WATER-QUALITY ASSESSMENT OF SOUTH-CENTRAL TEXAS—OCCURRENCE AND DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS IN SURFACE WATER AND GROUND WATER, 1983–94, AND IMPLICATIONS FOR FUTURE MONITORING

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Abbreviations:

ft, foot
gal, gallon
in., inch
µg/L, microgram per liter
mi^2, square mile
mg/kg, milligram per kilogram

Water-Quality Assessment of South-Central Texas—Occurrence and Distribution of Volatile Organic Compounds in Surface Water and Ground Water, 1983–94, and Implications for Future Monitoring

By Patricia B. Ging, Linda J. Judd, *and* Kirby H. Wynn

Abstract

The study area of the South-Central Texas study unit of the National Water-Quality Assessment Program comprises the Edwards aquifer in the San Antonio region and its catchment area. The first phase of the assessment includes evaluation of existing water-quality data for surface water and ground water, including volatile organic compounds, to determine the scope of planned monitoring. Most analyses of volatile organic compounds in surface water are from the National Pollutant Discharge Elimination System sites in San Antonio, Texas. Nine volatile organic compounds were detected at the six sites. The three compounds with the most detections at National Pollutant Discharge Elimination System sites are 1,2,4-trimethylbenzene, toluene, and xylene. Analysis of volatile organic compounds in ground water was limited to Edwards aquifer wells. Twenty-eight volatile organic compounds were detected in samples from 89 wells. The five most commonly detected compounds in samples from wells, in descending order, are tetrachloroethene, trichloroethene, bromoform, chloroform, and dibromochloromethane. Detections of volatile organic compounds in surface water and ground water within the South-Central Texas study area are limited to site-specific sources associated with development; therefore, planned monitoring for possible detections of volatile organic compounds as part of the National Water-Quality Assessment Program will emphasize areas of expanding population and development. Monitoring of volatile organic compounds is planned at National Pollutant Discharge Elimination System sites, at basic fixed surface-water sites, and in the ground-water study-unit surveys.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status and trends in water quality of a large, representative part of the Nation's surface- and ground-water resources. This program, when fully implemented, will be accomplished through investigation of 60 study units ranging in size from 1,200 to 60,000 mi^2. Twenty study-unit investigations began in fiscal year 1991, 16 additional study units began in fiscal year 1994, 17 are scheduled to begin in fiscal year 1997, and the remaining study units are not scheduled yet. The South-Central Texas (SCTX) study unit is in the second group (starting in 1994) of study units in the NAWQA Program (fig. 1). The first phase of this study includes evaluation of existing water-quality data.

Analysis of available volatile organic compound (VOC) data for surface water and ground water was done as part of the evaluation of existing water-quality data for the SCTX study unit. Contamination of water by VOCs can pose a threat to the health of humans when concentrations greater than 1 part per million are ingested or inhaled (Bloemen and Burn, 1993). Possible effects include eye, nose, and throat irritation and central nervous system responses such as dizziness, headaches, and loss of short-term memory. Some VOCs are considered to be human carcinogens (benzene, vinyl chloride), and others are animal carcinogens (chloroform, methylene chloride, tetrachloroethene, and trichloroethene) that also might be human carcinogens (Bloemen and Burn, 1993). Therefore, the presence and

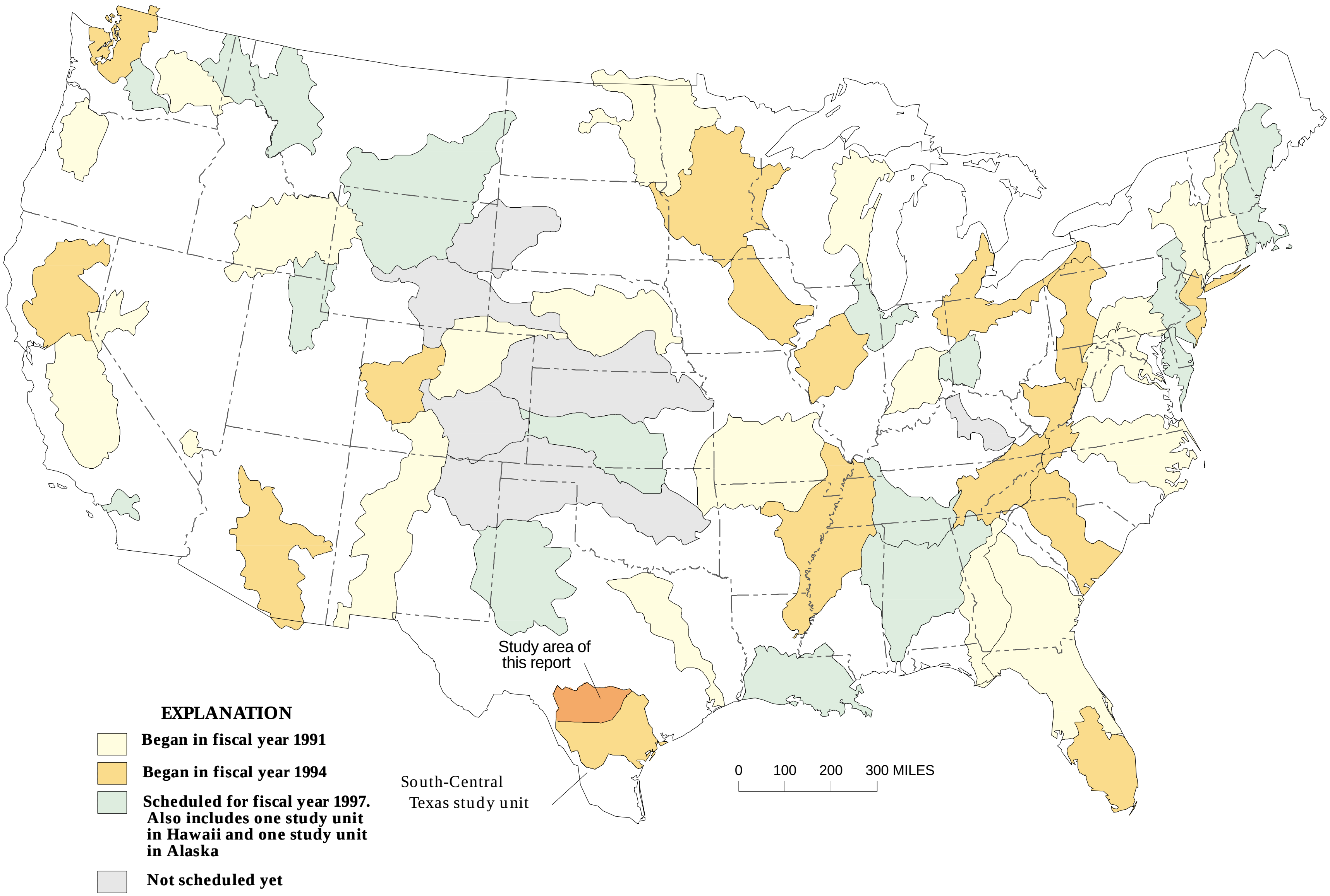

Figure 1. Study units of the National Water-Quality Assessment Program.

extent of VOCs in surface and ground water is a public health issue.

Purpose and Scope

The purposes of this report are to (1) describe the occurrence and distribution of VOCs in the San Antonio region of the SCTX study unit and (2) discuss implications of this information for planned monitoring of VOCs by SCTX NAWQA in the San Antonio region of the SCTX study unit based on occurrence and distribution of VOCs within the study unit. VOC data from the USGS WATer STOrage and REtrieval (WATSTORE) data base from 1983 to 1994 for both surface and ground water are reviewed.

Description of Study Unit

The San Antonio region of the SCTX study unit (hereafter called the study area) is a 10,500-mi^2 area that comprises the Edwards aquifer in the San Antonio region and its catchment area (fig. 2). The study area includes parts of two other major aquifers, the Edwards-Trinity and the Trinity. The entire study unit extends beyond the San Antonio region to the Gulf Coast of Texas to include the watersheds of three major rivers (Nueces, San Antonio, and Guadalupe Rivers).

The city of San Antonio and the surrounding area contain several large military installations, manufacturing industries, and a tourism industry. Away from the San Antonio area, the study unit consists mainly of rangeland with some agriculture and small urban areas.

The Edwards aquifer is the source of water for about 1.3 million people in and near San Antonio and for ranchers and farmers in the region. Water from the aquifer provides habitat for threatened and endangered species associated with major springs in the region. The Edwards aquifer is a sequence of extensively faulted, fractured, and dissolutioned limestone and dolostone that yields large quantities of water to wells and springs. The aquifer crops out and is unconfined in the recharge zone. The aquifer is confined (artesian zone) beneath much less permeable rocks downdip from the recharge zone. Further downdip, where the rocks are virtually impermeable, they contain moderately saline to very saline water (saline-water zone).

The study area comprises parts of three geographic subareas: the Edwards Plateau, the Hill Country, and the Gulf Coastal Plain (fig. 3). The Edwards Plateau is characterized by rolling hills capped with a thick mantle of limestone rocks and thin soils. The Hill Country consists of rugged terrain where upland areas have been extensively eroded, leaving deeply incised alluvial valleys with limestone caps. The Gulf Coastal Plain is characterized by rolling prairies with thick, fertile soils suitable for farming.

Methods for Data Selection

Surface Water

The data used for the analysis of VOCs in surface water were collected by the USGS. The River Authorities in the study unit (Nueces, San Antonio, and Guadalupe-Blanco) have not collected VOC data. The majority of VOC analyses in the SCTX study area are from water samples collected as part of the National Pollutant Discharge Elimination System (NPDES) program of the U.S. Environmental Protection Agency (USEPA). The NPDES work was done in cooperation with the San Antonio Water System from August 1992 through September 1994. Six NPDES urban-stormwater sampling sites were selected on the basis of three criteria: drainage-area characteristics; hydraulic factors; and accessibility and safety factors. All six NPDES sites are within the San Antonio city limits (fig. 4). Descriptions of the sites, including drainage area, land-use category, and sampling dates, are listed in table 1. Drainage areas of the NPDES sites range from 11 to 178 acres. Most of the drainage areas were characterized by a single land-use category, predominantly residential, commercial, or light industrial. Each site was fitted with a flow-control device, either a Palmer-Bowlus flume or sharp-crested rectangular weir for computation of streamflow. A straight, uniform channel the length of at least six outfall conduit diameters upstream from the flow-control device was required to insure complete mixing of stormwater. Good accessibility required that the sites be located at outfalls or at manholes 18 in. or greater in size.

Samples were collected according to the USEPA stormwater-sampling criteria: (1) the dry period preceding the storm is at least 72 hours; (2) the depth of precipitation over the basin is at least 0.10 in.; and (3) if possible, precipitation does not vary by more than 50 percent from the average precipitation amount and duration. Quality-control/quality-assurance procedures included analyses of equipment blanks and spike samples throughout the data-collection phase of the study. VOC samples were collected within the first 30 minutes of runoff, when possible, using discrete (grab) sampling

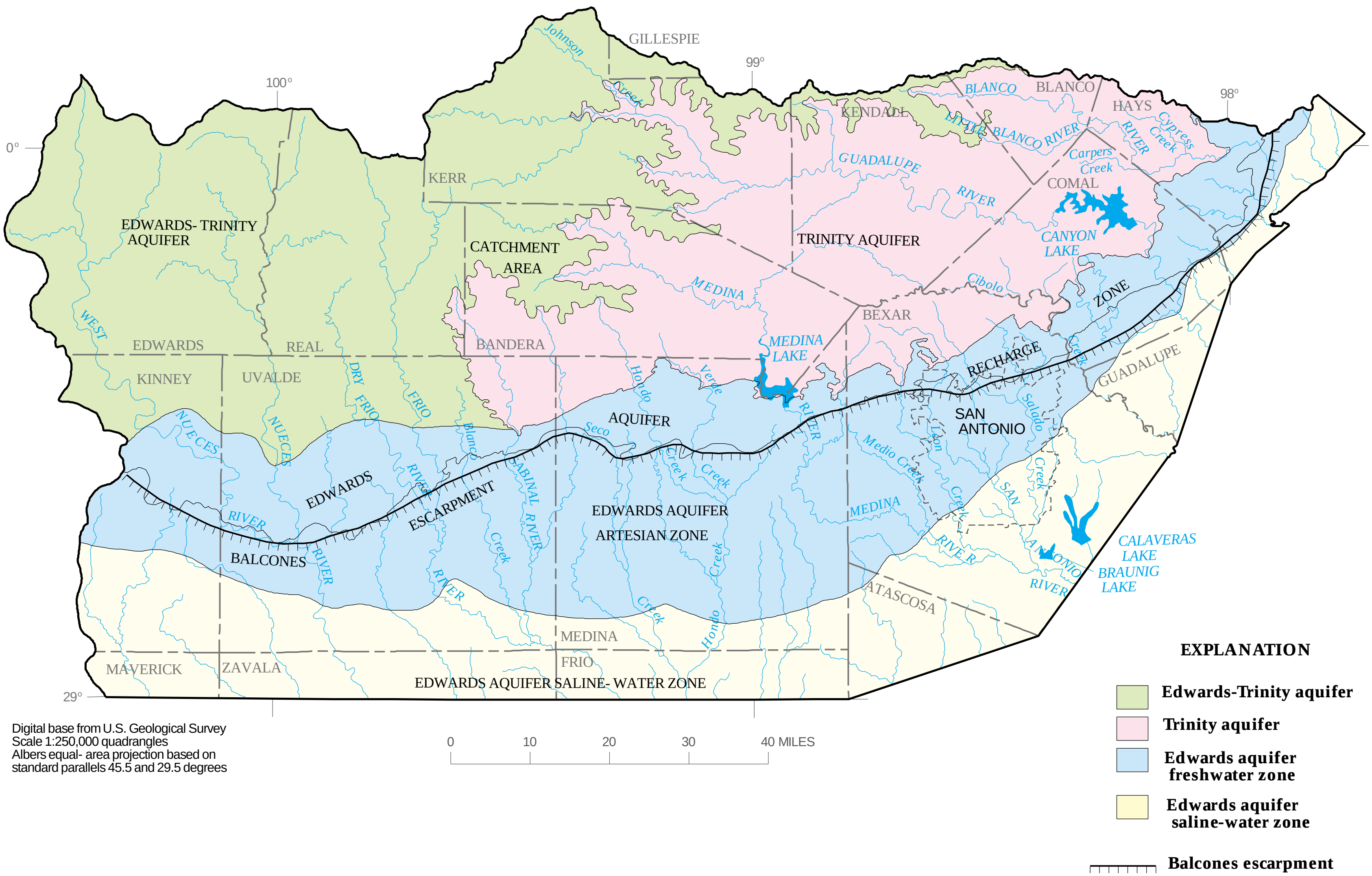

Figure 2. Study area—San Antonio region of the South-Central Texas study unit.

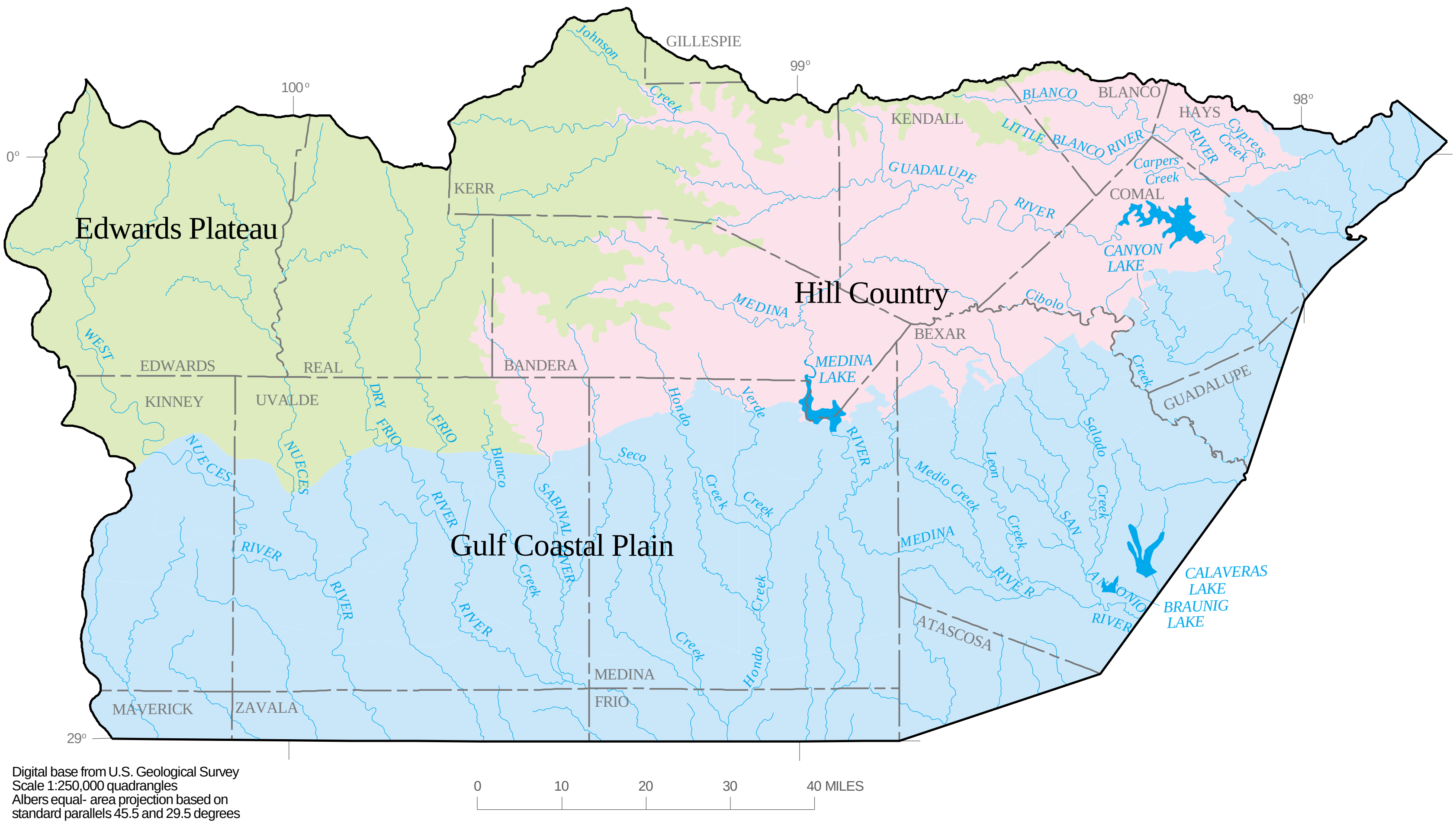

Figure 3. Geographic subareas of the South-Central Texas study area.

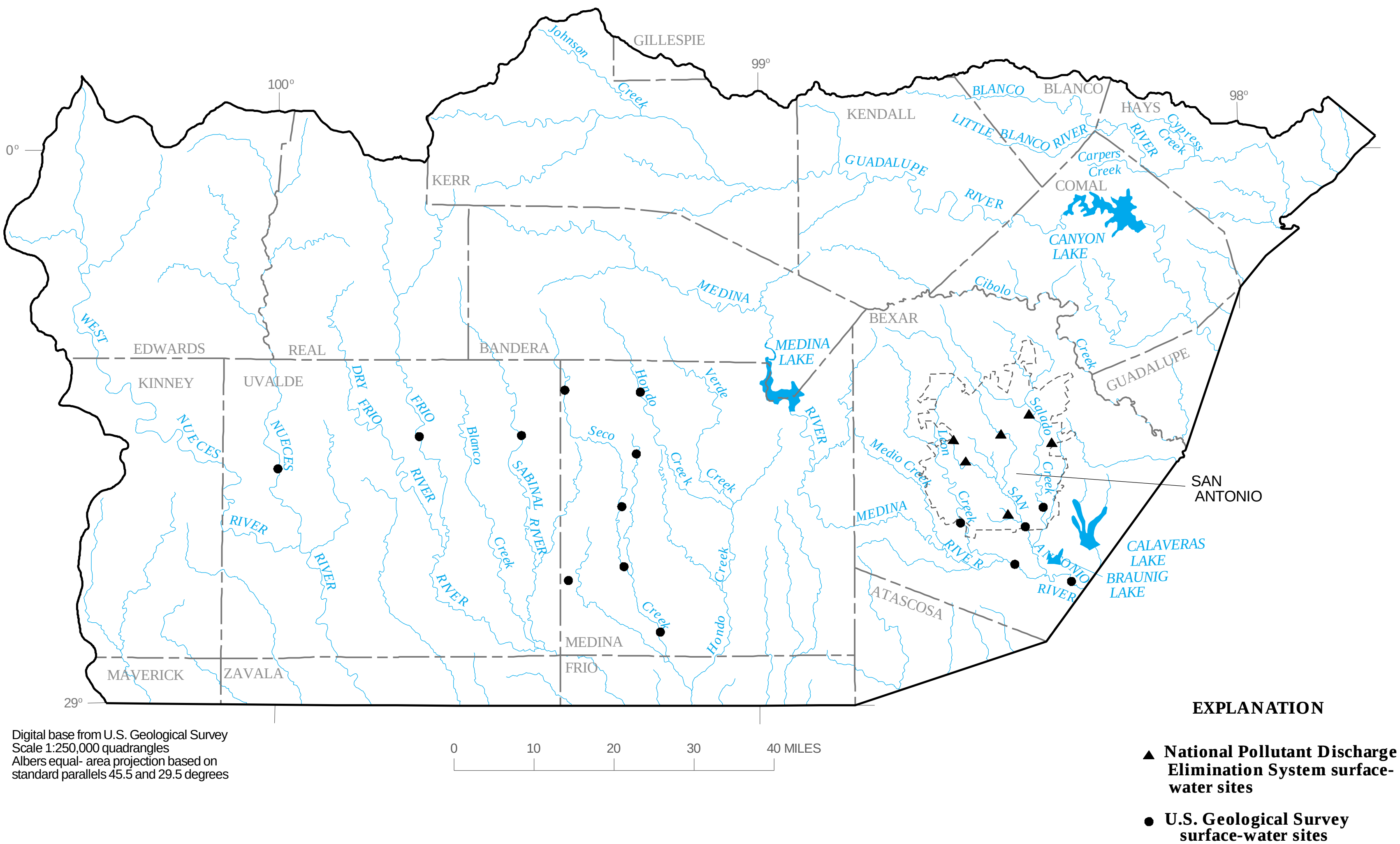

Figure 4. Locations of National Pollutant Discharge Elimination System and other U.S. Geological Survey surface-water sites, South-Central Texas study area.

Table 1. Description of National Pollutant Discharge Elimination System surface-water sites, South-Central Texas study area

Station name: San Pedro Avenue at Olmos Creek
Station number: 08177720
Drainage area: 71 acres
Land use: 58-percent commercial, 36-percent residential, 5-percent light industrial, and 1-percent nonurban
Method of collection: Grab sample
Measuring device: Palmer-Bowlus flume

Storm number	Sampling date	Total precipitation (inches)
1	09/10/92	0.83
2	10/29/92	.63
3	11/18/92	.60
4	01/19/93	.50
5	02/25/93	.28
6	02/28/93	.39
7	03/12/93	.66

Station name: Bandera Road at Zarzamora Creek
Station number: 08178420
Drainage area: 92.6 acres
Land use: 71-percent commercial, 13-percent low-density residential, and 16-percent nonurban
Method of collection: Grab sample
Measuring device: Palmer-Bowlus flume

Storm number	Sampling date	Total precipitation (inches)
1	03/30/93	0.55
2	04/03/93	.17
3	04/07/93	.94
4	04/29/93	.38
5	05/05/93	.47
6	06/26/93	.33

Station name: Alderette Park at Zarzamora Creek
Station number: 08178430
Drainage area: 99.78 acres
Land use: 5-percent commercial, 92-percent residential, and 3-percent nonurban
Method of collection: Grab sample
Measuring device: Palmer-Bowlus flume

Storm number	Sampling date	Total precipitation (inches)
1	02/10/93	1.37
2	04/03/93	.25
3	04/07/93	.48
4	05/05/93	.66
5	06/20/93	.29

Station name: South Flores Street at Drainage Channel no. 69
Station number: 08178520
Drainage area: 62.4 acres
Land use: 22-percent commercial, 66-percent mixed-density residential, and 12-percent nonurban
Method of collection: Grab sample
Measuring device: Palmer-Bowlus flume

Storm number	Sampling date	Total precipitation (inches)
1	08/03/92	1.56
2	09/10/92	2.54
3	10/29/92	.52
4	11/18/92	.67
5	01/19/93	.28
6	02/03/93	.24

Station name: Bitters Road at Salado Creek tributary
Station number: 08178690
Drainage area: 178 acres
Land use: 9-percent commercial and 91-percent residential
Method of collection: Grab sample
Measuring device: Rectangular weir

Storm number	Sampling date	Total precipitation (inches)
1	02/09/93	0.73
2	04/03/93	.69
3	05/05/93	.62
4	05/18/93	.40
5	05/22/93	1.12
6	06/12/93	.77

Station name: Business Park (at Rittiman Road) at Rosillo Creek tributary
Station number: 08178820
Drainage area: 11 acres
Land use: 100-percent light industrial
Method of collection: Grab sample
Measuring device: Rectangular weir

Storm number	Sampling date	Total precipitation (inches)
1	09/10/92	1.05
2	11/18/92	.63
3	01/19/93	.63
4	02/03/93	.33
5	02/09/93	.35
6	02/25/93	.30

Table 2. Volatile organic compounds analyzed for in surface-water and ground-water samples collected in South-Central Texas study area

[MRL, minimum reporting level; μg/L, micrograms per liter]

Volatile organic compound	MRL (μg/L)	Volatile organic compound	MRL (μg/L)	Volatile organic compound	MRL (μg/L)
1,1,1,2-Tetrachloroethane	0.2	1,4-Dichlorobenzene	0.2	Ethylbenzene	0.2
1,1,1-Trichloroethane	.2	2,2-Dichloropropane	.2	Hexachlorobutadiene	.2
1,1,2,2-Tetrachloroethane	.2	2-Chloroethyl vinyl ether	1.0	Isopropylbenzene	.2
1,1,2-Trichloroethane	.2	Acrolein	20.0	Methyl bromide	.2
1,1-Dichloroethane	.2	Acrylonitrile	20.0	Methyl chloride	.2
1,1-Dichloroethene	.2	Benzene	.2	Methylene chloride	.2
1,1-Dichloropropene	.2	Bromobenzene	.2	Methyl-tert-butyl ether	1.0
1,2,3-Trichlorobenzene	.2	Bromochloromethane	.2	n-Butylbenzene	.2
1,2,3-Trichloropropane	.2	Bromoform	.2	n-Propylbenzene	.2
1,2,4-Trichlorobenzene	.2	Bromodichloromethane	.2	Naphthalene	.2
1,2,4-Trimethylbenzene	.2	Carbon tetrachloride	.2	p-Isopropyltoluene	.2
1,2-Chlorotoluene	.2	Chlorobenzene	.2	sec-Butylbenzene	.2
1,2-Dibromoethane	.2	Chloroethane	.2	Styrene	.2
1,2-Dichlorobenzene	.2	Chloroform	.2	tert-Butylbenzene	.2
1,2-Dichloroethane	.2	cis-1,2-Dichloroethene	.2	Tetrachloroethene	.2
1,2-Dichloropropane	.2	cis-1,3-Dichloropropene	.2	Toluene	.2
trans-1,2-Dichloroethene	.2	Dibromochloromethane	.2	trans-1,3-Dichloropropene	.2
1,3,5-Trimethylbenzene	.2	Dibromochloropropane	.2	Trichloroethene	.2
1,3-Dichlorobenzene	.2	Dibromomethane	.2	Trichlorofluoromethane	.2
1,3-Dichloropropane	.2	Dichlorodifluoromethane	.2	Vinyl chloride	.2
1,4-Chlorotoluene	.2	Trichlorotrifluoroethane	.2	Xylene	.2

techniques. The grab samples were analyzed at the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. The VOC compounds and minimum reporting levels (MRL) are listed in table 2.

VOC data collected between December 1991 and December 1994 are available from 15 additional USGS surface-water sites (fig. 4). Many of these sites were previously sampled in January 1985. These USGS sites, on larger stream channels than the NPDES sites, are not characterized by land use as are the NPDES sites, and therefore, detailed analysis of VOC detections for these sites comparable to that for the NPDES sites is not presented.

Ground Water

VOC data from ground-water samples were obtained from the USGS data base WATSTORE. All ground-water analyses are from samples of the Edwards aquifer. Available data comprise 307 sample analyses from 157 wells completed in the Edwards aquifer in the SCTX study area from 1983 to 1993. Most of the samples were collected during investigations done in cooperation with the Edwards Underground Water District (EUWD). Locations of wells sampled are shown in figure 5. These samples were analyzed for 26 to 35 VOCs. Table 2 lists possible VOCs sampled for in ground water. All samples were collected from untreated well water. Sample documentation in the data base includes location by latitude and longitude, date sampled, and compounds analyzed. Information regarding land use, open interval, or population served for wells sampled is not available. Some of the Edwards aquifer wells can be greater than 1,000 ft deep, and most are usually unscreened, open-hole wells.

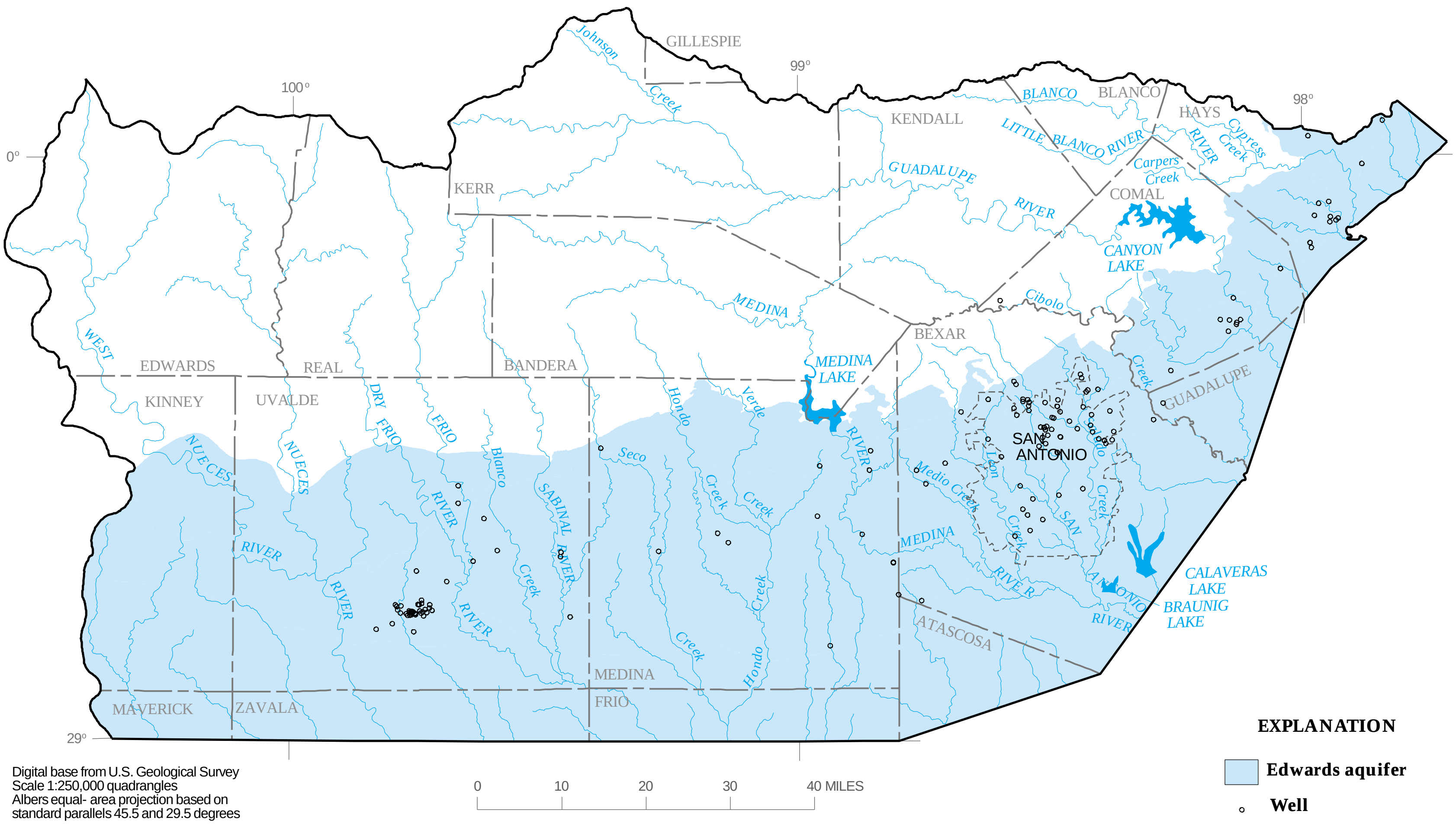

Figure 5. Locations of Edwards aquifer wells, South-Central Texas study area.

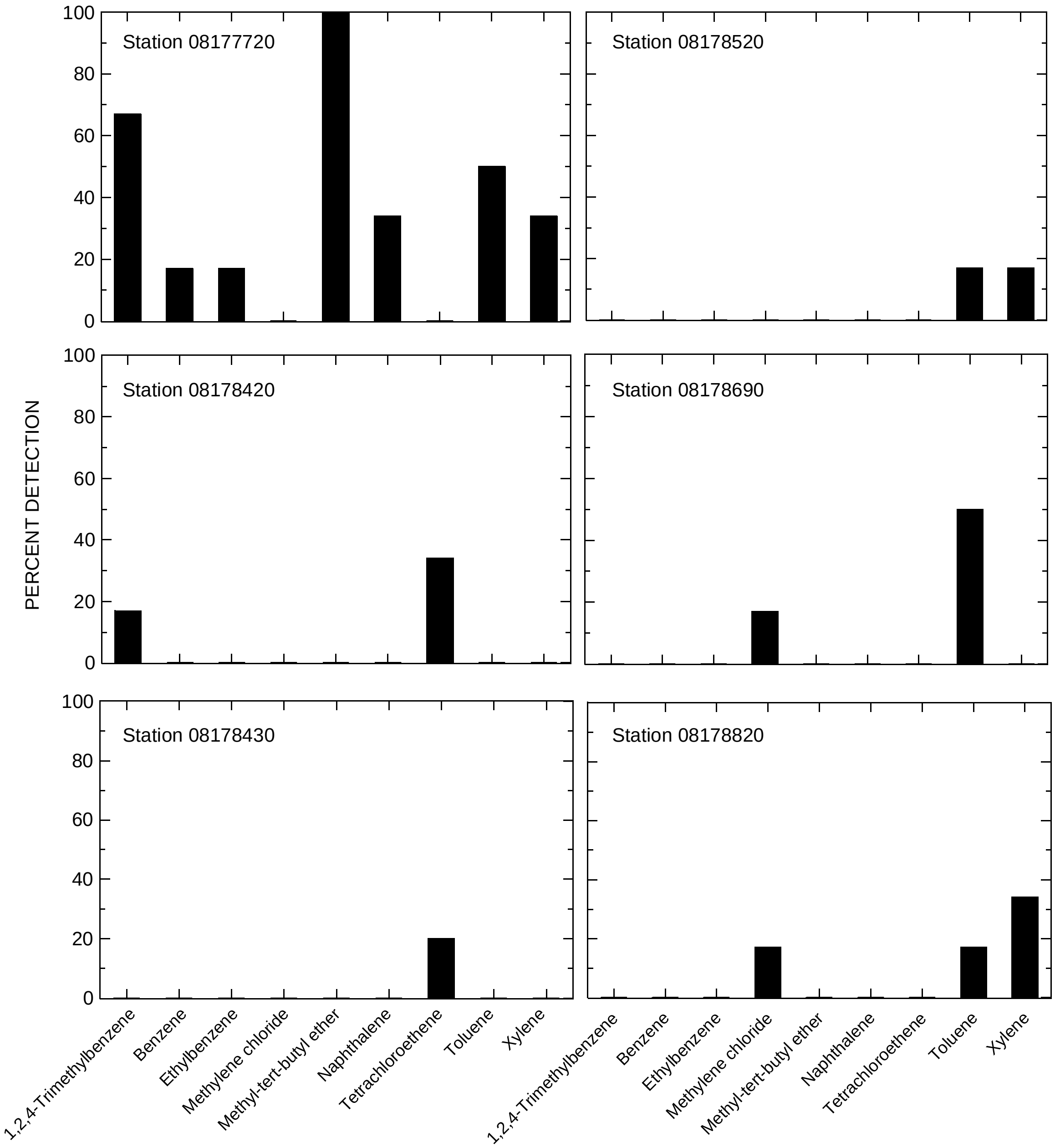

Figure 6. Detections of nine volatile organic compounds in samples from National Pollutant Discharge Elimination System surface-water sites, South-Central Texas study area.

OCCURRENCE AND DISTRIBUTION OF VOLATILE ORGANIC COMPOUNDS

Surface Water

Samples collected at the six NPDES sites were analyzed for most of the VOCs listed in table 2. Detections were recorded for 9 of the 63 VOCs: 1,2,4-trimethylbenzene, benzene, ethylbenzene, methylene chloride, methyl-tert-butyl ether (MTBE), naphthalene, tetrachloroethene, toluene, and xylene. Number of sites, total number of samples, and number of samples above detection limit per volatile organic compound for NPDES surface-water sites are listed in table 3. The three VOCs with the most detections at NPDES sites are 1,2,4-trimethylbenzene, toluene, and xylene. Concentrations of these compounds are less than 2 µg/L. Figure 6 and table 4 show percent detections of the 9 VOCs

Table 3. Number of sites, total number of samples, and number of samples with compounds above detection limit per volatile organic compound for National Pollutant Discharge Elimination System surface-water sites, South-Central Texas study area

Volatile organic compound	Number of sites	Total number of samples	Number of samples with compound above detection limit	Volatile organic compound	Number of sites	Total number of samples	Number of samples with compound above detection limit
1,1,1,2-Tetrachloroethane	6	70	0	Chlorobenzene	6	70	0
1,1,1-Trichloroethane	6	70	0	Chloroethane	6	70	0
1,1,2,2-Tetrachloroethane	6	70	0	Chloroform	6	70	0
1,1,2-Trichloroethane	6	70	0	cis-1,2-Dichloroethene	6	70	0
1,1-Dichloroethane	6	70	0	cis-1,3-Dichloropropene	6	70	0
1,1-Dichloroethene	6	70	0	Dibromochloromethane	6	70	0
1,1-Dichloropropene	6	70	0	Dibromochloropropane	6	70	0
1,2,3-Trichlorobenzene	6	70	0	Dibromomethane	6	70	0
1,2,3-Trichloropropane	6	70	0	Dichlorodifluoromethane	6	70	0
1,2,4-Trichlorobenzene	6	106	0	Trichlorotrifluoroethane	6	52	0
1,2,4-Trimethylbenzene	6	70	10	Ethylbenzene	6	70	2
1,2-Chlorotoluene	6	70	0	Hexachlorobutadiene	6	106	0
1,2-Dibromoethane	6	70	0	Isopropylbenzene	6	70	0
1,2-Dichlorobenzene	6	106	0	Methyl bromide	6	70	0
1,2-Dichloroethane	6	70	0	Methyl chloride	6	70	0
1,2-Dichloropropane	6	70	0	Methylene chloride	6	70	4
trans-1,2-Dichloroethene	6	70	0	Methyl-tert-butyl ether	6	52	6
1,3,5-Trimethylbenzene	6	70	0	n-Butylbenzene	6	70	0
1,3-Dichlorobenzene	6	106	0	n-Propylbenzene	6	70	0
1,3-Dichloropropane	6	70	0	Naphthalene	6	106	6
1,4-Chlorotoluene	6	70	0	p-Isopropyltoluene	6	70	0
1,4-Dichlorobenzene	6	106	0	sec-Butylbenzene	6	70	0
2,2-Dichloropropane	6	70	0	Styrene	6	70	0
2-Chloroethyl vinyl ether	6	70	0	tert-Butylbenzene	6	70	0
Acrolein	6	70	0	Tetrachloroethene	6	70	6
Acrylonitrile	6	70	0	Toluene	6	70	16
Benzene	6	70	2	trans-1,3-Dichloropropene	6	70	0
Bromobenzene	6	70	0	Trichloroethene	6	70	0
Bromochloromethane	6	52	0	Trichlorofluoromethane	6	70	0
Bromoform	6	70	0	Vinyl chloride	6	70	0
Bromodichloromethane	6	70	0	Xylene	6	70	10
Carbon tetrachloride	6	70	0				

Table 4. Detections of volatile organic compounds in samples from National Pollutant Discharge Elimination System surface-water sites, South-Central Texas study area

[In percent detections. Numbers in parentheses are number of detections per total number of samples.]

Station number	1,2,4-Trimethyl-benzene	Benzene	Ethyl-benzene	Methylene chloride	Methyl-tert-butyl ether	Naphthalene	Tetra-chloro-ethene	Toluene	Xylene
08177720	67 (8/12)	17 (2/12)	17 (2/12)	0 (0/12)	100 (6/6)	33 (6/18)	0 (0/12)	50 (6/12)	33 (4/12)
08178420	17 (2/12)	0 (0/12)	0 (0/12)	0 (0/12)	0 (0/12)	0 (0/19)	33 (4/12)	0 (0/12)	0 (0/12)
08178430	0 (0/10)	0 (0/10)	0 (0/10)	0 (0/10)	0 (0/10)	0 (0/15)	20 (2/10)	0 (0/10)	0 (0/10)
08178520	0 (0/12)	0 (0/12)	0 (0/12)	0 (0/12)	0 (0/4)	0 (0/18)	0 (0/12)	17 (2/12)	17 (2/12)
08178690	0 (0/12)	0 (0/12)	0 (0/12)	17 (2/12)	0 (0/12)	0 (0/18)	0 (0/12)	50 (6/12)	0 (0/12)
08178820	0 (0/12)	0 (0/12)	0 (0/12)	17 (2/12)	0 (0/8)	0 (0/18)	0 (0/12)	17 (2/12)	33 (4/12)

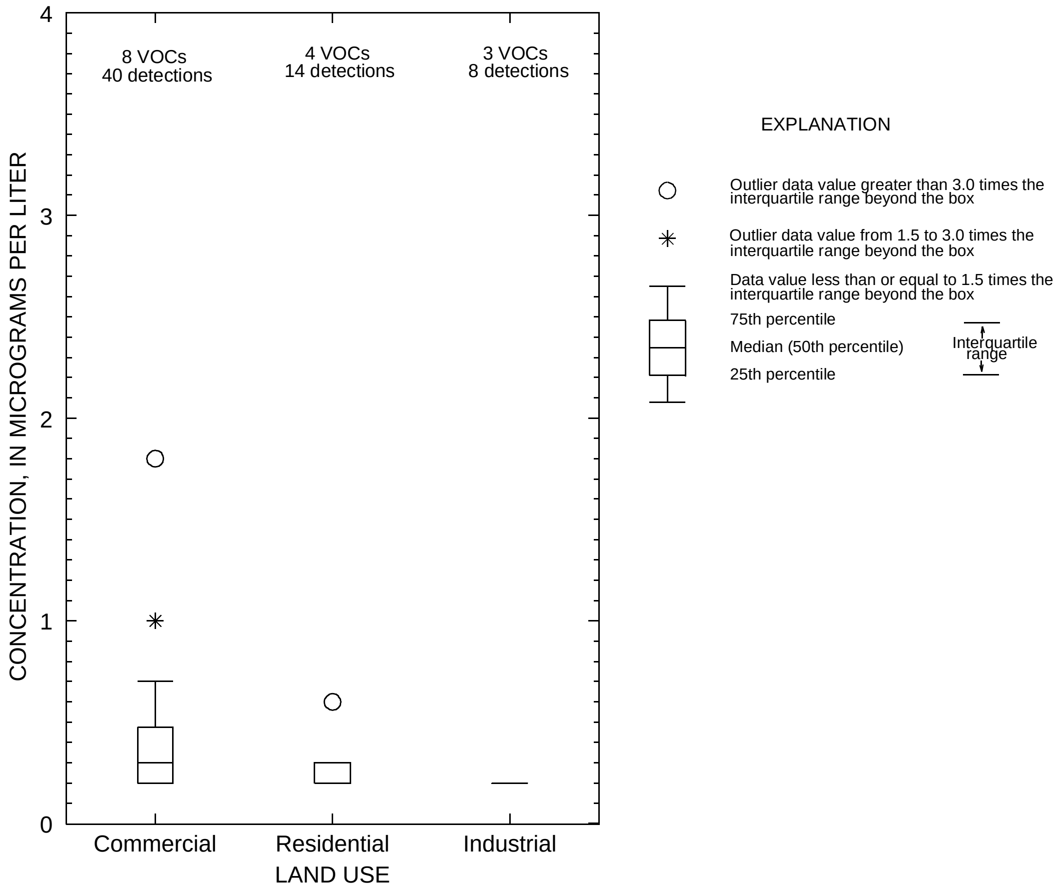

Figure 7. Range and distribution of volatile organic compound concentrations in samples from National Pollutant Discharge Elimination System surface-water sites grouped by land use, South-Central Texas study area.

detected at each of the NPDES sites. Detections per sampling site ranged from 1 VOC at station 08178430 to 7 VOCs at station 08177720. Three of the VOCs (1,2,4-trimethylbenzene, MTBE, and toluene) detected at station 08177720, San Pedro Avenue at Olmos Creek, were detected in at least 50 percent of the samples collected.

Concentrations of VOCs detected in samples from NPDES surface-water sites grouped by site-associated land use (commercial, residential, or light industrial) and sampling date are listed in tables 5–7. Eight VOCs were detected in 40 samples collected in commercial land-use areas; 4 VOCs were detected in 14 samples collected in residential land-use areas; and 3 VOCs were detected in 8 samples collected in light industrial land-use areas. The boxplots in figure 7 show the range and distribution of VOC concentrations grouped by land use.

The number of VOCs analyzed for in samples from the other USGS surface-water sites varied from site to site, and the total number of samples per VOC varied from 60 to 82. The 12 VOCs detected in these samples comprise 1,1,1-trichloroethane, 1,2,4-trimethylbenzene, bromoform, bromodichloromethane, chloroethane, cis-1,2-dichloroethene, dibromochloromethane, methylene chloride, tetrachloroethene, toluene, trichloroethene, and trichlorofluoromethane (table 8).

Ground Water

Twenty-eight VOCs were detected in water samples from 89 Edwards aquifer wells; the total number of detections per VOC ranged from 1 detection for 7 VOCs to 95 detections for tetrachloroethene, the most commonly detected (table 9). The range in concentration for the detected VOCs are listed in table 9. Locations of Edwards aquifer wells with VOC detections are shown in figure 8. VOCs detected at a given well ranged from 1 to 10. Two wells in San Antonio had 10 VOC

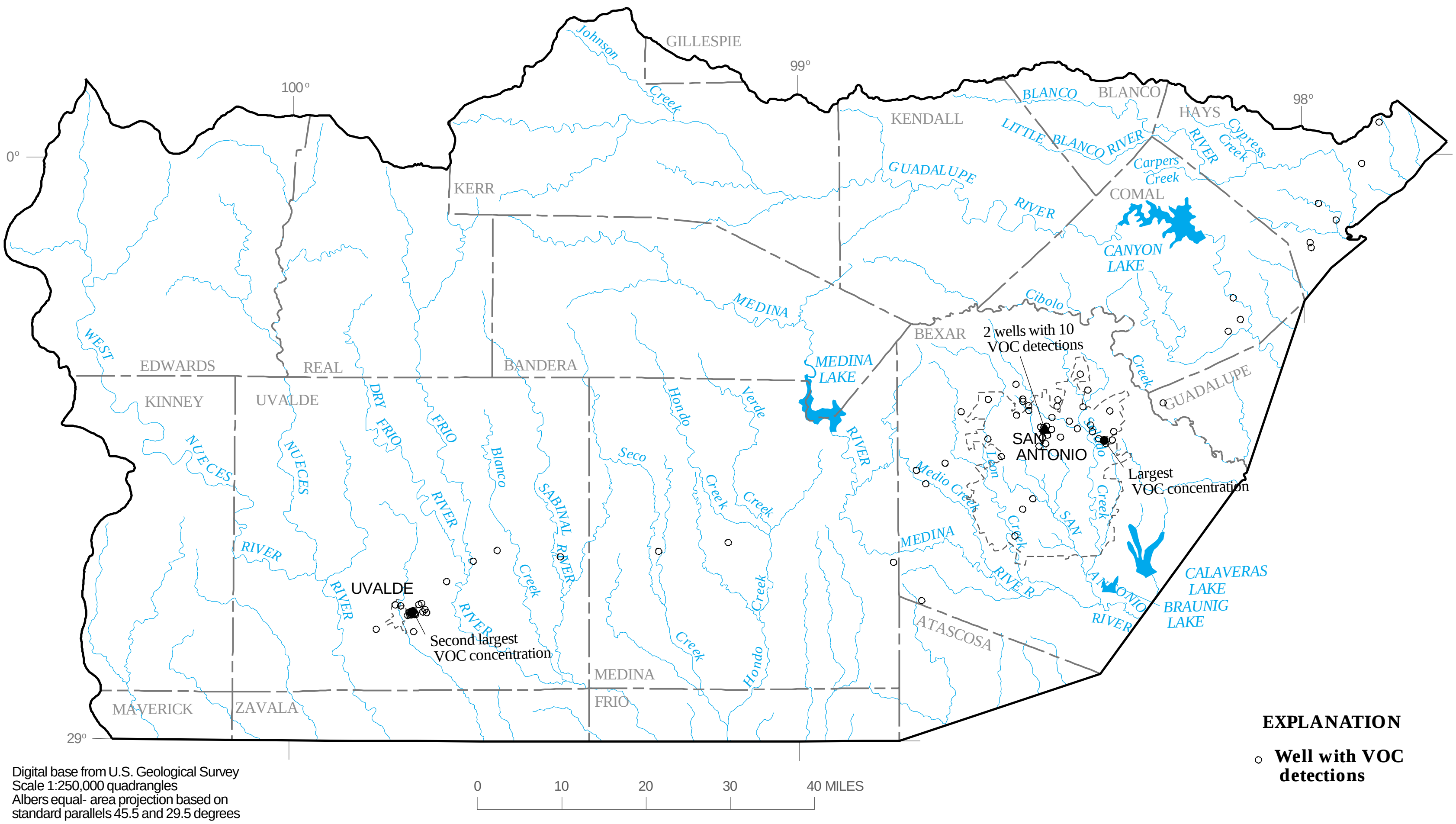

Figure 8. Locations of Edwards aquifer wells with volatile organic compound detections, South-Central Texas study area.

Table 5. Concentrations of volatile organic compounds detected in samples from National Pollutant Discharge Elimination System surface-water sites in commercial land-use areas, South-Central Texas study area

[In micrograms per liter; --, not detected]

Volatile organic compound	Sampling date												
	09/10/92	10/29/92	11/18/92	01/19/93	02/25/93	02/28/93	03/12/93	03/30/93	04/03/93	04/07/93	04/29/93	05/05/93	06/26/93
1,2,4-Trimethylbenzene	0.5 .5	0.3 .3	0.2 .2	--	--	0.2 .2	--	--	--	--	--	0.3 .3	--
Benzene	--	--	--	--	--	.2 .2	--	--	--	--	--	--	--
Ethyl benzene	--	--	.2 .2	--	--	--	--	--	--	--	--	--	--
Methyl-tert-butyl ether	--	--	--	1.0 1.0	1.0 1.0	1.8 1.8	--	--	--	--	--	--	--
Naphthalene	--	.2 .2 .2	--	--	--	.3 .3 .3	--	--	--	--	--	--	--
Tetrachloroethene	--	--	--	--	--	--	--	0.7 .7	0.4 .4	--	--	--	--
Toluene	--	--	.2 .2	--	.2 .2	.2 .2	--	--	--	--	--	--	--
Xylene	--	--	.3 .3	--	--	.2 .2	--	--	--	--	--	--	--

Table 6. Concentrations of volatile organic compounds detected in samples from National Pollutant Discharge Elimination System surface-water sites in residential land-use areas, South-Central Texas study area

[In micrograms per liter; --, not detected]

Volatile organic compound	Sampling date														
	08/03/92	09/10/92	10/29/92	11/18/92	01/19/93	02/03/93	02/09/93	02/10/93	04/03/93	04/07/93	05/05/93	05/18/93	05/22/93	06/12/93	06/20/93
Methylene chloride	--	--	--	--	--	--	--	--	0.2 .2	--	--	--	--	--	--
Tetrachloroethene	--	--	--	--	--	--	--	--	.2 .2	--	--	--	--	--	--
Toluene	--	--	--	--	--	0.2 .2	0.2 .2	--	.3 .3	--	0.6 .6	--	--	--	--
Xylene	--	--	--	--	--	.3 .3	--	--	--	--	--	--	--	--	--

Table 7. Concentrations of volatile organic compounds detected in samples from National Pollutant Discharge Elimination System surface-water sites in light industrial land-use areas, South-Central Texas study area

[In micrograms per liter. --, not detected]

Volatile organic compound	Sampling date					
	09/10/92	11/18/92	01/19/93	02/03/93	02/09/93	02/25/93
Methylene chloride	--	--	--	0.2	--	--
				.2		
Toluene	--	--	--	--	--	0.2
						.2
Xylene	--	--	0.2	--	--	.2
			.2			.2

Table 8. Number of sites, total number of samples, and number of samples with compounds above detection limit per volatile organic compound for other U.S. Geological Survey surface-water sites, South-Central Texas study area

Volatile organic compound	Number of sites	Total number of samples	Number of samples with compound above detection limit
1,1,1,2-Tetrachloroethane	8	68	0
1,1,1-Trichloroethane	15	82	2
1,1,2,2-Tetrachloroethane	15	82	0
1,1,2-Trichloroethane	15	82	0
1,1-Dichloroethane	15	82	0
1,1-Dichloroethene	15	82	0
1,1-Dichloropropene	8	68	0
1,2,3-Trichlorobenzene	8	68	0
1,2,3-Trichloropropane	8	68	0
1,2,4-Trichlorobenzene	8	70	0
1,2,4-Trimethylbenzene	8	68	1
1,2-Chlorotoluene	8	68	0
1,2-Dibromoethane	11	77	0
1,2-Dichlorobenzene	11	79	0
1,2-Dichloroethane	15	82	0
1,2-Dichloropropane	9	79	0
trans-1,2-Dichloroethene	9	79	0
1,3,5-Trimethylbenzene	8	68	0
1,3-Dichlorobenzene	11	79	0
1,3-Dichloropropane	8	68	0
1,4-Chlorotoluene	8	68	0
1,4-Dichlorobenzene	11	79	0
2,2-Dichloropropane	8	68	0
2-Chloroethyl vinyl ether	15	82	0
Acrolein	5	60	0
Acrylonitrile	5	60	0
Benzene	15	82	0
Bromobenzene	8	68	0
Bromochloromethane	8	65	0
Bromoform	15	82	11
Bromodichloromethane	15	82	18
Carbon tetrachloride	15	82	0

Volatile organic compound	Number of sites	Total number of samples	Number of samples with compound above detection limit
Chlorobenzene	15	82	0
Chloroethane	15	82	21
Chloroform	15	82	0
cis-1,2-Dichloroethene	9	70	6
cis-1,3-Dichloropropene	11	77	0
Dibromochloromethane	15	82	15
Dibromochloropropane	8	68	0
Dibromomethane	8	68	0
Dichlorodifluoromethane	15	82	0
Trichlorotrifluoroethane	8	65	0
Ethylbenzene	9	68	0
Hexachlorobutadiene	8	70	0
Isopropylbenzene	8	68	0
Methyl bromide	9	68	0
Methyl chloride	11	77	0
Methylene chloride	15	82	3
Methyl-tert-butyl ether	8	65	0
n-Butylbenzene	8	68	0
n-Propylbenzene	8	68	0
Naphthalene	8	70	0
p-Isopropyltoluene	8	68	0
sec-Butylbenzene	8	68	0
Styrene	11	77	0
tert-Butylbenzene	8	68	0
Tetrachloroethene	15	82	8
Toluene	15	82	2
trans-1,3-Dichloropropene	11	77	0
Trichloroethene	15	82	9
Trichlorofluoromethane	15	82	2
Vinyl chloride	15	82	0
Xylene	11	77	0

Table 9. Number of detections and range in concentration of volatile organic compounds detected in samples from Edwards aquifer wells, South-Central Texas study area

[μg/L, micrograms per liter]

Volatile organic compound	Number of detections	Range in concentration (μg/L)	Volatile organic compound	Number of detections	Range in concentration (μg/L)
1,1,1-Trichloroethane	3	0.2–.4	Chlorobenzene	3	0.2–2.4
1,1,2,2-Tetrachloroethane	1	1.0	Chloroethane	1	.2
1,1-Dichloroethane	9	.2–1.8	Chloroform	23	.2–22
1,1-Dichloroethene	1	.4	Dibromochloromethane	20	.2–9.7
1,2-Dibromomethane	1	.7	Dichlorodifluoromethane	12	.2–4.0
1,2-Dichlorobenzene	2	.3–0.7	Ethylbenzene	8	.2–4.7
1,2-Dichloroethane	15	.2–.6	Methyl chloride	1	.3
1,2-Dichloropropane	14	.2–3.0	Methylene chloride	16	.6–14
trans-1,2-Dichloroethene	16	.2–4.6	Tetrachloroethene	95	.2–120
1,3-Dichlorobenzene	1	4.0	Toluene	13	.2–1.8
1,4-Dichlorobenzene	11	.2–9.5	Trichloroethene	33	.2–130
Benzene	3	.2–15	Trichlorofluoromethane	12	.2–5.0
Bromoform	26	.2–13	Vinyl chloride	1	.3
Bromodichloromethane	15	.2–13	Xylene	3	.2–4.1

detections. The largest VOC concentration was 130 μg/L trichloroethene, and the second largest concentration was 120 μg/L tetrachloroethene.

Percent detections for all VOCs, 5 VOC subgroups, and the 5 most commonly detected VOCs in Edwards aquifer wells are shown in figure 9. Less than 50 percent of the samples had VOC detections. The majority of the detections are halogenated alkanes and alkenes. The five most commonly detected VOCs in Edwards aquifer wells are tetrachloroethene, trichloroethene, bromoform, chloroform, and dibromochloromethane. The range and distribution of concentrations of the five most commonly detected VOCs in Edwards aquifer wells are shown by boxplots in figure 10.

IMPLICATIONS FOR FUTURE MONITORING

Surface Water

At present (1996), the largest VOC concentration in surface water of the SCTX study area is within the city of San Antonio where population density is high. Urban development in San Antonio includes a large amount of impervious cover that enhances runoff and thus potential contaminants entering the streams. The streams are hydraulically connected to the Edwards aquifer, which is the sole source of drinking water for the city of San Antonio. Therefore, any contaminants entering the streams potentially could pollute the drinking-water supply.

Detections of VOCs in surface water in the SCTX study area seem to be associated with urban development. As water draining from the catchment area flows through urban development on the recharge area, the possibility of contaminating the Edwards aquifer exists. The number of detections of VOCs in surface-water samples collected in and around San Antonio compared to the relative lack of VOC detections outside the San Antonio area indicate the greater potential for VOC contamination because of increasing development in the recharge zone. Economic growth in the Hill Country is promoting development. Therefore, analyzing surface water near developing cities in the catchment area could facilitate awareness of the presence of VOC contaminants as development increases.

Even though VOC concentrations at NPDES surface-water sites are small (less than 2 μg/L), permit compliance monitoring of VOCs is expected to continue at these sites and at new sites within the San

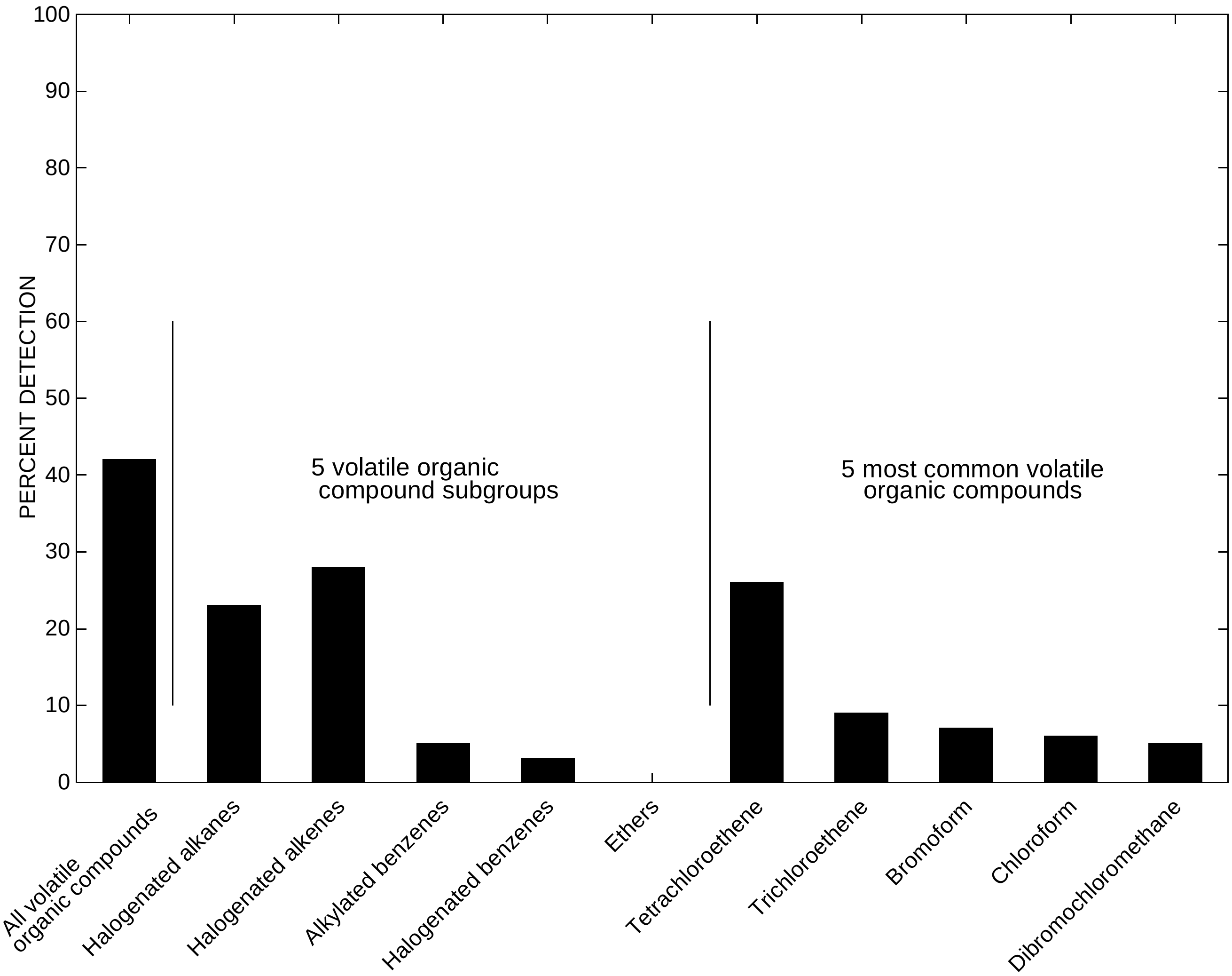

Figure 9. Detections of all volatile organic compounds, five volatile organic compound subgroups, and the five most commonly detected volatile organic compounds in samples from Edwards aquifer wells, South-Central Texas study area.

Antonio area. The SCTX NAWQA plans to incorporate these future data into the data analysis. In addition, nine surface-water sites were selected throughout the SCTX study unit as basic fixed sites (Gilliom and others, 1995), including eight sites in the San Antonio region. The locations of the eight surface-water sites in the San Antonio region of the SCTX study unit are shown in figure 11. VOCs would be measured at some of these stations during intensive sampling periods.

Ground Water

On the basis of available data, VOC contamination of water in the Edwards aquifer is greatest at two locations: in the city of San Antonio and at a site in Uvalde County (fig. 8). VOC contamination in ground water could be associated with three sources. In San Antonio the West Avenue landfill and a gasoline service station near Thousand Oaks Drive are coincident with sites of VOC detections. An abandoned industrial laundry facility near the municipal airport at Uvalde, Tex., is at the site of VOC detections in Uvalde County.

The West Avenue landfill site was a municipal solid-waste facility operated by the city of San Antonio from 1967 to 1972. The landfill occupied an old quarry where limestone was mined from rock units overlying the Edwards aquifer. Vertical permeability of the limestone enhanced by faults could increase the potential for vertical flow to the Edwards aquifer from overlying formations. The USGS, in cooperation with the EUWD,

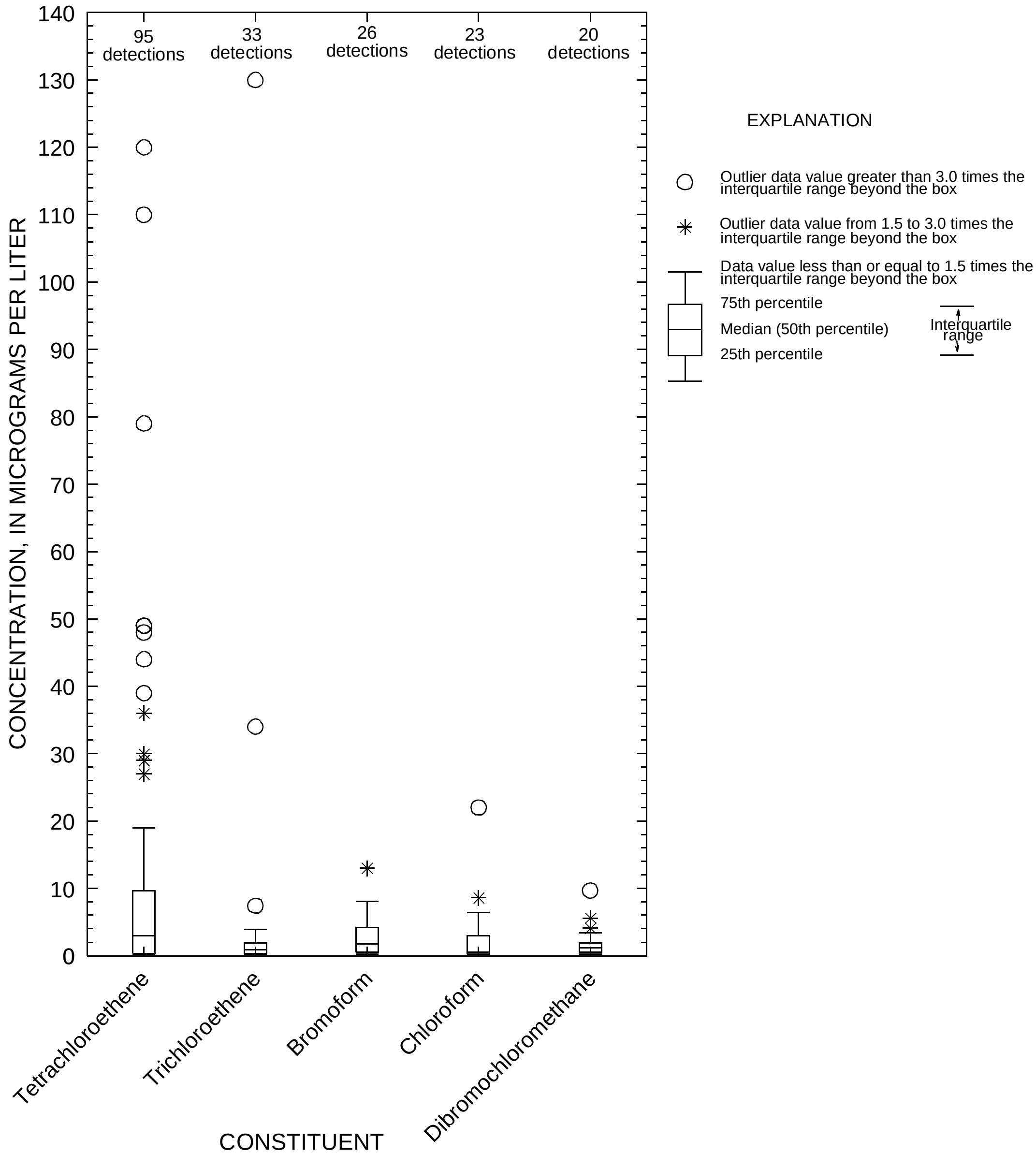

Figure 10. Range and distribution of concentrations of the five most commonly detected volatile organic compounds in samples from Edwards aquifer wells, South-Central Texas study area.

began a study in 1981 to determine possible VOC contamination of Edwards aquifer wells. Water from wells near the landfill have detectable concentrations of tetrachloroethene. Since the closing of the landfill in 1972, methane has been detected in a number of methane-collecter wells (Edwards Underground Water District, 1984).

The Thousand Oaks Drive service station was constructed in 1983 in northwest San Antonio. The underground storage tank was filled with unleaded gasoline in September 1983 after the tank had passed an air test for structural integrity. During December 1983, approximately 11,200 gal of gasoline leaked from the underground storage tank. The leak resulted from a hole that developed when the filled tank settled on a large rock in the bedding material. Investigation of the site indicated that an elongated contaminant plume formed in the rock units overlying the Edwards aquifer. Although the tank is not located in the recharge zone, hydrocarbons were detected in some nearby domestic wells. MTBE concentrations in Edwards aquifer wells in the vicinity of the service station range from 2 to

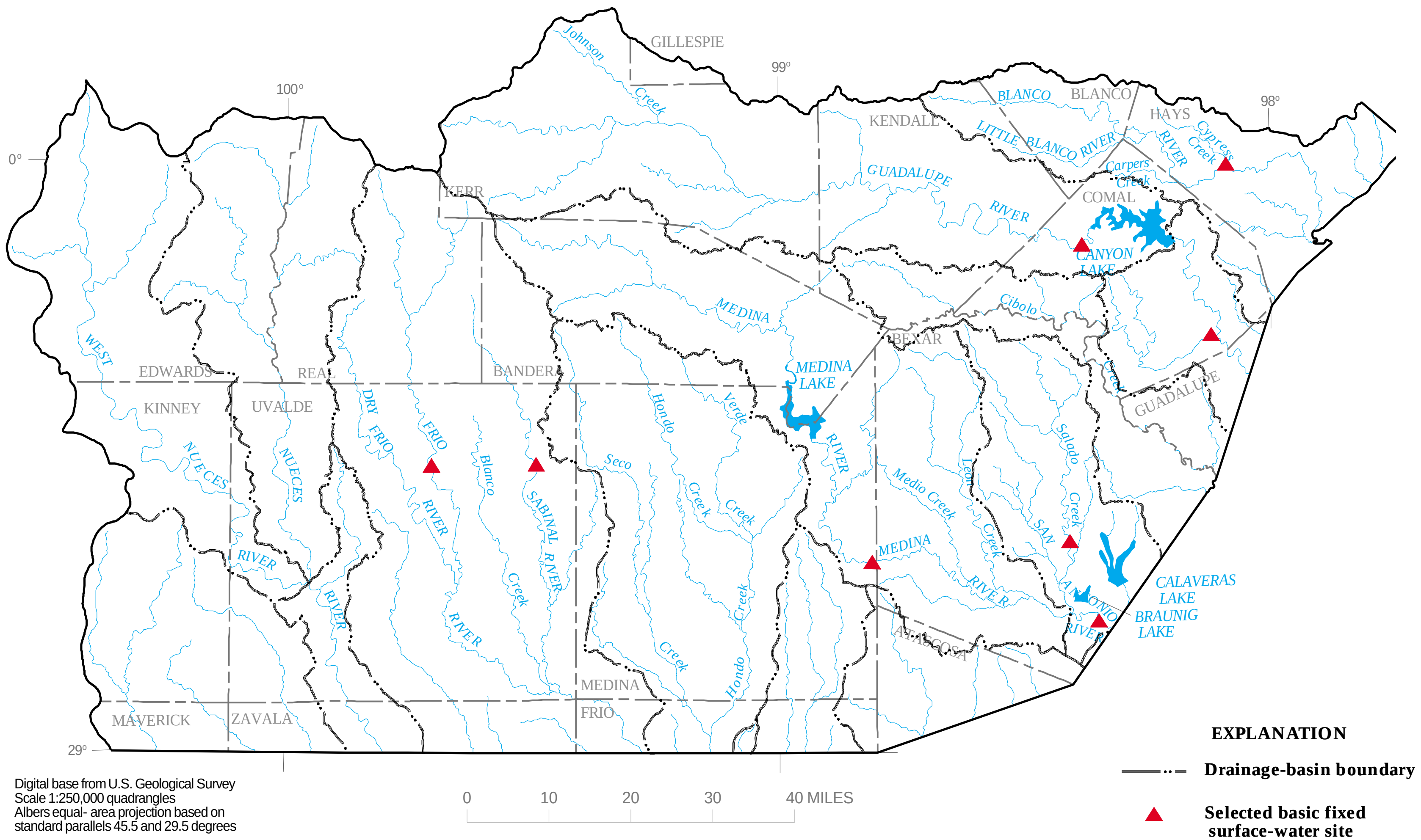

Figure 11. Locations of selected basic fixed surface-water sampling sites, South-Central Texas study area.

898 μg/L. The migration pathway from the rock units overlying the Edwards aquifer appears to have been crossflow through well bores and flow through faults or fractures in the area (Geraghty and Miller Hydrocarbon Services, 1989).

An industrial laundry facility was located near the present-day municipal airport in Uvalde, from 1966 to 1979. Before the industrial laundry facility was established, the site had been a pipe reclaimer/dealership, a farm machinery dealership, and a retail hardware store. After the industrial laundry facility was destroyed by a fire, the municipal airport was established nearby in 1979. While the airport was being built, a concrete sump tank from the industrial laundry facility was discovered. Sludge samples taken from the sump showed 1,2-dichloroethene concentrations of as much as 208 mg/kg. From 1984 to 1988 the EUWD studied surrounding wells to determine possible contamination of Edwards aquifer wells. In August 1985, three tetrachloroethene compounds were detected in Edwards aquifer wells in the vicinity of the airport. In October 1985, tetrachloroethene was detected in four more Edwards aquifer wells. By November 1985, tetrachloroethene had been detected in 11 Edwards aquifer wells (Edwards Underground Water District, 1988).

The karstic features of the Edwards aquifer, which make the limestone aquifer so productive, also can make it susceptible to contamination. The secondary porosity of the Edwards aquifer creates preferential ground-water flowpaths that enhance the potential for migration of contaminants in the aquifer (R.A. Barker, U.S. Geological Survey, written commun., 1995). VOC contamination of ground water in the SCTX study area appears to be limited to the two localized areas in the city of San Antonio and Uvalde County described above. San Antonio is located primarily on strata that confine the Edwards aquifer, but residential and commercial development has expanded to the outcrop of the Edwards aquifer where some VOCs have been detected. In Uvalde County some development also has occurred on the Edwards aquifer outcrop.

The SCTX NAWQA proposes to sample ground water throughout the SCTX study unit with particular emphasis on areas where the Edwards aquifer crops out. These samples will be analyzed for VOCs. The study would be part of the ground-water study-unit survey to determine baseline water-quality conditions (Gilliom and others, 1995). Synoptic sampling studies also might be done in San Antonio and where VOC concentrations are detected.

SUMMARY

At present (1996), VOC contamination in the SCTX study area appears to be associated with urban development. Analysis of VOCs in surface water, primarily from NPDES urban-stormwater sampling sites in San Antonio, indicates that the three most commonly detected VOCs are 1,2,4-trimethylbenzene, toluene, and xylene. Detections of VOCs in water from the Edwards aquifer are limited to two localized areas in the SCTX study area: one in the city of San Antonio and one in Uvalde County. The five most commonly detected VOCs in water samples from the Edwards aquifer, in descending order, are tetrachloroethene, trichloroethene, bromoform, chloroform, and dibromochloromethane.

The fractured nature of the limestone in the study area increases the potential for contamination of the Edwards aquifer. Any VOCs entering the recharge zone from streams originating in the catchment area or direct infiltration can enter the Edwards aquifer immediately and contaminate the water supply. The SCTX NAWQA plans to sample and analyze for VOCs in surface water and ground water throughout the study area with emphasis on areas of development. VOCs would be monitored at NPDES sites, at SCTX NAWQA basic fixed sites, and in the SCTX NAWQA ground-water study-unit surveys to determine baseline water-quality conditions.

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