3	1.2	1.7
Potassium, dissolved (mg/L)	1.6	2.6	1.6	3.0	2.4
Alkalinity (mg/L as $CaCO_3$)	45	54	48	57	102
Sulfate, dissolved (mg/L)	4.9	4.0	2.3	2.2	4.0
Chloride, dissolved (mg/L)	1.5	1.0	1.8	1.6	2.5
Dissolved solids, sum of constituents (mg/L)	52	60	52	98	119
Suspended solids (mg/L)	114	111	54	42	48
Nitrogen, nitrite plus nitrate, dissolved (mg/L)	.41	.20	.28	.20	.44
Nitrogen, ammonia, dissolved (mg/L)	.10	.10	.08	.03	<.02
Nitrogen, ammonia plus organic, total (mg/L)	.60	.80	1.0	.80	1.02
Nitrogen, ammonia plus organic, dissolved (mg/L)	.30	.30	.40	.40	.39
Phosphorus, total (mg/L)	.20	.18	.19	.14	.07
Arsenic, total (µg/L)	2	2	12	3	--
Cadmium, total (µg/L)	<1	<1	<1	<1	<1
Chromium, total (µg/L)	4	6	1	2	<1
Copper, total (µg/L)	7	6	6	3	2.1
Lead, total (µg/L)	9	10	3	10	2.2
Mercury, total (µg/L)	<.1	<.1	<.1	<.1	<.1
Nickel, total (µg/L)	3	4	2	2	--
Zinc, total (µg/L)	100	45	37	16	<10
Organic carbon, total (mg/L)	14	13	10	12	10
Cyanide, total (mg/L)	<.01	<.01	<.01	<.01	<.01
Phenols, total (µg/L)	4	--	<1	4	<1
Oil and grease, total (mg/L)	3	--	2	<1	<1
DDD, total (µg/L)	<.1	<.1	<.1	<.1	<.1
DDE, total (µg/L)	<.04	<.04	<.04	<.04	<.04
DDT, total (µg/L)	<.1	<.1	<.1	<.1	<.1
Diazinon, total (µg/L)	<.05	<.05	.5	<.05	<.05

of selected trace elements (chromium, copper, lead, and zinc) by land use (fig. 4). Water-quality data from watersheds with similar land uses (1 and 2; 3 and 4) (table 1) were grouped together. Boxplots with data less than the laboratory minimum reporting levels were truncated at the reporting level. The numbers of samples with concentrations less than the reporting levels are shown in brackets in figure 4. In most cases, less than 25 percent of the data were below the reporting levels and the interquartile range is plotted. Boxplots for the undeveloped land-use category were not constructed because only four samples were collected.

Total chromium, lead, and zinc concentrations were significantly larger, at the 95-percent confidence level, for commercial land use than for residential land use on the basis of one-sided Mann-Whitney tests (Helsel and Hirsch, 1992). The statistical test for total copper concentrations did not show significant difference between commercial and residential land use. Statistical comparisons of concentrations in samples from the undeveloped watershed were not included because of the small data set (four samples).

Example of Mass Yields

The effect of land use and percent impervious cover of a watershed in generating stormwater-runoff pollutants is evident when examining the annual mass

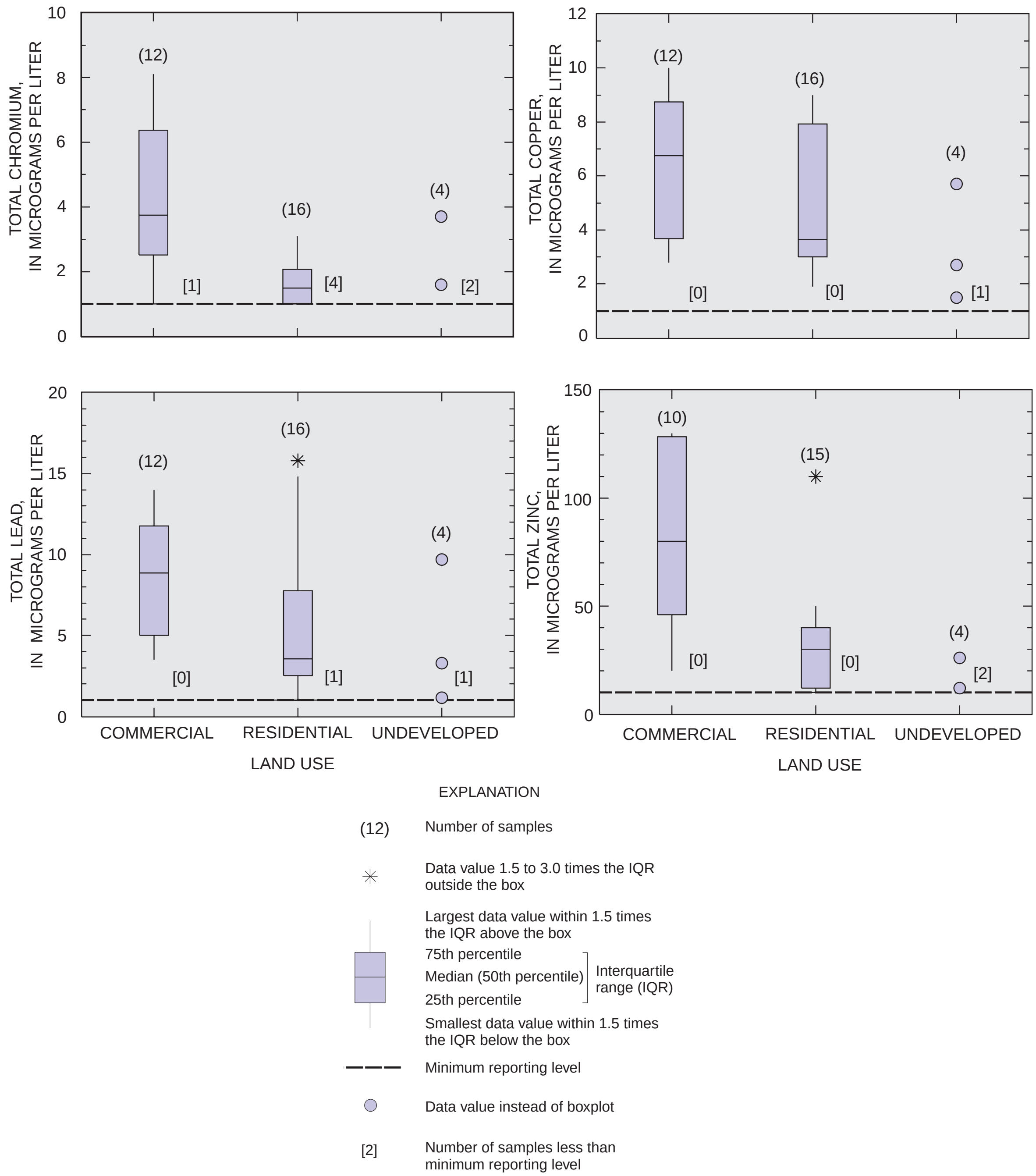

Figure 4. Distributions of total chromium, copper, lead, and zinc concentrations by land use, Bexar County, Texas, 1996–98.

yield of total lead, for example, for the watersheds. Annual mass yields for 1997 were computed for total lead for each watershed using the equation:

$$Y = \frac{QC}{A} \bullet cf,$$

where

Y = annual mass yield in pounds per year per acre;

Q = annual runoff in acre-feet per year;

C = flow-weighted average of EMCs in micrograms per liter;

A = watershed area in acres; and

cf = conversion factor (0.00272).

Annual runoff, flow-weighted averages of EMCs, and mass yields of total lead for the five watersheds are listed in table 3. All samples collected from June 1996 through October 1998 (some watersheds had limited runoff during 1997) were used to compute the flow-weighted average of total lead EMCs, except for watershed 5. In 1997, all of the runoff for watershed 5 occurred during a single event. Samples collected for watershed 5 during the event yielded total lead concentrations that were less than the laboratory minimum reporting level, so a value equal to the reporting level was used as the average EMC to calculate a maximum for the annual yield. The magnitude of differences in annual mass yields among the watersheds is illustrated in figure 5.

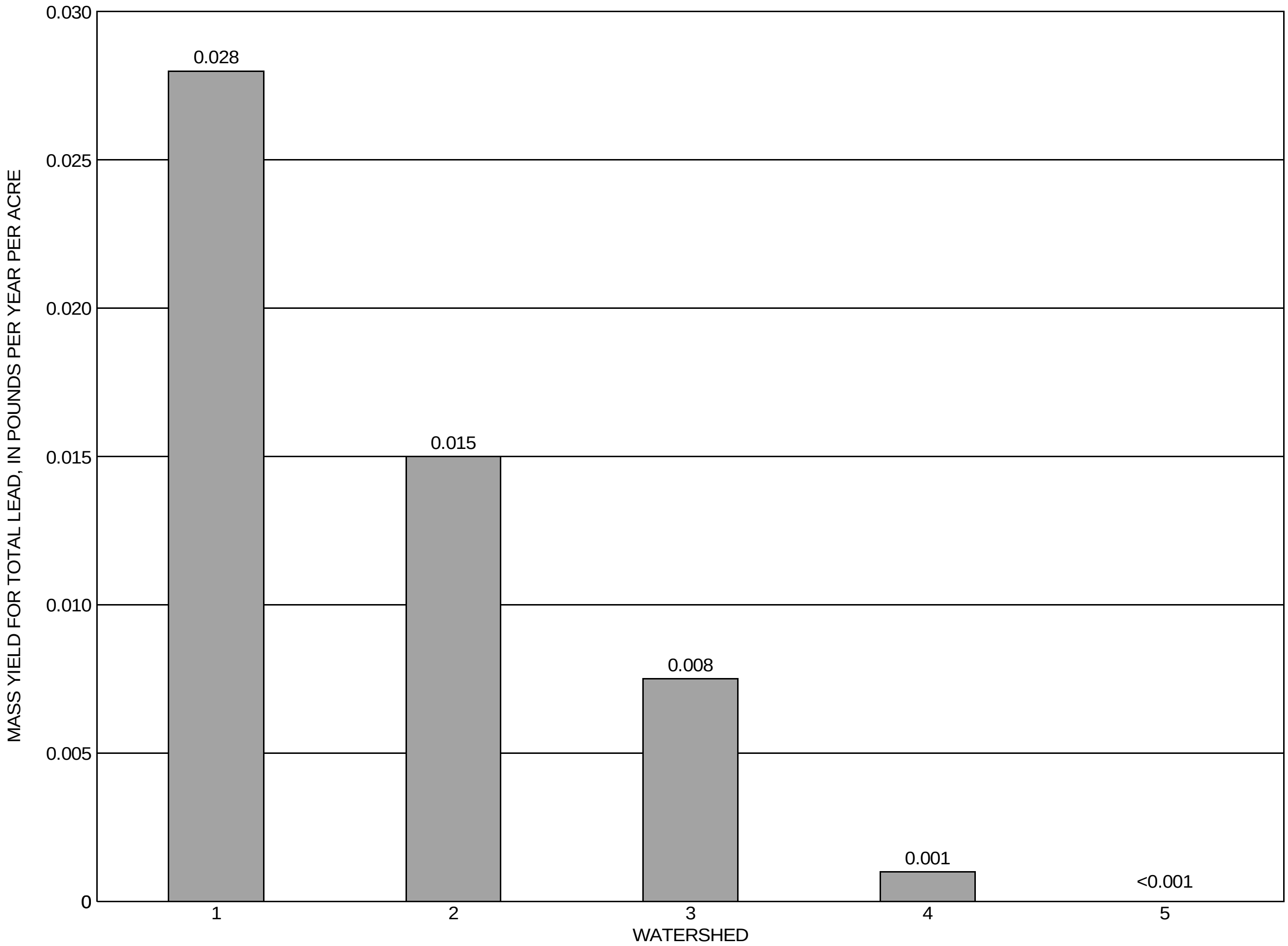

Figure 5. Annual mass yields for total lead by watershed, Bexar County, Texas, 1997.

References

Helsel, D.R., and Hirsch, R.M., 1992, Studies in environmental science 49—Statistical methods in water resources: Amsterdam, Elsevier, 522 p.

Stein, W.G., and Ozuna, G.B., 1995, Geologic framework and hydrogeologic characteristics of the Edwards aquifer recharge zone, Bexar County, Texas: U.S. Geological Survey Water-Resources Investigations Report 95–4030, 8 p., 1 pl.

Table 3. Runoff, flow-weighted averages of event-mean concentrations of lead, and mass yields by watershed, Bexar County, Texas, 1997

[µg/L, micrograms per liter; <, less than]

Watershed	Runoff (acre-feet per year)	Flow-weighted average of event-mean concentrations of total lead (µg/L)	Mass yield of total lead (pounds per year per acre)
1	24.5	8	0.028
2	149	12	.015
3	41.5	5	.008
4	39.6	3	.001
5	2,650	<1	<.001

—D.J. Ockerman, B.L. Petri, and R.N. Slattery

For more information, please contact:

San Antonio Subdistrict Chief
U.S. Geological Survey
435 Isom Road, Suite 234
San Antonio, TX 78216

Phone: (210) 321–5200
FAX: (210) 530–6008
E-mail: gbozuna@usgs.gov
World Wide Web: http://tx.usgs.gov