

A contribution of the National Water-Quality Assessment Program

Water-Quality Assessment of South-Central Texas— Descriptions and Comparisons of Nutrients, Pesticides, and Volatile Organic Compounds at Three Intensive Fixed Sites, 1996–98

Water-Resources Investigations Report 99–4155



U.S. Department of the Interior
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By Patricia B. Ging

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

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.

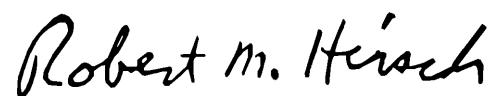
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of more than 50 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within these study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Chief Hydrologist

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Water-Quality Assessment of South-Central Texas— Descriptions and Comparisons of Nutrients, Pesticides, and Volatile Organic Compounds at Three Intensive Fixed Sites, 1996–98

By Patricia B. Ging

Abstract

Water-quality samples were collected during April 1996–April 1998 at three intensive fixed sites in the San Antonio region of the South-Central Texas study unit as part of the U.S. Geological Survey National Water-Quality Assessment Program. The sampling strategy for the intensive fixed-site assessment is centered on obtaining information about the occurrence and seasonal patterns of selected constituents including nutrients, pesticides, and volatile organic compounds. The three sites selected to determine the effects of agriculture and urbanization on surface-water quality in the study unit are Medina River at LaCoste (agriculture indicator site), Salado Creek (lower station) at San Antonio (urban indicator site), and San Antonio River near Elmendorf (integrator site).

Concentrations of two nutrients, dissolved nitrite plus nitrate nitrogen and total phosphorus, were largest at the integrator site, which is downstream of municipal wastewater treatment plants. Nitrite plus nitrate nitrogen concentrations at this site often exceeded the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for drinking water. All total phosphorus concentrations at the site exceeded the EPA recommended maximum concentration for streams not discharging directly into reservoirs. Nitrite plus nitrate nitrogen concentrations at the integrator site tended to be smaller, and total phosphorus concentrations at the urban site tended to be larger in samples collected during stormflow than during base flow. The most detections and largest concentrations of three pesticides (atrazine, diazinon, and

prometon) were in samples collected at the urban site. Some pesticide concentrations at the agriculture site showed a seasonal pattern of increasing concentrations during spring, the peak application season. Four pesticides (atrazine, deethylatrazine, diazinon, and prometon) were detected in at least 38 percent of samples collected at all three sites. The concentrations of all detected pesticides that have an MCL were less than the MCL at the three sites. More volatile organic compounds (VOC) were detected at the urban indicator site than at the agriculture indicator site, mostly likely because more sources are located in urbanized areas. The most VOCs detected and the largest concentrations of two VOCs (chloroform and tetrahydrofuran) were in samples from the integrator site. More VOCs were detected in samples collected at the integrator site during stormflow than during base flow. The concentrations of all detected VOCs that have an MCL were less than the MCL at the three sites.

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 is based on a multidisciplinary approach using standard protocols to collect data in more than 50 study units (Hirsch and others, 1988; Leahy and others, 1990). The intensive fixed-site assessment is a component of the surface-water study design for the high intensity phase of sampling (Gilliom and others, 1995). The purpose of the intensive fixed-site assessment is to increase the sampling frequency and the number (relative to

basic fixed-site sampling) of constituents analyzed at selected sites in the study unit. Dissolved pesticides and volatile organic compounds (VOC) were added to the list of constituents analyzed that already included major anions and cations, nutrients, suspended sediment, and suspended and dissolved organic carbon. The site selection and sampling strategy for the intensive fixed sites is centered on specific land use activities. The premise of the sampling strategy is that relatively frequent sampling at a few carefully chosen sites during key periods yields superior information about occurrence and seasonal patterns of constituents. This sampling strategy can provide information on seasonal and short-term temporal variability of general water quality and constituent transport and determine the occurrence and seasonal patterns of selected constituents such as nutrients, pesticides, and VOCs (Gilliom and others, 1995).

The major water-quality issue in the South-Central Texas (SCTX) NAWQA study unit (fig. 1) is the potential for contamination of the Edwards aquifer. The Edwards aquifer is the main aquifer in the study unit and is the sole source of water for the greater San Antonio area and for ranchers and farmers in the region. The intensive fixed-site assessment was designed to determine the effects of agriculture and urbanization on surface-water quality within the SCTX study unit that ultimately could affect the water quality of the Edwards aquifer. The Medina River watershed just west of San Antonio was used as an agricultural land use indicator, and the Salado Creek watershed within the San Antonio city limits was used as an urban land use indicator. The San Antonio River downstream of the San Antonio city limits, which is downstream of the inflows of the Medina River and Salado Creek, was used as an integrator of agricultural and urban land uses.

Purpose and Scope

The purpose of this report is to describe and compare concentrations of nutrients, pesticides, and VOCs at three sites affected by different upstream land use in the San Antonio region of the study unit. Three intensive fixed sites with different upstream land use were selected for sampling on a weekly to monthly basis during April 1996–April 1998. Descriptions and comparisons of concentrations and temporal patterns of nutrients, pesticides, and VOCs at the three sites are based on graphs, boxplots, and tables.

Description of Study Unit

The SCTX study unit in the San Antonio region comprises mainly the Edwards aquifer and its catchment area. The entire study unit extends beyond the San Antonio region to the Gulf of Mexico to include the complete watersheds of three major rivers (Nueces, San Antonio, and Guadalupe). Salado Creek and Medina River are in the San Antonio River system. For this report, the study area is defined as the San Antonio region of the SCTX study unit (fig. 1).

The Edwards aquifer is the sole source of water for about 1.3 million people in the San Antonio region. Water from the aquifer provides habitat for threatened and endangered species associated with major springs in the region. The Edwards aquifer is a dipping 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 (fig. 1). 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) (U.S. Geological Survey, 1994).

The major process that can affect the quality of water from the Edwards aquifer in the study area is urban development in the greater San Antonio area. Land use in the city of San Antonio and surrounding area (fig. 2) is predominantly commercial and residential, including several large military installations and manufacturing and tourism facilities. Land use in the rest of the study area is mainly forest and rangeland with some agricultural land and small urban areas.

Three intensive fixed sites (fig. 1) were selected to determine the effects of agriculture and urbanization on surface-water quality in the study area. These sites are Medina River at LaCoste (08180640), Salado Creek (lower station) at San Antonio (08178800), and San Antonio River near Elmendorf (08181800). The drainage area of the Medina River watershed upstream of the sampling site, Medina River at LaCoste, is about 805 square miles (mi²) of which 634 mi² is upstream of the dam forming Medina Lake west of San Antonio. Streamflow at this site is controlled by the dam at Medina Lake (Gandara and others, 1997). The predominant land use within the Medina watershed is forest and rangeland with small urban areas. Land use in about 10 percent of the watershed is agricultural. The Medina

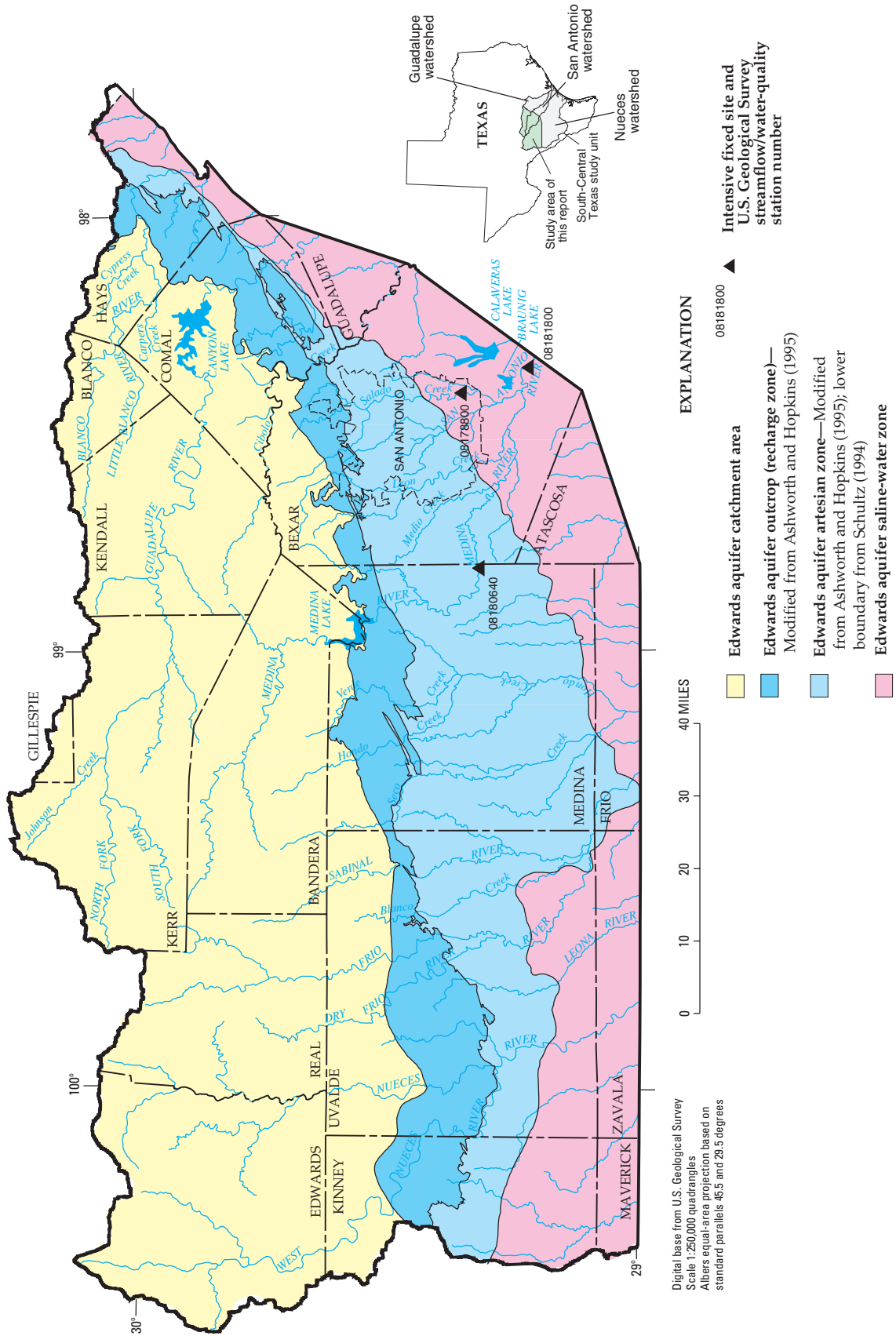


Figure 1. Location of intensive fixed sites in the San Antonio region of the South-Central Texas study unit.

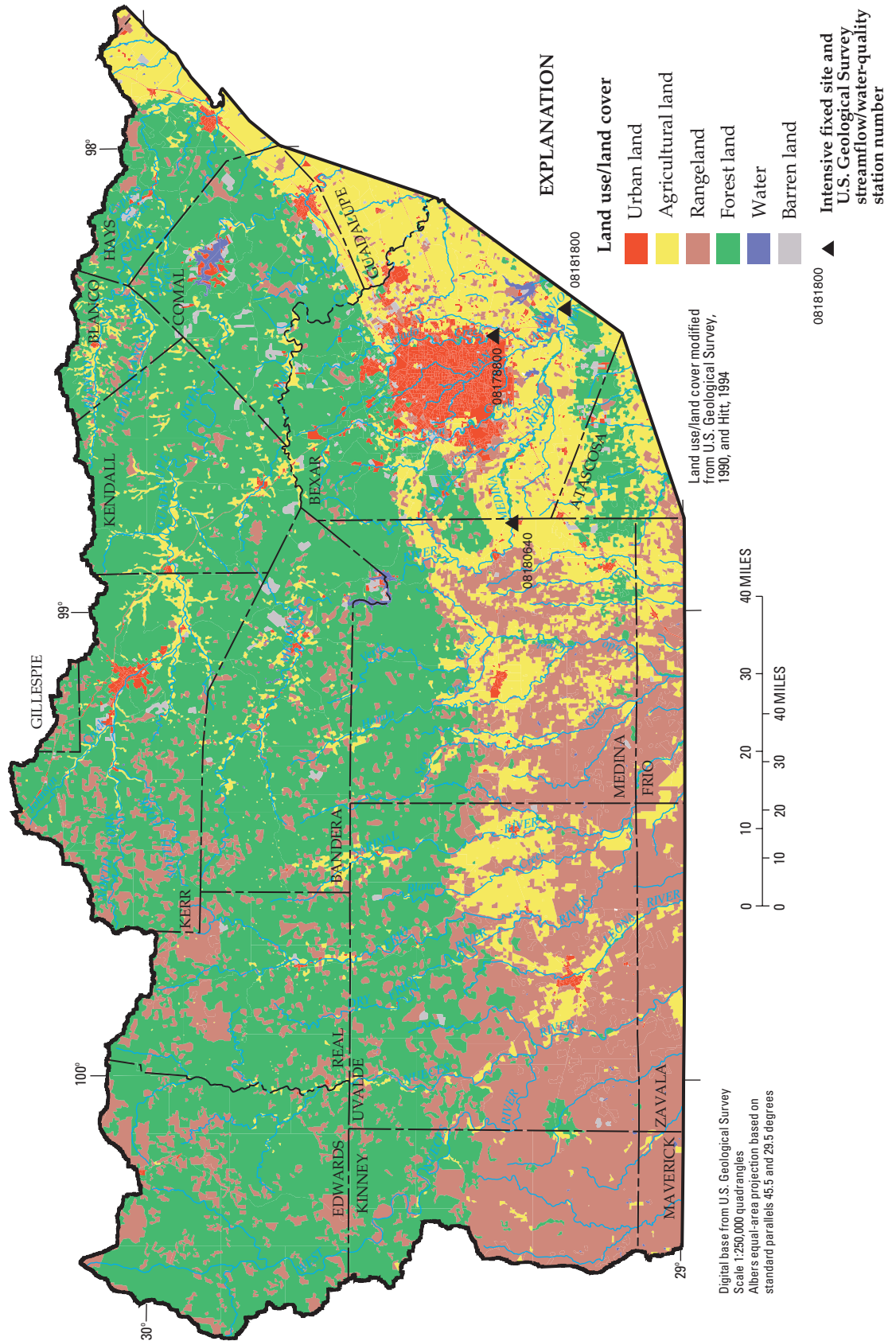


Figure 2. Land use/land cover in the San Antonio region of the South-Central Texas study unit.

River sampling site was selected as an agriculture indicator site because of the proximity of agricultural activity. The predominant crops grown in the watershed are cotton, corn, and sorghum. Most of the cultivated fields are irrigated with Edwards aquifer water. Water quality at this site is affected by runoff from the fields into the river.

The drainage area of the Salado Creek watershed upstream of the sampling site, Salado Creek (lower station) at San Antonio, is about 189 mi² and is mostly within the San Antonio city limits. Land use in this watershed is 80 percent urban and 20 percent agricultural and rangeland. Because of predominantly urban land use upstream, the Salado Creek site is considered an urban indicator site. The urban land use is predominantly commercial and residential with only a small percentage of industrial. Streamflow at this site might be affected during storm events by 11 floodwater-retarding structures in the upper part of the watershed (Gandara and others, 1997). Closer to the site, streamflow is maintained by precipitation and municipal wastewater discharges.

The drainage area of the San Antonio River watershed upstream of the sampling site, San Antonio River near Elmendorf, is about 1,740 mi². Land use in this watershed is 14 percent urban, 22 percent agricultural, 61 percent rangeland and forest, and 3 percent water and barren land. Because of mixed land use upstream, the San Antonio River site is considered an integrator site. The city of San Antonio discharges wastewater effluent into the San Antonio River from three treatment plants located within the watershed (Gandara and others, 1997). The sampling site is downstream of Medina River and Salado Creek inflows to the San Antonio River.

Methods of Sample Collection

The intensive fixed-site sampling strategy is to collect detailed data on the occurrence of contaminants such as pesticides and VOCs at fixed intervals and during high flows for approximately 1 year. The emphasis of the intensive sampling strategy is to collect samples when pesticides and VOCs are most likely to be detected. Most samples were collected monthly although pesticide sampling was more frequent during the spring when pesticides usually are applied, and VOC sampling was more frequent during the winter because VOC detections tend to be greatest during cold months (Lopes and Price, 1997). Pesticide and VOC

samples also were collected during high-flow events. Tables 1–3 (at end of report) show when samples were collected at the three intensive fixed sites. Stream hydrographs for the three intensive fixed sites show discharge and sample collection (fig. 3).

Specific nutrients, pesticides, and VOCs analyzed in the samples are listed in table 4 (at end of report). Other constituents analyzed were major cations and anions, suspended and dissolved organic carbon, and suspended sediment, the concentrations of which are consistent among sites (Gandara and others, 1997, 1998).

Discrete fixed-interval and some high-flow samples were obtained for most constituents analyzed by collecting depth-integrated subsamples at equal-width increments (EWI) across the stream channel using either a US DH–81 or a US D–77 sampler (Edwards and Glysson, 1988; Shelton, 1994). Suspended and dissolved organic carbon samples were collected separately in a baked amber glass bottle using a weighted sampler at a single midstream vertical (Shelton, 1994). VOC samples were collected with a specially designed Wildco sampler, which has 40-milliliter (mL) vials placed directly in the sampler to collect a sample at a single point in the stream (Shelton, 1997). In addition, autosamplers were used to collect storm composite samples at a single point in the stream by programming the sampler to collect subsamples throughout the rise and fall of stream discharge (fig. 4). Autosamplers were used because of the short time period for the rise and fall. Field measurements of specific conductance, pH, water temperature, dissolved oxygen, and alkalinity were collected with the samples.

Samples were processed in the field immediately after collection to reduce the chance of chemical or biological alteration. After collection, all samples were composited in glass bottles using a cone splitter. Major cation and anion samples were filtered through a Gelman capsule filter of 0.45-micrometer (µm) pore size, and pesticide samples were filtered through a glass fiber filter of 0.45-µm pore size. Suspended and dissolved organic carbon samples were filtered through a silver filter of 0.45-µm pore size (Shelton, 1994). Major cation samples were preserved with nitric acid (HNO₃), and VOC samples were preserved with concentrated hydrochloric acid (HCl).

Suspended and dissolved organic carbon filtering equipment was cleaned with organic-free deionized water. The pesticide filter assembly and VOC sampler were cleaned with dilute phosphate-free detergent

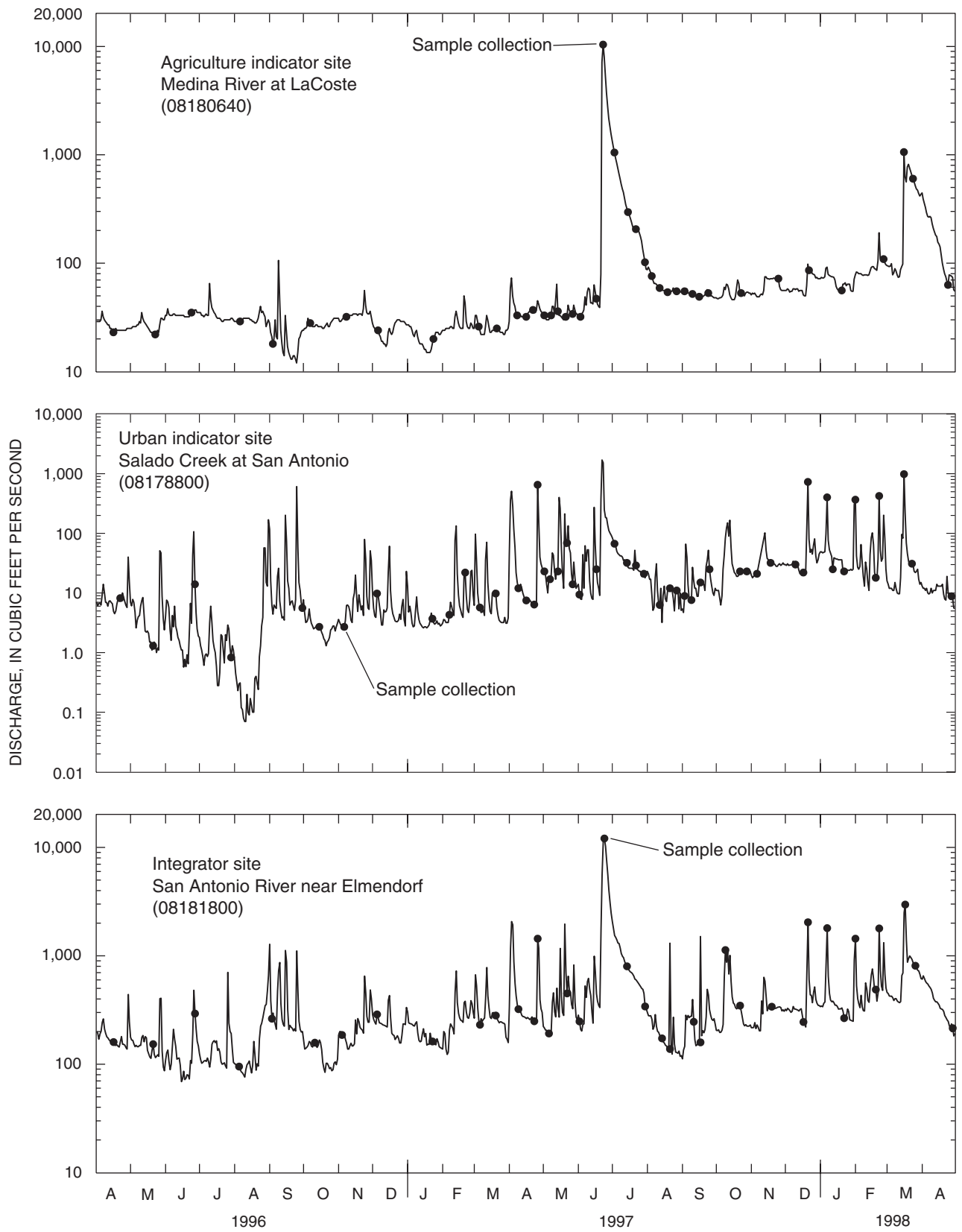


Figure 3. Hydrographs showing discharge and sample collection at intensive fixed sites in the San Antonio region of the South-Central Texas study unit, April 1996–April 1998.

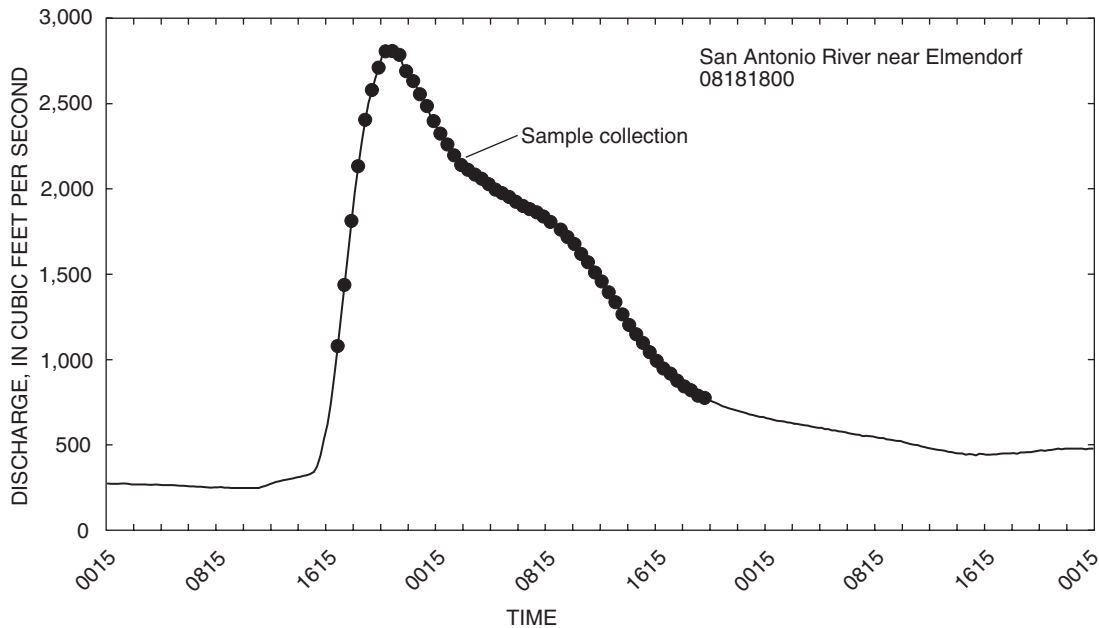


Figure 4. Storm hydrograph showing discharge and sample collection with autosampler at integrator site in the San Antonio region of the South-Central Texas study unit.

solution, deionized water, and methanol. All other equipment used to collect and process samples was cleaned with a dilute phosphate-free detergent solution, rinsed with tap water, soaked in 5-percent HCl, rinsed with deionized water, rinsed with methanol, and then air dried (Shelton, 1994; 1997).

Quality-control samples comprised field blanks, equipment blanks, replicates, trip blanks, and field matrix spikes. These quality-control samples are described in Mueller and others (1997). One field blank and one replicate for major cations and anions, nutrients, suspended and dissolved organic carbon, and suspended sediment were collected each month during the study. In addition, four pesticide field blanks and three VOC field blanks were collected during the study. Two equipment blanks for trace elements and nutrients were collected. Four sets of split-concurrent replicates were collected during the study and analyzed for major cations and anions, nutrients, suspended sediment, and pesticides. One replicate and one trip blank were collected for VOC analysis. One field matrix spike was collected for pesticides and one for VOCs.

Quality-control samples were obtained for autosamplers by collecting an EWI sample at the same time that a discrete one-time sample was collected by the autosampler. This procedure was to help determine if there was bias in chemical concentrations from sam-

ples collected at a single point in the stream with an autosampler compared to samples collected using the EWI method, which might help determine a correction factor for chemical concentrations of samples collected with an autosampler. Field blank samples also were collected with the autosamplers.

NUTRIENTS

Nutrients in surface water are essential for aquatic plant and animal life, but large nutrient concentrations can have adverse ecological effects. In general, sources of nutrients include wastewater treatment plants, fertilizer, manure, plant decay, and atmospheric deposition (Hem, 1989). Concentrations of nutrients analyzed in samples collected during the study at the three intensive fixed sites are shown in tables 5–7 (at end of report). Concentrations of nutrients in equipment blank samples were small compared to concentrations in environmental samples. Small concentrations of some nutrients detected in field blanks could cause a positive bias in small nutrient concentrations in environmental samples. The small concentrations of nutrients in field blanks probably were from residual contamination in the collection and processing equipment. The nutrients of most concern are nitrite plus nitrate nitrogen and phosphorus.

Nitrite plus nitrate nitrogen is a concern for drinking water because excessive concentrations of nitrate

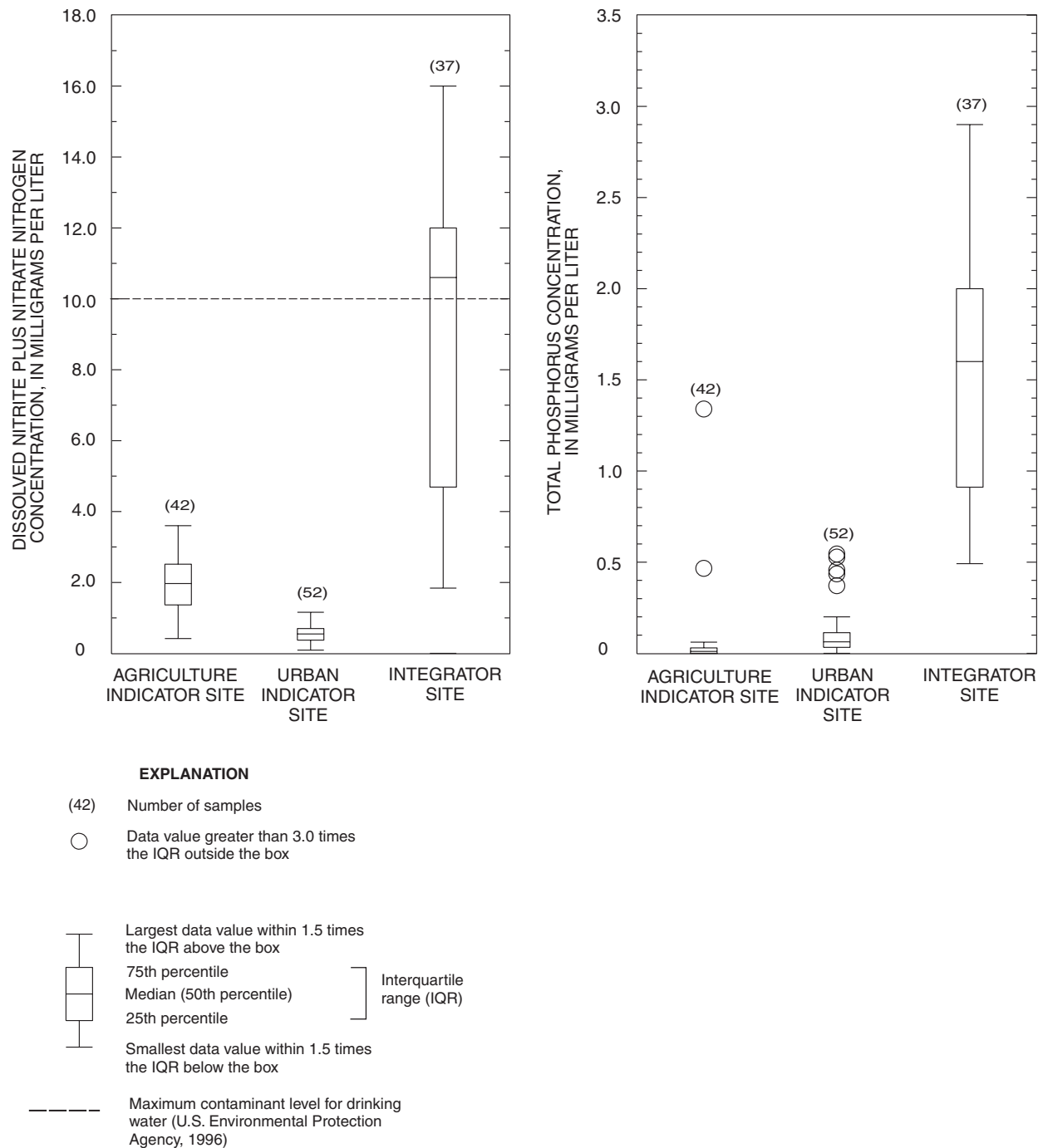


Figure 5. Range and distribution of dissolved nitrite plus nitrate nitrogen and total phosphorus concentrations at intensive fixed sites in the San Antonio region of the South-Central Texas study unit, April 1996–April 1998.

can cause methemoglobinemia (blue baby syndrome), which restricts oxygen transport in the bloodstream of infants (Hem, 1989). The maximum contaminant level (MCL) for dissolved nitrite plus nitrate nitrogen in U.S. Environmental Protection Agency (EPA) drinking water regulations is 10 milligrams per liter (mg/L) for

water delivered to any user of a public water system (U.S. Environmental Protection Agency, 1996). Box-plots of the distribution of dissolved nitrite plus nitrate nitrogen concentrations for the three intensive fixed sites are shown in figure 5. Median concentrations were 1.97 mg/L at the agriculture indicator site, 0.551 mg/L

at the urban indicator site, and 10.6 mg/L at the integrator site.

Nitrite plus nitrate nitrogen concentrations were graphed for the three intensive fixed sites to show any concentration fluctuations over time or seasonal patterns (fig. 6). Nitrite plus nitrate nitrogen concentrations at all three sites did not indicate seasonal patterns. Nitrite plus nitrate nitrogen concentrations at the integrator site, which is downstream from three municipal wastewater treatment plants, often exceeded the MCL for drinking water.

Nitrite plus nitrate nitrogen concentrations were smaller in samples collected during storm events (larger discharge) than during base flow at the agriculture indicator site (table 5). Nitrite plus nitrate nitrogen concentrations in storm-event samples at the urban indicator site did not vary from concentrations in base-flow samples (table 6). Nitrite plus nitrate nitrogen concentrations also were smaller in samples collected during storm events than during base flow at the integrator site (table 7). Nitrite plus nitrate nitrogen concentrations in base-flow samples at the agriculture indicator site did not seem to vary with discharge, but nitrite plus nitrate nitrogen concentrations in base-flow samples at the urban indicator site generally increased with increasing discharge (fig. 7). In contrast, nitrite plus nitrate nitrogen concentrations in base-flow samples at the integrator site generally decreased with increasing discharge (fig. 8).

Phosphorus often is associated with eutrophication, which is the enrichment of a body of water with nutrients that results in accelerated algal or plant production (Hem, 1989). Eutrophication can result in fish kills, unpleasant odors, loss of recreational value, and other water-quality related problems (Land and others, 1998). The EPA recommends that total phosphorus concentrations not exceed 0.10 mg/L in streams not discharging directly into reservoirs and not exceed 0.05 mg/L in streams discharging directly into reservoirs (U.S. Environmental Protection Agency, 1986). Boxplots of total phosphorus concentrations for the three intensive fixed sites are shown in figure 5. Total phosphorus concentrations at the agriculture indicator site exceeded 0.10 mg/L only in two samples collected during storm events (table 5). Total phosphorus concentrations at the urban indicator site ranged from <0.010 mg/L to 0.545 mg/L and also were greater in samples collected during storm events (table 6). Total phosphorus concentrations in all samples collected at the inte-

grator site exceeded 0.10 mg/L (but were less than 3.0 mg/L) (table 7).

PESTICIDES

Pesticides (herbicides and insecticides) commonly are used in the study area to control unwanted vegetation and insects and to improve crop production; although useful, pesticides can adversely affect the environment and human health. The greatest potential for adverse effects of pesticides is through contamination of the hydrologic system (Larson and others, 1997). Water is one of the primary pathways by which pesticides are transported from their application areas to other parts of the environment.

Samples collected at the three intensive fixed sites were analyzed for 84 pesticides and pesticide metabolites (table 4). The pesticides detected at the sites and the range in concentrations are listed in table 8 (at end of report). No pesticides were detected in field blanks. The agriculture indicator site had the least number of pesticides detected with 15 in the 32 samples collected. The most commonly detected pesticides at the agriculture site were atrazine, deethylatrazine, and prometon, each detected in at least 20 samples. Diazinon was detected in 12 samples. Concentrations of some pesticides detected (for example, atrazine and diazinon) increased in the spring during peak pesticide application (fig. 9). Concentrations of all pesticides detected at the agriculture site were less than 0.12 microgram per liter ($\mu\text{g/L}$) (table 8).

The urban indicator site had the most pesticides detected with 25 in the 35 samples collected (table 8). The most commonly detected pesticides were atrazine, deethylatrazine, diazinon, prometon, simazine, and tebuthiuron, each detected in at least 27 samples. Tebuthiuron, bromacil, and diuron had the largest concentrations among the pesticides detected at the urban site, 2.8, 1.6, and 1.1 $\mu\text{g/L}$, respectively. Concentrations of some of the pesticides detected at the urban site also increased in spring (fig. 10).

Results from the integrator site showed 18 pesticides detected in the 26 samples collected. The most commonly detected pesticides were atrazine, deethylatrazine, diazinon, prometon, and simazine, each detected in at least 20 samples. Carbaryl, chlorpyrifos, lindane, metolachlor, and tebuthiuron were detected in at least 15 samples. Concentrations of all pesticides detected at the integrator site were less than 0.44 $\mu\text{g/L}$ (table 8). As at the agriculture and urban indicator sites,

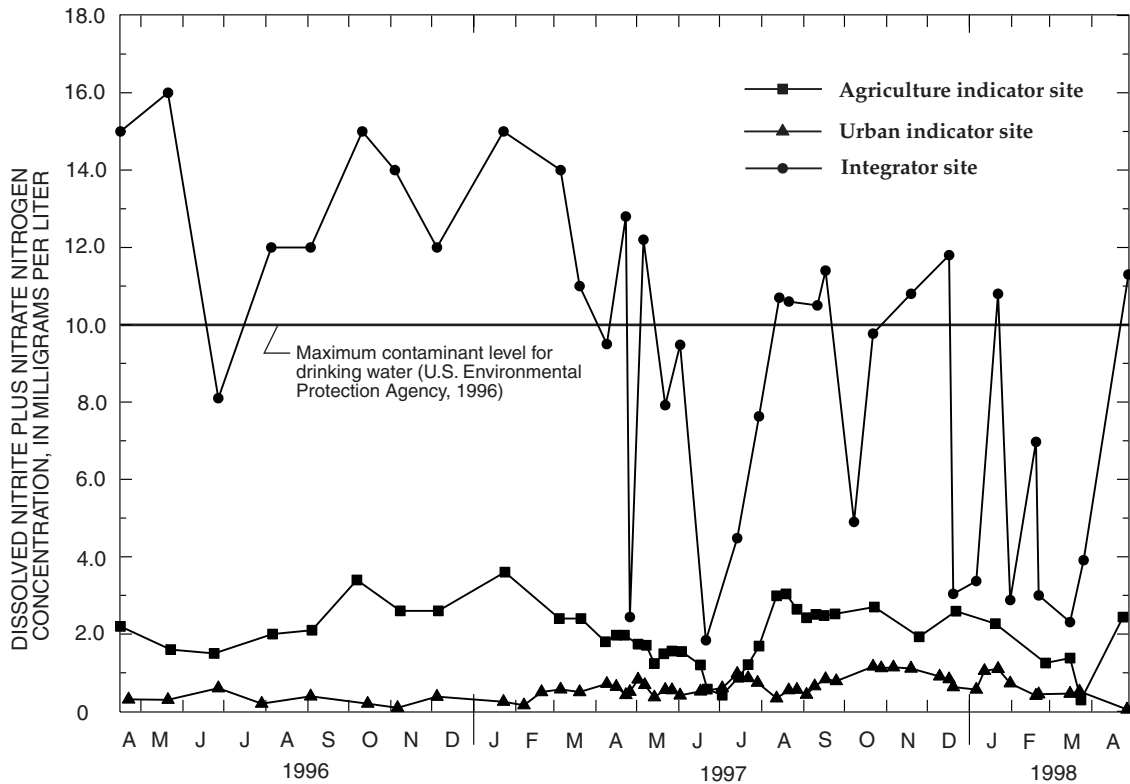


Figure 6. Dissolved nitrite plus nitrate nitrogen concentrations at intensive fixed sites in the San Antonio region of the South-Central Texas study unit, April 1996–April 1998.

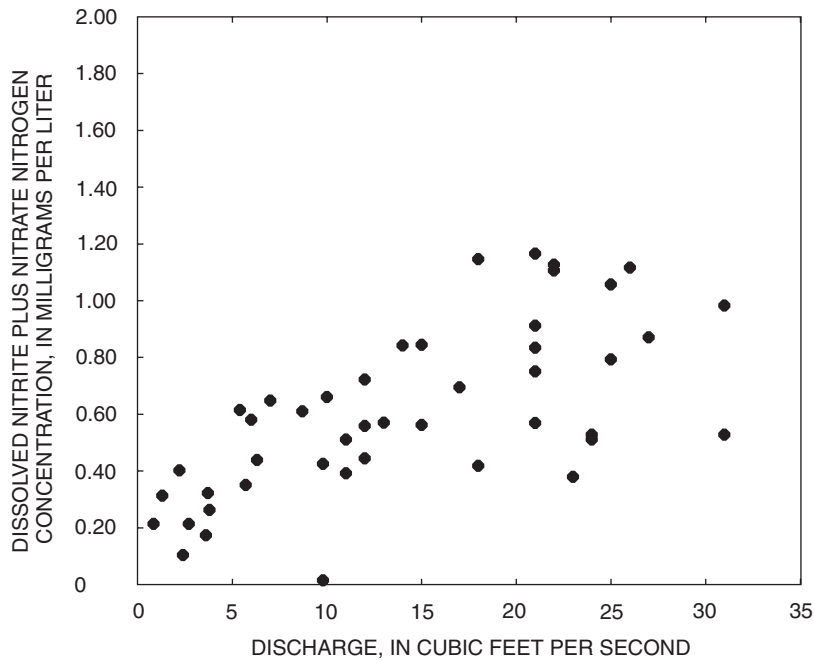


Figure 7. Dissolved nitrite plus nitrate nitrogen concentrations with respect to discharge in base-flow samples at the urban indicator site in the San Antonio region of the South-Central Texas study unit.

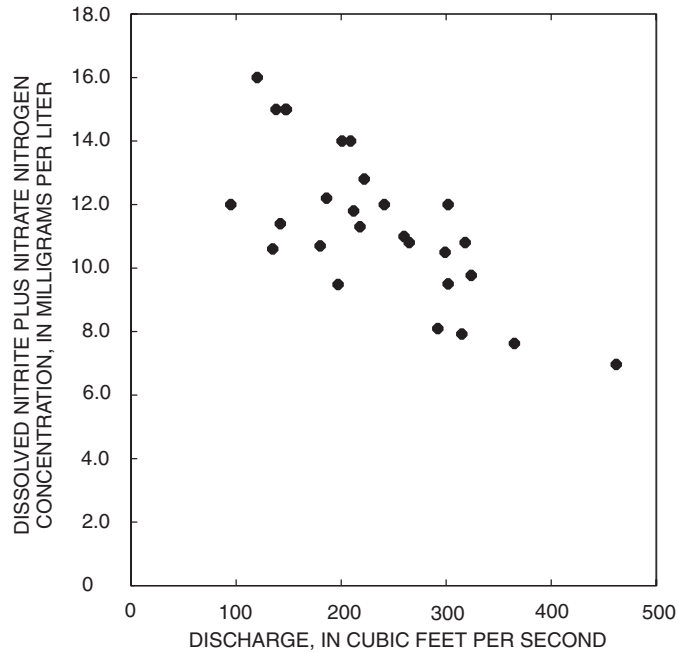


Figure 8. Dissolved nitrite plus nitrate nitrogen concentrations with respect to discharge in base-flow samples at the integrator site in the San Antonio region of the South-Central Texas study unit.

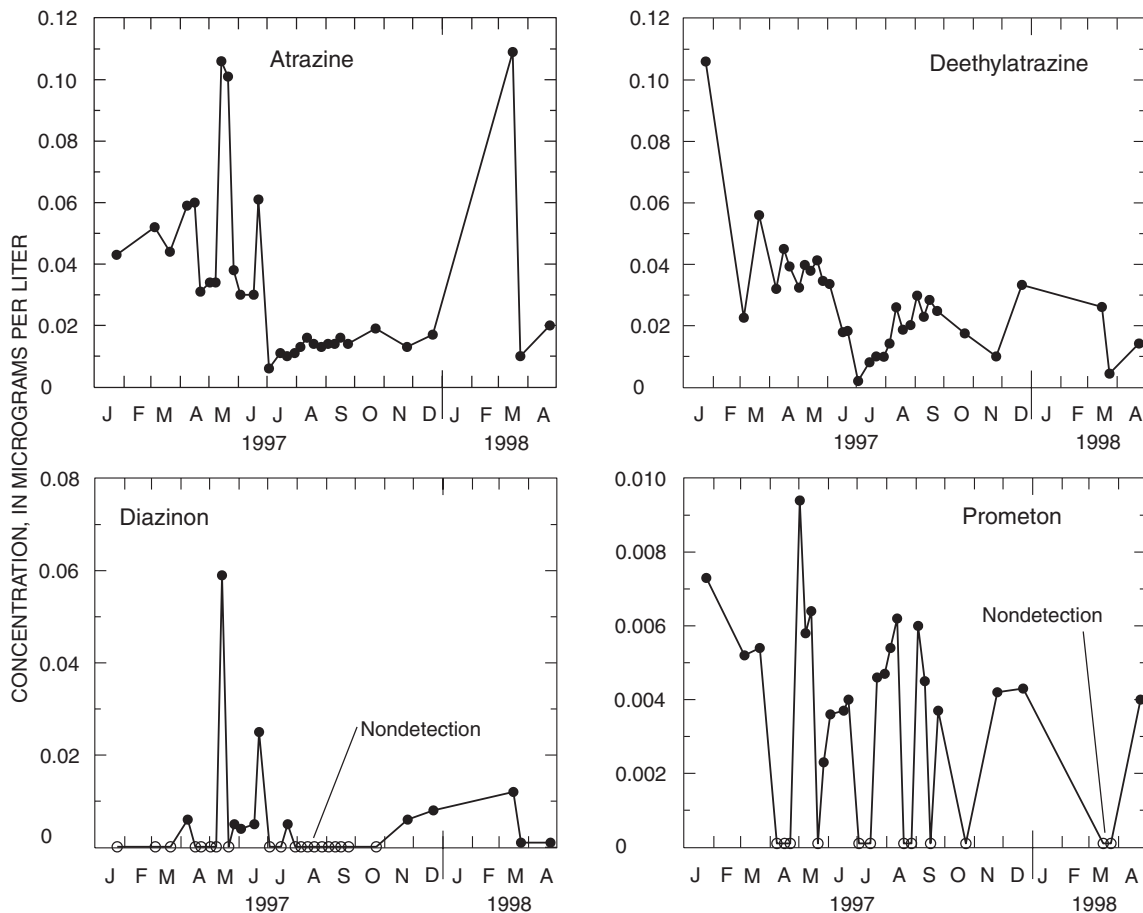


Figure 9. Concentrations of selected pesticides in samples collected at the agriculture indicator site in the San Antonio region of the South-Central Texas study unit, January 1997–April 1998.

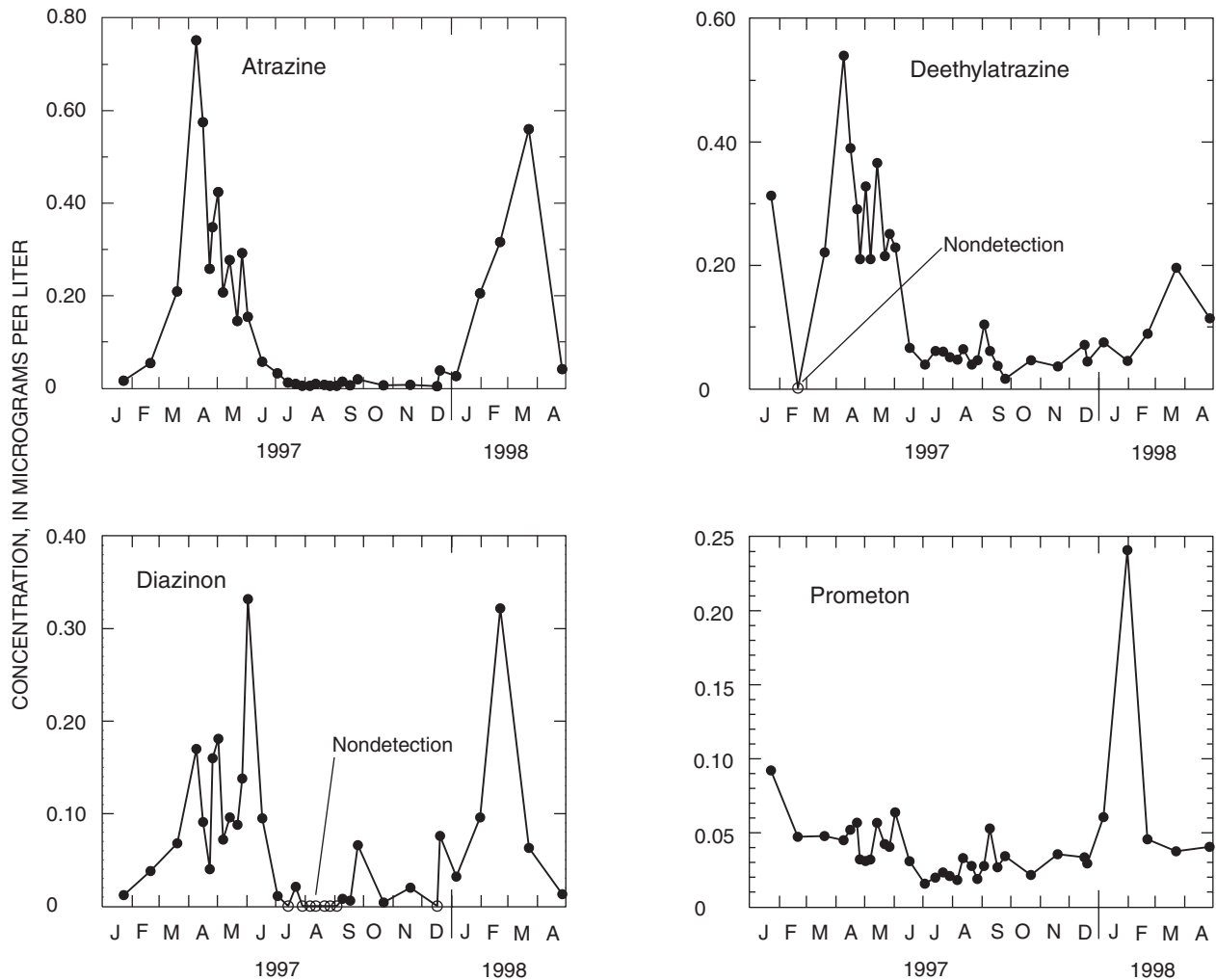


Figure 10. Concentrations of selected pesticides in samples collected at the urban indicator site in the San Antonio region of the South-Central Texas study unit, January 1997–April 1998.

concentrations of some of the pesticides detected at the integrator site showed increases in spring (fig. 11).

Under provisions of the Safe Drinking Water Act, the EPA has established MCLs for concentrations of certain chemicals in drinking water (U.S. Environmental Protection Agency, 1996). These MCLs are health-based standards and are a result of chronic toxicity tests conducted with animals (Larson and others, 1997). Not all pesticides analyzed in the samples collected at the intensive fixed sites have an MCL listed in the drinking water regulations. Concentrations of all pesticides that were detected at the intensive fixed sites and have an MCL were less than the MCL.

Four pesticides detected in a large percentage (38 to 100 percent) of samples collected at the three intensive fixed sites were atrazine, deethylatrazine,

diazinon, and prometon. Boxplots of these pesticide concentrations show that median concentrations of atrazine at the three sites were similar (fig. 12). The largest median concentration of deethylatrazine was at the agriculture indicator site. The largest median concentrations of diazinon and prometon were at the urban indicator site. The largest concentrations of three of the four pesticides shown were at the urban indicator site (atrazine, 0.75 µg/L; diazinon, 0.33 µg/L; prometon, 0.24 µg/L).

VOLATILE ORGANIC COMPOUNDS

VOCs are present in many natural and synthetic materials and commonly are used as fuel additives, solvents, and aerosols. Despite their high evaporation rates, VOCs have been detected in natural waters

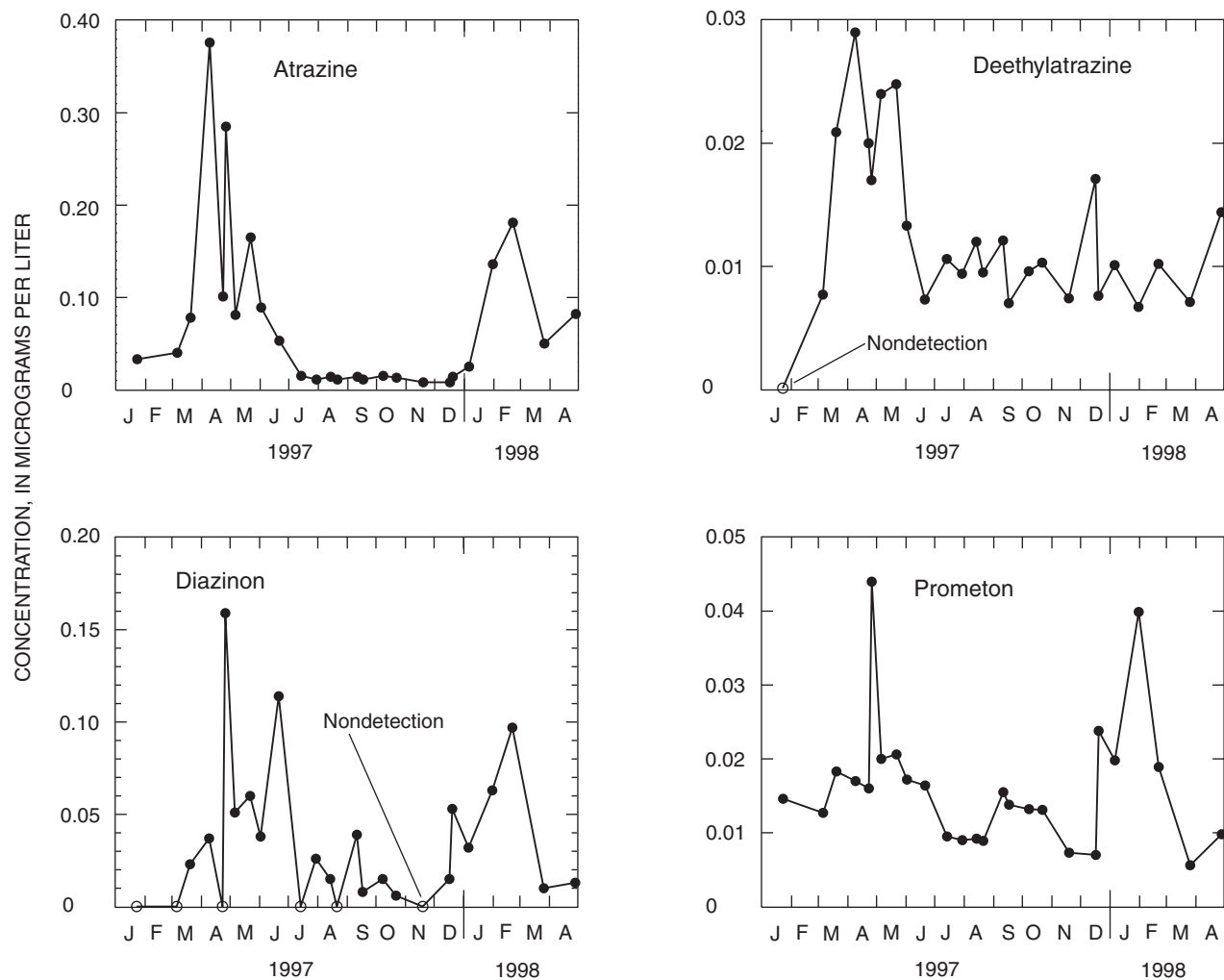


Figure 11. Concentrations of selected pesticides in samples collected at the integrator site in the San Antonio region of the South-Central Texas study unit, January 1997–April 1998.

(Kotzias and Sparta, 1993). The likely sources of VOCs in surface water are industrial and wastewater discharges, accidental fuel and oil spills, and chlorinated municipal drinking water. However, all of the water sources that sustain streamflow are susceptible to contamination by VOCs. VOCs in rainfall originate from vehicle and industrial emissions; direct runoff from streets and paved surfaces is another source of VOCs (Terracciano and O'Brien, 1997). Contamination of water by VOCs is a concern because of the threat to human health. Possible effects to humans ingesting water containing VOCs include eye, nose, and throat irritation; central nervous system responses such as dizziness, headaches, and loss of short-term memory; and carcinogenesis (Wallace, 1993).

Samples collected for VOCs were analyzed for 86 compounds (table 4). The VOCs detected at the three intensive fixed sites and the range in concentrations are listed in table 9 (at end of report). Small concentrations of carbon disulfide, toluene, and xylene were detected in VOC field blanks. These same VOCs also were detected in source water for VOC field blanks, indicating that the source of the VOCs in the field blanks likely was not associated with sample collection and processing. The agriculture indicator site had the least number of VOCs detected with 15 in the 7 samples collected. The most commonly detected VOCs at the agriculture site were bromoform, carbon disulfide, chloroform, *p*-isopropyltoluene, and *meta*- and *para*-xylene, each detected in at least three samples. Concentrations of all VOCs detected at the agriculture site were less than

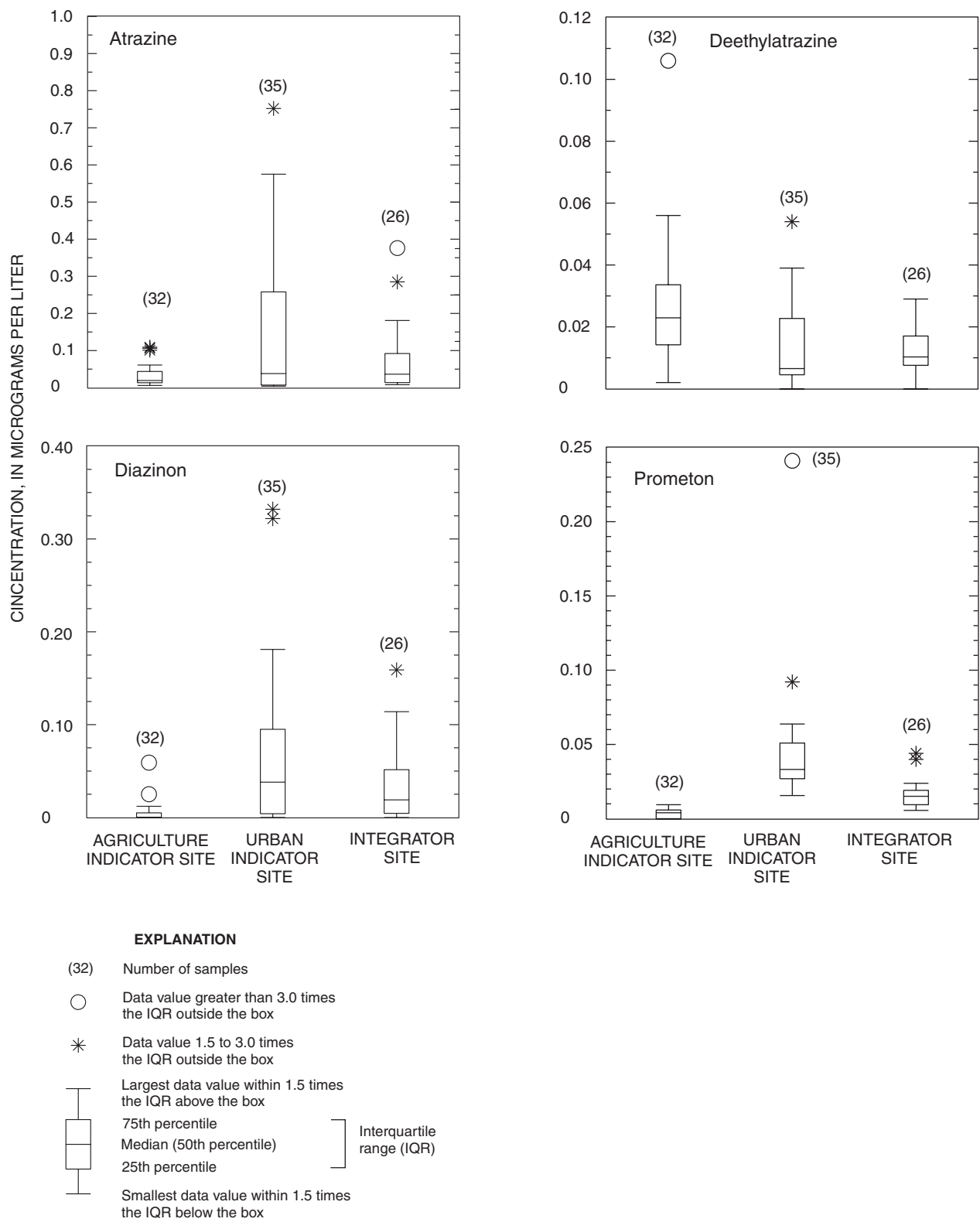


Figure 12. Range and distribution of selected pesticide concentrations at intensive fixed sites in the San Antonio region of the South-Central Texas study unit, January 1997–April 1998.

1.0 µg/L. More VOCs were detected at the site in samples collected during storm events than during base-flow conditions—six compounds (benzene, ethylbenzene, naphthalene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and xylene) were detected only in storm-event samples.

More VOCs were detected at the urban indicator site (21 in 22 samples, table 9) than at the agriculture site, probably because the sources of VOCs are more likely to be in urban areas. The most commonly detected VOCs at the urban site were *cis*-1,2-dichloroethene, methyl *tert*-butyl ether (MTBE), and toluene—all detected in at least 12 samples. Concentrations of all VOCs detected were less than 1.0 µg/L except those for acetone, which were less than 7.0 µg/L (table 9). Correlation between discharge and number of VOCs detected was not apparent at the urban site.

The integrator site had the most VOCs detected, 33 in the 13 samples collected (table 9). The most commonly detected VOCs at the integrator site were bromoform, chlorodibromomethane, chloroform, 1,4-dichlorobenzene, and dichlorobromomethane, each detected in at least 10 samples. Four of these VOCs (bromoform, chlorodibromomethane, chloroform, and dichlorobromomethane) commonly are referred to as trihalomethanes (THMs), which are generated when water is chlorinated at treatment plants. THMs are present in chlorinated water worldwide in concentrations typically ranging from 10 to 30 µg/L (Thurman, 1986). Concentrations of THMs in samples collected from the integrator site were less than the typical range. More VOCs were detected in samples collected at the integrator site during winter storm events than in other samples. Two of the largest VOC concentrations from the study were chloroform, 4.6 µg/L, and tetrahydrofuran, 3.9 µg/L, detected in samples collected at the integrator site. The concentrations of some VOCs detected at the integrator site were about equal to or larger than the combined concentrations of the same VOCs detected at the agriculture and urban indicator sites upstream of the integrator site.

Not all VOCs analyzed in the samples collected at the intensive fixed sites have an MCL listed in the EPA drinking water regulations. Concentrations of all VOCs that were detected at the intensive fixed sites and have an MCL were less than the MCL.

SUMMARY

Three sites with different upstream land use in the San Antonio region of the SCTX NAWQA study unit (study area) were selected as intensive fixed sites. The sampling strategy for intensive fixed sites is based on obtaining information about the occurrence and seasonal patterns of selected water-quality constituents, which include nutrients, pesticides, and VOCs. The three intensive fixed sites selected to determine the effects of agriculture and urbanization on surface-water quality in the study area are Medina River at LaCoste (agriculture indicator site), Salado Creek (lower station) at San Antonio (urban indicator site), and San Antonio River near Elmendorf (integrator site). Surface-water quality is a major issue in the SCTX study unit because of the potential for contamination of the Edwards aquifer.

Samples were collected at the three intensive fixed sites during April 1996–April 1998. Sample collection usually was done when pesticides and VOCs were likely to be detected. Most samples were collected monthly, although pesticide sampling was more frequent during the spring, and VOC sampling was more frequent during the winter. Some samples were collected with autosamplers, which can collect composite samples during storms. Quality-control samples comprised field blanks, equipment blanks, replicates, trip blanks, and field matrix spikes.

Seasonal patterns in nitrite plus nitrate nitrogen concentrations were not evident at all three intensive fixed sites. Nitrite plus nitrate nitrogen concentrations often exceeded the MCL (10 mg/L) for drinking water at the integrator site, which is downstream of municipal wastewater treatment plants. Nitrite plus nitrate nitrogen concentrations in samples collected during storm-flow were smaller than concentrations in samples collected during base flow at the agriculture and integrator sites.

Total phosphorus concentrations at the agriculture indicator site were mostly less than 0.10 mg/L, the maximum concentration recommended by EPA for streams not discharging directly into reservoirs, and the majority of concentrations at the urban indicator site also were less than 0.10 mg/L. All total phosphorus concentrations at the integrator site were greater than 0.10 mg/L.

Samples collected at the three intensive fixed sites were analyzed for 84 pesticides. Concentrations of some pesticides detected tended to increase in the

spring during peak pesticide application. More pesticides were detected at the urban indicator site and at the integrator site than at the agriculture indicator site. Four pesticides (atrazine, deethylatrazine, diazinon, and prometon) were detected in at least 38 percent of samples at all sites. The largest concentrations of atrazine (0.75 µg/L), diazinon (0.33 µg/L), and prometon (0.24 µg/L) were at the urban indicator site. The concentrations of detected pesticides that have an MCL were less than that MCL at all three intensive fixed sites.

Samples collected for VOCs were analyzed for 86 compounds. More VOCs were detected at the urban indicator site than at the agriculture indicator site, most likely because more sources of VOCs are located in urbanized areas. The most VOCs detected (33 in 13 samples) and the largest concentrations of two VOCs (chloroform, 4.6 µg/L and tetrahydrofuran, 3.9 µg/L) were in samples collected at the integrator site. Some of the VOCs detected (THMs), especially at the integrator site, could be associated with the chlorination process at wastewater treatment plants in the watershed. More VOCs were detected in samples collected at the integrator site during winter storm events than during base flow. The concentrations of all detected VOCs that have an MCL were less than the MCL at all three intensive fixed sites.

Sampling at the three intensive fixed sites during April 1996–April 1998 indicates that more detections and larger concentrations of nutrients, pesticides, and VOCs tend to be associated with an urban or integrated urban setting. Continued sampling of these constituents at the sites could provide additional information on changes in surface-water quality with urban development.

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Table 1. Number of samples collected each month at agriculture indicator site, Medina River at LaCoste

[SOC/DOC, suspended and dissolved organic carbon; VOCs, volatile organic compounds]

Type of sample	1997												1998															
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.			
Major ions	1	1	1	0	1	1	1	1	1	1	0	2	3	5	3	4	4	4	1	1	1	1	1	1	2	1		
Nutrients	1	1	1	0	1	1	1	1	1	1	0	2	3	5	3	4	4	4	1	1	1	1	1	1	1	2	1	
SOC/DOC	1	1	1	0	1	1	1	1	1	1	0	2	3	5	3	4	4	4	1	1	1	1	1	1	1	2	1	
Suspended sediment	1	1	1	0	1	1	1	1	1	1	0	2	3	5	3	4	4	4	1	1	1	1	1	1	1	2	1	
Pesticides	0	0	0	0	0	0	0	0	0	1	0	2	3	5	3	4	4	4	1	1	1	1	0	0	2	2	1	
VOCs	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0	0	0	1	1	1	0	0	1	0	1	0

Table 2. Number of samples collected each month at urban indicator site, Salado Creek (lower station) at San Antonio

[SOC/DOC, suspended and dissolved organic carbon; VOCs, volatile organic compounds]

Type of sample	1997												1998													
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
Major ions	1	1	1	1	0	1	1	1	1	1	2	2	4	5	2	4	4	4	2	2	2	3	4	2	2	1
Nutrients	1	1	1	1	0	1	1	1	1	1	2	2	4	5	2	4	4	4	2	2	2	3	4	2	2	1
SOC/DOC	1	1	1	1	0	1	1	1	1	1	2	2	4	5	2	4	4	4	2	2	2	3	4	2	2	1
Suspended sediment	1	1	1	1	0	1	1	1	1	1	2	2	4	5	2	4	4	4	2	2	2	3	4	2	2	1
Pesticides	0	0	0	0	0	0	0	0	0	1	1	1	4	5	2	4	4	4	1	1	1	2	2	1	1	1
VOCs	0	0	0	0	0	0	0	0	0	1	2	2	2	1	0	2	1	1	2	2	2	3	3	0	0	0

Table 3. Number of samples collected each month at integrator site, San Antonio River near Elmendorf

[SOC/DOC, suspended and dissolved organic carbon; VOCs, volatile organic compounds]

Type of sample	1997												1998												
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Major ions	1	1	1	0	1	1	1	1	1	1	1	0	2	2	2	2	2	2	2	1	2	3	2	2	1
Nutrients	1	1	1	0	1	1	1	1	1	1	1	0	2	2	2	2	2	2	2	1	2	3	2	2	1
SOC/DOC	1	1	1	0	1	1	1	1	1	1	1	0	2	2	2	2	2	2	2	1	2	3	2	2	1
Suspended sediment	1	1	1	0	1	1	1	1	1	1	1	0	2	2	2	2	2	2	2	1	2	3	2	2	1
Pesticides	0	0	0	0	0	0	0	0	0	1	0	2	3	2	2	2	2	2	2	1	2	2	1	1	1
VOCs	0	0	0	0	0	0	0	0	0	1	0	2	1	1	1	0	1	1	1	1	1	2	0	0	0

Table 4. List of specific nutrients, pesticides, and volatile organic compounds analyzed in samples collected at intensive fixed sites

[MDL, method detection limit; mg/L, milligrams per liter; µg/L, micrograms per liter]

Nutrients ¹	MDL (mg/L)	Pesticides ² (herbicides and insecticides)	MDL (µg/L)	Volatile organic compounds ³	MDL (µg/L)
Nitrogen, ammonia, dissolved	0.015, .020	Acifluorfen	0.035	Acetone	2.452
Nitrogen, ammonia plus organic, dissolved	.20, .10	Alachlor	.002	Acrolein	.716
Nitrogen, ammonia plus organic, total	.20, .10	Aldicarb	.016	Acrylonitrile	.613
Nitrogen, nitrite, dissolved	.010	Aldicarb sulfone	.016	Benzene	.016
Nitrogen, nitrite plus nitrate, dissolved	.050	Aldicarb sulfoxide	.021	Bromobenzene	.018
Phosphorus, total	.010	Atrazine	.001	Bromochloromethane	.022
Phosphorus, dissolved	.010	Azinphos-methyl	.001	Bromoform	.052
Phosphorus, orthophosphate, dissolved	.010	Bentfluralin	.002	Bromomethane	.074
		Bentazon	.014	2-Butanone	.825
		Bromacil	.035	<i>n</i> -Butylbenzene	.093
		Bromoxynil	.035	<i>sec</i> -Butylbenzene	.024
		Butylate	.002	<i>tert</i> -Butylbenzene	.048
		Carbaryl	.003	Carbon disulfide	.040
		Carbofuran	.003	Chlorobenzene	.014
		Chloramben	.011	Chlorodibromomethane	.091
		Chlorothalonil	.035	Chloroethane	.060
		Chlorpyrifos	.004	Chloroform	.026
		Clopyralid	.05	Chloromethane	.127
		Cyanazine	.004	3-Chloropropene	.098
		2,4-D	.035	2-Chlorotoluene	.021
		Dacthal	.017	4-Chlorotoluene	.028
		2,4-DB	.035	1,2-Dibromoethane	.018
		DCPA	.002	Dibromomethane	.025
		<i>p,p'</i> -DDE	.006	1,2-Dichlorobenzene	.024
		Deethylatrazine	.002	1,3-Dichlorobenzene	.027
		Diazinon	.002	1,4-Dichlorobenzene	.025
		Dicamba	.035	Dichlorobromomethane	.024
		Dichlobenil	.02	<i>trans</i> -1,4-Dichloro-2-butene	.346
		Dichlorprop (2,4-DP)	.032	Dichlorodifluoromethane	.048
		Dieldrin	.001	1,1-Dichloroethane	.033
		2,6-Diethylaniline	.003	1,2-Dichloroethane	.067
		Dinoseb	.035	1,1-Dichloroethene	.022
		Disulfoton	.017	<i>cis</i> -1,2-Dichloroethene	.019
		Diuron	.02	<i>trans</i> -1,2-Dichloroethene	.016
		DNOC	.035	1,2-Dichloropropane	.034
		EPTC	.002	1,3-Dichloropropane	.058
		Esfenvalerate	.019	2,2-Dichloropropane	.039
		Ethalfuralin	.004	1,1-Dichloropropene	.013
		Ethoprop	.003	<i>cis</i> -1,3-Dichloropropene	.046
		Fenuron	.013	<i>trans</i> -1,3-Dichloropropene	.067
		Fluometuron	.035	Diethyl ether	.085
		Fonofos	.003	Diisopropylether	.049
		<i>alpha</i> -HCH	.002	Ethylbenzene	.015
		<i>gamma</i> -HCH (Lindane)	.004	Ethyl <i>tert</i> -butyl ether (ETBE)	.027
		3-Hydroxycarbofuran	.014	Ethyl methacrylate	.139
		Linuron	.002	<i>o</i> -Ethyl toluene	.050
		Malathion	.005	Hexachlorobutadiene	.071
		MCPA	.05	Hexachloroethane	.181
		MCPB	.035	2-Hexanone	.373
		Methiocarb	.026	Isopropylbenzene	.016
		Methomyl	.017	<i>p</i> -Isopropyltoluene	.055
		Methyl parathion	.006	Methyl acrylate	.306
		Metolachlor	.002	Methyl acrylonitrile	.285
		Metribuzin	.004	Methyl <i>tert</i> -butyl ether (MTBE)	.056
		Molinate	.004	Methylene chloride	.191
		1-Naphthol	.007	Methyl iodide	.038
		Napropamide	.003	Methyl methacrylate	.175
		Neburon	.015	4-Methyl-2-pentanone (MIBK)	.187
		Norflurazon	.024	Naphthalene	.125
		Oryzalin	.019	<i>tert</i> -Pentyl methyl ether (TAME)	.056
		Oxamyl	.018	<i>n</i> -Propylbenzene	.021
		Parathion	.004	Styrene	.021
		Pebulate	.004	1,1,1,2-Tetrachloroethane	.022
		Pendimethalin	.004	1,1,2,2-Tetrachloroethane	.066
		<i>cis</i> -Permethrin	.005	Tetrachloroethene	.019
		Phorate	.002	Tetrachloromethane	.044
		Picloram	.05	Tetrahydrofuran	.574
		Prometon	.018	1,2,3,4-Tetramethylbenzene	.115
		Pronamide	.003	1,2,3,5-Tetramethylbenzene	.120
		Propachlor	.007	Toluene	.019
		Propanil	.004	1,2,3-Trichlorobenzene	.133
		Propargite	.013	1,2,4-Trichlorobenzene	.094
		Propham	.035	1,1,1-Trichloroethane	.016
		Propoxur	.035	1,1,2-Trichloroethane	.032
		Simazine	.005	Trichloroethene	.019
		2,4,5-T	.035	Trichlorofluoromethane (CFC 11)	.046
		Tebuthiuron	.01	1,2,3-Trichloropropane	.035
		Terbacil	.007	1,1,2-Trichlorotrifluoroethane	.016
		Terbufos	.013	1,2,3-Trimethylbenzene	.062
		Thiobencarb	.002	1,2,4-Trimethylbenzene	.028
		2,4,5-TP	.021	1,3,5-Trimethylbenzene	.022
		Triallate	.001	Vinyl acetate	.631
		Triclopyr	.05	Vinyl bromide	.050
		Trifluralin	.002	Vinyl chloride	.056
				<i>meta</i> - and <i>para</i> -Xylene	.032
				<i>ortho</i> -Xylene	.032

¹ U.S. Geological Survey National Water-Quality Laboratory schedule 2702.² U.S. Geological Survey National Water-Quality Laboratory schedules 2001, 2050.³ U.S. Geological Survey National Water-Quality Laboratory schedule 2020.

Table 5. Concentrations of nutrients in samples collected at the agriculture indicator site, Medina River at LaCoste

[ft³/s, cubic feet per second; mg/L, milligrams per liter; <, less than; MDL, method detection limit]

Date	Dis-charge (ft ³ /s)	Nitrogen, ammonia, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L)	Nitrogen, ammonia plus organic, dissolved (mg/L)	Nitrogen, ammonia plus organic, total (mg/L)	Nitrogen, nitrite plus nitrate, dissolved (mg/L)	Phos-phorus, total (mg/L)	Phos-phorus, dissolved (mg/L)	Phosphorus, ortho-phosphate, dissolved (mg/L)
04-16-96	23	0.0200	0.0100	<0.20	0.30	2.20	0.0300	0.0100	0.0100
05-23-96	22	.0400	.0100	<.20	.30	1.60	.0200	<.010	<.010
06-24-96	35	.0500	.0100	<.20	.30	1.50	<.010	<.010	<.010
08-06-96	29	.0200	.0100	<.20	.30	2.00	.0300	.0300	.0100
09-04-96	18	<.015	.0100	<.20	.30	2.10	.0300	<.010	<.010
10-07-96	29	<.015	<.010	<.20	<.20	3.40	<.010	<.010	<.010
11-08-96	32	.0300	.0200	<.20	.20	2.60	<.010	<.010	<.010
12-06-96	24	<.015	.0200	<.20	<.20	2.60	.0600	.0200	<.010
01-24-97	21	<.015	.0100	<.20	<.20	3.60	.0300	<.010	<.010
03-05-97	26	.0200	<.010	<.20	.20	2.40	<.010	<.010	<.010
03-21-97	25	<.015	<.010	<.20	<.20	2.40	.0400	<.010	<.010
04-08-97	33	.0200	.0100	<.20	<.20	1.80	.0100	<.010	<.010
04-16-97	32	<.015	<.010	<.20	.24	1.97	.0300	<.010	<.010
04-22-97	37	.0940	<.010	<.20	.26	1.97	.0130	<.010	<.010
05-02-97	33	<.015	<.010	.20	<.20	1.74	.0130	.0100	<.010
05-08-97	33	<.015	<.010	<.20	.21	1.71	.0240	<.010	<.010
05-14-97	36	.0210	.0130	<.20	.23	1.24	.0260	<.010	<.010
05-21-97	32	.0190	<.010	<.20	.23	1.49	.0320	<.010	<.010
05-27-97	33	.0190	<.010	<.20	.25	1.56	.0270	<.010	<.010
06-03-97	32	<.015	<.010	<.20	<.20	1.55	.0610	.0360	.0100
06-17-97	46	<.015	<.010	<.20	.28	1.20	.0260	.0190	.0290
06-22-97	2,760	.0630	<.010	.23	5.8	.577	1.34	.0160	.0160
07-03-97	1,050	.0150	<.010	.31	.30	.417	<.010	<.010	<.010
07-15-97	296	.0300	<.010	<.20	.23	.882	<.010	<.010	.0130
07-22-97	198	<.015	<.010	.26	.26	1.21	.0280	<.010	.0130
07-30-97	102	<.015	<.010	<.20	<.20	1.69	<.010	<.010	<.010
08-05-97	78	.0200	.0110	.24	<.20	2.48	<.010	<.010	.0120
08-12-97	59	<.015	.0100	<.20	<.20	2.99	<.010	<.010	.0150
08-19-97	54	<.015	.0100	<.20	<.20	3.04	<.010	<.010	<.010
08-27-97	56	<.015	.0130	<.20	<.20	2.64	<.010	<.010	<.010
09-03-97	54	<.015	<.010	<.20	<.20	2.42	<.010	.0160	<.010
09-10-97	52	<.015	<.010	<.20	<.20	2.51	<.010	<.010	<.010
09-16-97	49	<.015	<.010	<.20	<.20	2.48	<.010	<.010	<.010
09-24-97	54	<.015	<.010	<.20	<.20	2.52	.0110	<.010	<.010
10-23-97	51	<.015	<.010	<.20	<.20	2.70	<.010	<.010	<.010
Change in MDL for nitrogen, ammonia, dissolved; nitrogen, ammonia plus organic, dissolved; and nitrogen, ammonia plus organic, total for the following analyses; see table 4									
11-25-97	71	<.020	<.010	<.10	.11	1.93	<.010	<.010	.0190
12-22-97	94	<.020	<.010	.11	.15	2.59	<.010	.0130	.0110
01-20-98	57	<.020	<.010	<.10	.12	2.27	<.010	<.010	.0100
02-26-98	118	<.020	<.010	.12	.23	1.25	<.010	<.010	.0190
03-16-98	959	.0370	.0370	.40	1.9	1.38	.466	.0120	.0110
03-24-98	670	.0320	<.010	.11	.19	.295	<.010	<.010	<.010
04-24-98	63	.0330	.0110	.12	.12	2.44	.0130	.0160	<.010

Table 6. Concentrations of nutrients in samples collected at the urban indicator site, Salado Creek (lower station) at San Antonio

[ft³/s, cubic feet per second; mg/L, milligrams per liter; <, less than: MDL, method detection limit]

Date	Dis-charge (ft ³ /s)	Nitrogen, ammonia, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L)	Nitrogen, ammonia plus organic, dissolved (mg/L)	Nitrogen, ammonia plus organic, total (mg/L)	Nitrogen, nitrite plus nitrate, dissolved (mg/L)	Phos-phorus, total (mg/L)	Phos-phorus, dissolved (mg/L)	Phosphorus, ortho-phosphate, dissolved (mg/L)
04-22-96	4	0.110	0.0100	0.30	0.50	0.310	0.100	0.0400	0.0300
05-21-96	1	.150	.0200	.30	.60	.300	.200	.0700	.0800
06-27-96	9	.100	.0500	.40	.70	.600	.150	.0700	.0600
07-29-96	1	.120	<.010	.40	.70	.200	.120	.0300	.0400
09-03-96	2	.0500	.0200	.30	.40	.390	.0700	.0400	.0600
10-15-96	3	.0700	.0200	.20	.30	.200	.0500	.0400	.0400
11-06-96	2	.0300	.0100	<.20	.20	.0900	.0300	.0400	.0300
12-05-96	11	.0300	.0100	<.20	.30	.380	.0800	.0600	.0400
01-23-97	4	<.015	.0300	<.20	.40	.250	.0600	.0200	<.010
02-07-97	4	.0200	.0100	.30	.40	.160	.0400	<.010	<.010
02-20-97	24	<.015	.0300	.30	.40	.500	.0400	.0100	.0200
03-06-97	6	.0800	.0200	.30	.40	.570	.0800	.0700	.0600
03-20-97	11	.0700	.0300	.30	.30	.500	.120	.110	.0400
04-09-97	12	.0870	.0370	.37	.51	.713	.102	.0650	.0750
04-16-97	7	.0360	.0220	.27	.37	.638	.0710	.0570	.0670
04-23-97	6	.0520	<.010	.23	.30	.427	.0810	.0770	.0520
04-26-97	834	.123	.0230	.35	1.7	.506	.528	.0960	.0990
05-02-97	21	.0470	.0210	.30	.23	.825	.0850	.0690	.0730
05-07-97	17	.0400	.0200	<.20	.32	.685	.0550	.0380	.0700
05-14-97	23	.0560	.0320	.24	.38	.367	.0920	.0650	.0640
05-22-97	21	.0470	.0190	.34	.48	.559	.150	.109	.0840
05-27-97	15	.0550	.0210	.37	.40	.551	.121	.109	.0840
06-02-97	10	.0200	.0100	.26	.30	.413	.126	.0650	.0780
06-17-97	24	.0290	.0150	.26	.42	.517	.111	.0730	.0710
07-03-97	68	<.015	.0110	.35	.24	.602	.0250	.0160	.0270
07-14-97	31	<.015	<.010	<.20	<.20	.975	.0130	<.010	.0270
07-22-97	27	.0260	<.010	.27	.29	.862	.0470	.0310	.0310
07-29-97	21	<.015	<.010	<.20	<.20	.742	.0190	.0420	.0260
08-06-97	5	.0230	.0110	<.20	<.20	.604	<.010	<.010	.0160
08-12-97	6	.0300	<.010	<.20	.34	.339	.0160	.0300	.0290
08-21-97	12	<.015	.0100	<.20	<.20	.548	.0570	.0290	.0250
08-27-97	13	.0150	<.010	<.20	<.20	.560	.0280	.0210	.0220
09-03-97	12	.0180	<.010	<.20	<.20	.433	.0160	.0250	.0160
09-09-97	10	<.015	<.010	<.20	.21	.651	.0160	.0150	.0240
09-17-97	15	<.015	<.010	.23	<.20	.836	.0220	.0230	.0300
09-25-97	25	.0170	<.010	<.20	.28	.784	.0930	.0270	.0370
10-22-97	21	<.015	<.010	<.20	<.20	1.16	.0340	.0270	.0270
Change in MDL for nitrogen, ammonia, dissolved; nitrogen, ammonia plus organic, dissolved; and nitrogen, ammonia plus organic, total for the following analyses; see table 4									
10-28-97	22	<.020	<.010	<.10	.13	1.12	.0350	.0100	.0230
11-06-97	18	<.020	.0390	<.10	.10	1.14	.0210	<.010	.0160
11-19-97	26	.362	<.010	.14	.16	1.11	.0540	.0290	.0420
12-10-97	21	<.020	<.010	<.10	<.10	.904	.0310	<.010	.0180
12-17-97	14	<.020	.0340	<.10	.14	.834	.0660	.0610	.0380
12-20-97	1,230	<.020	.0210	.26	1.4	.629	.456	.0850	.0720
01-06-98	1,180	<.020	<.010	.26	.44	.565	.114	.0410	.0640
01-12-98	25	<.020	<.010	.17	.25	1.05	.0790	.0580	.0530
01-22-98	22	<.020	.0150	<.10	.13	1.10	.0320	.0100	.0280
01-31-98	1,190	.0360	.0110	.35	1.4	.726	.371	.0570	.0520
02-19-98	18	<.020	<.010	.22	.33	.406	.0590	.0350	.0390
02-21-98	1,210	.0520	<.010	.27	1.4	.443	.436	.0750	.0690
03-16-98	1,070	.0360	.0560	.36	2.0	.459	.545	.0790	.0830
03-23-98	31	.0400	<.010	.19	.31	.517	.0400	.0230	.0270
04-27-98	10	.0330	<.010	.26	.26	<.050	.0380	.0260	<.010

Table 7. Concentrations of nutrients in samples collected at the integrator site, San Antonio River near Elmendorf[ft³/s, cubic feet per second; mg/L, milligrams per liter; <, less than; MDL, method detection limit]

Date	Dis-charge (ft ³ /s)	Nitrogen, ammonia, dissolved (mg/L)	Nitrogen, nitrite, dissolved (mg/L)	Nitrogen, ammonia plus organic, dissolved (mg/L)	Nitrogen, ammonia plus organic, total (mg/L)	Nitrogen, nitrite plus nitrate, dissolved (mg/L)	Phos-phorus, total (mg/L)	Phos-phorus, dissolved (mg/L)	Phosphorus, ortho-phosphate, dissolved (mg/L)
04-16-96	138	0.240	0.200	0.90	1.0	15.0	2.20	1.90	1.90
05-21-96	120	.0900	.0700	.70	.80	16.0	2.90	2.60	2.60
06-27-96	292	.110	.0400	.70	1.0	8.10	.850	.710	.720
08-05-96	95	.0400	.0300	.60	.70	12.0	2.20	2.10	2.00
09-03-96	241	.0600	.0300	.60	.80	12.0	2.00	1.90	1.80
10-11-96	148	.0500	.0300	.70	.70	15.0	2.00	2.00	1.10
11-04-96	209	.0300	.0400	.60	.80	14.0	2.30	2.10	1.10
12-05-96	302	.0900	.0200	.60	.80	12.0	1.90	1.90	1.10
01-23-97	147	.150	.170	1.0	1.0	15.0	2.10	2.20	2.10
03-06-97	201	.170	.0900	.90	1.1	14.0	1.80	1.70	1.60
03-20-97	260	.0900	.0700	.80	1.0	11.0	1.60	1.50	1.50
04-09-97	302	.0800	.0400	.60	.90	9.50	2.00	1.90	1.10
04-23-97	222	.229	.168	.81	.97	12.8	2.15	1.99	2.00
04-26-97	2,750	.138	.0300	.37	2.8	2.44	1.36	.370	.400
05-06-97	186	.125	.101	.67	.85	12.2	2.17	2.03	2.01
05-22-97	315	.0500	.0300	.52	.95	7.92	.885	.720	.720
06-02-97	197	.0320	.0780	.55	.74	9.48	1.11	1.08	1.00
06-21-97	4,850	.0540	.0590	.28	1.1	1.84	.536	.490	.270
07-14-97	856	.0440	.0260	<.20	.44	4.48	.522	.420	.420
07-30-97	365	.0830	.0630	.55	.62	7.63	1.23	1.13	.960
08-14-97	180	.0430	.0360	.56	.74	10.7	1.54	1.44	1.38
08-21-97	135	.0230	.0460	.51	.62	10.6	1.50	1.35	1.33
09-11-97	299	.0840	.151	.59	.81	10.5	1.60	1.51	1.34
09-17-97	142	.0310	.0490	.63	.70	11.4	1.92	1.79	1.66
10-08-97	1,110	.0300	.0350	.48	1.3	4.90	.935	.570	.540
10-22-97	324	.0840	.0740	.47	.53	9.77	1.70	1.62	1.62
Change in MDL for nitrogen, ammonia, dissolved; nitrogen, ammonia plus organic, dissolved; and nitrogen, ammonia plus organic, total for the following analyses; see table 4									
11-19-97	318	<.020	.0210	.55	.59	10.8	1.63	1.70	1.58
12-17-97	212	<.020	.0620	.65	.75	11.8	2.00	1.99	1.74
12-20-97	1,250	<.020	.0350	.37	3.7	3.04	1.50	.360	.350
01-06-98	1,050	.124	.0430	.57	.78	3.37	.497	.460	.450
01-22-98	265	.0210	.0360	.52	.62	10.8	1.54	1.47	1.40
01-31-98	1,270	.0300	.0130	.35	1.2	2.88	.608	.340	.370
02-19-98	462	.125	.0450	.67	.91	6.97	.888	.810	.770
02-21-98	1,080	.127	.0180	.35	1.7	3.00	.776	.380	.340
03-16-98	1,360	.129	.0690	.40	3.1	2.31	1.26	.270	.270
03-26-98	812	.0410	.0370	.24	.55	3.91	.492	.400	.380
04-28-98	218	.369	.108	.98	1.1	11.3	1.81	1.73	1.76

Table 8. Number of detections and range in concentration of pesticides detected in samples collected at intensive fixed sites
[µg/L, micrograms per liter]

Pesticide	Agriculture indicator site			Urban indicator site			Integrator site		
	Number of detections (32 samples)	Range in concentration (µg/L)	Pesticide	Number of detections (35 samples)	Range in concentration (µg/L)	Pesticide	Number of detections (26 samples)	Range in concentration (µg/L)	Pesticide
Atrazine	32	0.0060-.11	Alachlor	3	0.0040-.018	Alachlor	4	0.0030-.020	
Benfluralin	3	.0026-.0047	Atrazine	35	.0040-.75	Atrazine	26	.0080-.38	
Carbaryl	4	.0044-.090	Benfluralin	2	.0036-.0047	Carbaryl	16	.0051-.36	
Chlorpyrifos	7	¹ .0033-.0075	Bentazon	1	.020	Carbofuran	5	.012-.042	
2,4-D	1	.090	Bromacil	7	.060-1.6	Chlorpyrifos	15	.0028-.0094	
DCPA	1	¹ .0019	Carbaryl	21	.0071-.33	DCPA	9	¹ .0006-.016	
<i>p,p'</i> -DDE	2	¹ .0015-.0030	Chlorpyrifos	16	¹ .0027-.011	Deethylatrazine	25	.0067-.029	
Deethylatrazine	32	.0020-.11	Cyanazine	2	.0045-.011	Diazinon	20	.0060-.16	
Diazinon	12	¹ .0010-.059	2,4-D	1	.22	Diuron	3	.070-.24	
Malathion	3	.0040-.0080	DCPA	6	.0006-.0031	<i>alpha</i> -HCH	1	.014	
Metolachlor	6	¹ .0010-.0060	<i>p,p'</i> -DDE	4	.0017-.0046	Lindane	16	.0050-.044	
Prometon	20	.0023-.0094	Deethylatrazine	34	¹ .0016-.054	Malathion	7	.0060-.036	
Simazine	2	¹ .0018-.0026	Diazinon	27	.0040-.33	Metolachlor	18	.0030-.016	
Terbufos	1	.0080	Diuron	15	.020-1.1	Prometon	26	¹ .0056-.044	
Trifluralin	2	.0022-.0052	Malathion	13	.0050-.11	Propachlor	1	¹ .0009	
			MCPA	1	.080	Simazine	21	¹ .0025-.043	
			Metolachlor	16	.0030-.018	Tebuthiuron	15	¹ .0073-.43	
			Metribuzin	1	.029	Terbufos	1	¹ .011	
			Oryzalin	1	.030				
			Prometon	35	¹ .016-.24				
			Pronamide	1	.014				
			Propanil	1	.0078				
			Simazine	29	¹ .0039-.25				
			Tebuthiuron	34	.041-2.8				
			Triclopyr	2	.070-.81				

¹ Values below method detection limit estimated by U.S. Geological Survey National Water-Quality Laboratory.

Table 9. Number of detections and range in concentration of volatile organic compounds detected in samples collected at intensive fixed sites

[µg/L, micrograms per liter]

Volatile organic compound	Agriculture indicator site			Urban indicator site			Integrator site		
	Number of detections (7 samples)	Range in concentration (µg/L)	Volatile organic compound	Number of detections (22 samples)	Range in concentration (µg/L)	Volatile organic compound	Number of detections (13 samples)	Range in concentration (µg/L)	Volatile organic compound
Acetone	1	1.0-0.70	Acetone	7	1.0-6.1	Acetone	3	1.0-2.0	
Benzene	2	.036-.10	Benzene	4	1.013-.028	Benzene	5	1.015-.082	
Bromoform	3	1.020-.030	2-Butanone	1	.90	Bromochloromethane	1	1.020	
Carbon disulfide	4	1.0080-.030	Carbon disulfide	6	1.020-.025	Bromoform	10	1.050-.28	
Chlorodibromomethane	1	1.020	Chloromethane	4	1.010-.024	2-Butanone	3	1.30-1.2	
Chloroform	4	1.0080-.030	1,4-Dichlorobenzene	2	1.010	Carbon disulfide	7	1.010-.033	
Dichlorobromomethane	2	1.010	1,1-Dichloroethane	1	1.013	Chlorobenzene	1	1.0060	
Ethylbenzene	2	1.0090-.030	<i>cis</i> -1,2-Dichloroethane	18	1.010-.065	Chlorodibromomethane	13	.10-1.9	
<i>p</i> -Isopropyltoluene	4	1.0040-.081	Ethylbenzene	2	1.010-.012	Chloroform	13	.40-4.6	
Naphthalene	1	1.020	<i>p</i> -Isopropyltoluene	3	1.0070-.010	Chloromethane	2	1.020-.024	
Toluene	2	1.010-.14	Methyl <i>tert</i> -butyl ether (MTBE)	13	.074-.57	2-Chlorotoluene	1	.050	
1,2,4-Trimethylbenzene	1	1.010	Methylene chloride	1	.80	Dibromomethane	1	1.010	
1,3,5-Trimethylbenzene	1	1.0050	4-Methyl-2-pentanone (MIBK)	1	1.10	1,4-Dichlorobenzene	11	1.0080-.030	
<i>meta</i> - and <i>para</i> -Xylene	3	1.010-.040	Naphthalene	1	1.083	Dichlorobromomethane	13	.19-2.3	
<i>ortho</i> -Xylene	1	1.020	Styrene	2	1.0050-.020	<i>cis</i> -1,2-Dichloroethane	1	1.014	
			Tetrachloroethene	5	1.0020-.0070	Ethylbenzene	3	1.010-.036	
			Toluene	12	1.020-.040	<i>o</i> -Ethyl toluene	1	1.011	
			1,1,2-Trichlorotrifluoroethane	2	1.0050-.0060	<i>p</i> -Isopropyltoluene	3	1.010-.026	
			1,2,4-Trimethylbenzene	5	1.0080-.038	Methyl <i>tert</i> -butyl ether (MTBE)	1	.080	
			<i>meta</i> - and <i>para</i> -Xylene	5	1.015-.038	Methyl iodide	1	1.010	
			<i>ortho</i> -Xylene	3	1.011-.020	4-Methyl-2-pentanone (MIBK)	1	1.080	
						Naphthalene	2	1.081-.13	
						<i>n</i> -Propylbenzene	1	1.0080	
						Styrene	1	1.010	
						Tetrachloroethene	4	1.0020-.0080	
						Tetrahydrofuran	4	1.40-3.9	
						1,2,3,5-Tetramethylbenzene	1	1.026	
						Toluene	7	.040-.21	
						1,2,3-Trimethylbenzene	2	1.022-.023	
						1,2,4-Trimethylbenzene	2	.050-.053	
						1,3,5-Trimethylbenzene	1	1.016	
						<i>meta</i> - and <i>para</i> -Xylene	4	1.010-.056	
						<i>ortho</i> -Xylene	2	1.029-.034	

¹ Values below method detection limit estimated by U.S. Geological Survey National Water-Quality Laboratory.

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