BIOLOGICAL AND ASSOCIATED WATER-QUALITY DATA FOR LOWER OLMOS CREEK AND UPPER SAN ANTONIO RIVER, SAN ANTONIO, TEXAS, APRIL–SEPTEMBER 1989

By R. Lynn Taylor and Rodger F. Ferreira

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
centimeter (cm)	0.3937	inch
cubic meter per second (m^3/s)	35.31	cubic foot per second
gram (g)	0.03527	ounce, avoirdupois
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
meter per second (m/s)	3.281	foot per second
milliliter (mL)	0.06102	cubic inch
millimeter (mm)	0.03937	inch
square centimeter (cm^2)	0.1550	square inch
square meter (m^2)	10.76	square foot
square millimeter (mm^2)	0.00155	square inch
	Temperature	
degree Celsius (°C)	1.8 x °C + 32	degree Fahrenheit

Abbreviated water-quality units:

µg/g, microgram per gram
µg/L, microgram per liter
mg/L, milligram per liter

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Biological and Associated Water-Quality Data for Lower Olmos Creek and Upper San Antonio River, San Antonio, Texas, April–September 1989

By R. Lynn Taylor *and* Rodger F. Ferreira

Abstract

Biological and associated water-quality data were collected from lower Olmos Creek and upper San Antonio River in San Antonio, Texas, during April–September 1989, the first year of a multi-year data-collection program. The data will be used to document water-quality conditions prior to implementation of a proposal to reuse treated wastewater to irrigate city properties in Olmos Basin and Brackenridge Parks and to augment flows in the Olmos Creek/San Antonio River system.

Benthic macroinvertebrate, periphyton, and phytoplankton communities were sampled at three sites along a 4.2-kilometer reach of the Olmos Creek/San Antonio River system. Total mean densities of benthic macroinvertebrates for the three sites ranged from 660 to 10,000 organisms per square meter. The most abundant macroinvertebrates were the classes Insecta (insects), Gastropoda (snails), and Pelecypoda (clams). Total densities of periphyton ranged from 2,900 to 110,000 cells per square millimeter. Cyanophyta (blue-green algae) and Bacillariophyta (diatoms) were the predominant periphyton organisms. Total densities of phytoplankton ranged from 5,000 to 47,000 cells per milliliter. Blue-green algae accounted for more than one-half of the phytoplankton in each sample. Diatoms and Chlorophyta (green algae) made up most of the rest of the phytoplankton. Mean diversity index for the three sites ranged from 0.5 to 2.4 for benthic macroinvertebrates. The diversity index for all sites ranged from 1.4 to 2.8 for periphyton and 1.4 to 2.8 for phytoplankton.

Hardness ranged from 160 to 250 milligrams per liter as calcium carbonate, and alkalinity ranged from 130 to 220 milligrams per liter as calcium carbonate. The largest dissolved nitrite concentration was 0.038 milligram per liter. Dissolved ammonia nitrogen generally was less than 0.100 milligram per liter. The largest total phosphorus concentration was 0.150 milligram per liter, more than one-half of which was dissolved orthophosphate.

Total aluminum and total iron were the only trace elements in water to exceed the reporting threshold by large concentrations. Total aluminum concentrations ranged from 70 to 280 micrograms per liter, and total iron concentrations ranged from 70 to 340 micrograms per liter. Lead was the most prominent trace element in bottom-material samples with concentrations ranging from 30 to 230 micrograms per gram.

Depths and velocities, measured at sample points after benthic macroinvertebrate sampling, ranged from 0.03 to 0.46 meter and from 0.05 to 1.1 meters per second, respectively. Measurable stream discharge ranged from 0.01 to 0.28 cubic meter per second. During three of the sampling periods, no flow was at site 1.

INTRODUCTION

Olmos Creek and the San Antonio River are the same channel hydrologically (fig. 1). Olmos Creek is an intermittent stream that runs through the northwest part of San Antonio, Tex. Historically, the San Antonio River began near Incarnate Word College, where springs fed into the channel providing perennial flow. With increased water use, the springs periodically have gone dry. A well drilled at Hildebrand Avenue provides

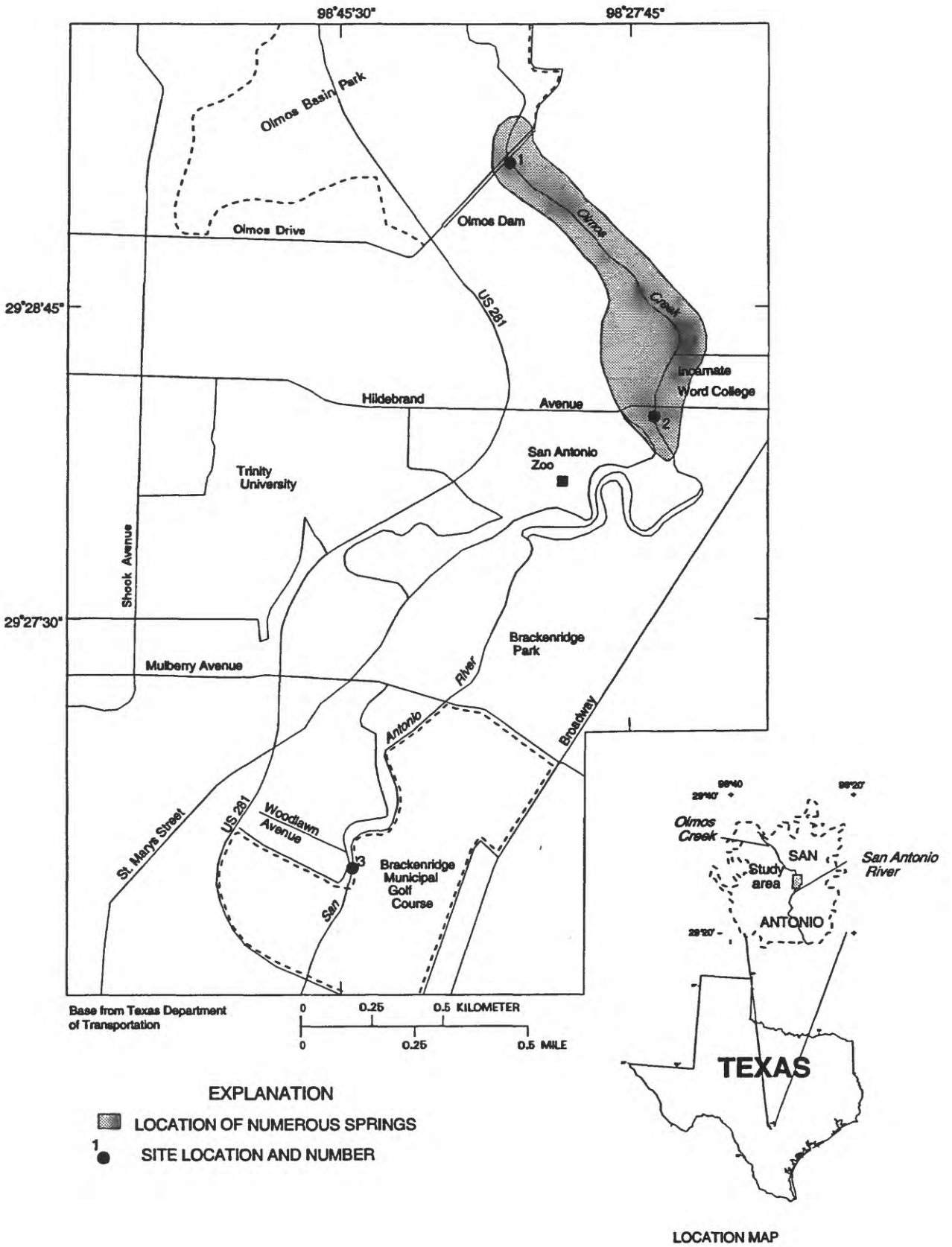


Figure 1. Location of study area.

flow to the river when the springs are not discharging; Hildebrand Avenue is the present boundary between Olmos Creek and the San Antonio River.

The San Antonio River is a valuable aesthetic and economic resource to San Antonio. As a result of population growth and increased demand for water, San Antonio officials have considered the reuse of treated wastewater as part of its regional water-supply system. A proposed plan is to use treated wastewater to irrigate city properties in Olmos Basin and Brackenridge Parks and to augment flows in the Olmos Creek/San Antonio River system. The proposed area for discharging treated wastewater is upstream from the area influenced by Olmos Dam; however, an actual discharge point has not been determined. As a result of the reuse plan, the water-quality conditions in the Olmos Creek/San Antonio River system are to be documented before wastewater reuse. These water-quality conditions then could be compared to water-quality conditions after wastewater reuse to evaluate possible changes. The U.S. Geological Survey, in cooperation with the San Antonio Water System, is conducting a multi-year data-collection program to provide the data to document water-quality conditions in lower Olmos Creek and upper San Antonio River. The program includes collection of selected aquatic-organism and water-quality data; 1989 is the first year of the data-collection program.

Aquatic organisms have long been used as indicators of water quality (Averett, 1981). Initially, only single species were used, but this evolved into communities of organisms being used as indicators (Cummins, 1974). Frenzel (1988) used the benthic community in the Boise River to determine the effects of trace elements from two Boise, Idaho, wastewater-treatment facilities on the quality of the river. Frenzel (1988) determined that trace-element concentrations in effluents did not adversely affect benthic macroinvertebrate communities.

The three aquatic-organism communities sampled for this study were benthic macroinvertebrates, periphyton (algae attached to rocks and similar substrates), and phytoplankton (passively floating algae). Benthic macroinvertebrates are relatively immobile and have a wide range of individual tolerances to environmental stresses (Goodnight, 1973). These characteristics make benthic macroinvertebrates well suited as indicators of water quality. Periphyton also are relatively immobile and can be important as substrate for benthic macroinvertebrates (Hynes, 1970, p. 213). Phytoplankton generally are considered inhabitants of still water such as lakes, ponds, and large rivers (Wetzel, 1975, p. 288).

Stream reaches can be categorized as riffles, where the water is shallow and fast flowing, or as pools, where the water is deeper and slow flowing. In riffles, fast-flowing water carries much of the sand, silt, and clay through the reach, leaving a larger percentage of boulders, cobbles, and pebbles settled on the streambed. In pools, slower flows allow sand, silt, and clay to settle on the streambed, covering any larger material that might have been deposited during high flows.

The material covering the streambed of riffles and pools serves as substrate for colonization by aquatic organisms. The larger, more complex substrate in riffles provides a larger quantity and variety of habitat niches than the smaller, more uniform substrate in pools. Therefore, though pools may support large populations, they typically support a more limited variety of organisms than riffles (Hynes, 1970, p. 208–210). To compile a large data base of organisms, biological sampling was conducted in the riffles rather than in the pools of each site.

The water-quality properties and constituents of a stream are critical to the type and number of aquatic organisms present (Hynes, 1970). Changes in water quality can shift the species structure of an aquatic-organism community from a mixture of many intolerant and tolerant species toward a few species that can tolerate more adverse conditions (Cairns and Dickson, 1971). Properties and constituents determined during the study included specific conductance, pH, water temperature, dissolved oxygen, major cations and anions, suspended residue, selected dissolved and total nitrogen and phosphorus species, total organic carbon, and trace elements.

The chemical composition of fine bottom material being transported in a stream also is critical to the type of organisms present. Bottom material is moved during periods of increased flows (Colby, 1963) and is a major source of suspended sediment (Horowitz, 1984). Trace elements tend to be associated with the fine fraction of the sediment (Horowitz, 1984) and can be toxic to organisms. Therefore, fine bottom material was sampled to determine the potential availability of trace elements to organisms. In addition, riffle bottom-material size and distribution were determined because of their influence on the type of aquatic-organism communities present.

Purpose and Scope

The purpose of this report is to present benthic macroinvertebrate, periphyton, and phytoplankton data, community characteristics, and associated water-quality data for lower Olmos Creek and upper San Antonio River. The data were collected during April–September 1989, the first year of data collection.

Location and Description of Study Area

The study area is within the San Antonio city limits and includes a 4.2-km reach of the Olmos Creek/San Antonio River system from Olmos Dam (a flood-control structure) down into Brackenridge Park (fig. 1). Three sites were selected for sampling. Site 1 is on Olmos Creek, immediately downstream from Olmos Dam, in the intermittent part of the system. Site 2 is 1.3 km below site 1, just downstream from Hildebrand Avenue, where the San Antonio River begins. Site 3 also is on the San Antonio River, about 2.9 km downstream from site 2, next to Brackenridge Municipal Golf Course near Woodlawn Avenue. Schematic diagrams of each site are shown in figures 2–4.

At site 1, ponded water is immediately downstream from Olmos Dam (fig. 2). The sampled reach begins at the lower end of this pond. Three riffle areas, designated as upper, middle, and lower, were sampled at this site because the riffles were too small individually to collect all the needed biological samples. The lower riffle is in two sections separated by a short stretch of deeper, slower water. The approximate area of each riffle, in downstream order, is 13, 5.6, and 6.8 m^2.

Site 2 (fig. 3) is near the San Antonio Zoo (fig. 1), but is upstream of any discharges from the zoo. When the channel upstream from Hildebrand Avenue is dry, discharge in the river actually is from an off-channel pond fed by a spring or well (fig. 3), depending on hydrologic conditions. The sampled riffle is approximately 60 m downstream from the eastern outlet of the pond (fig. 3). The riffle is on the left side of the channel, between a heavily vegetated mid-channel bar and the left bank. Most of the flow runs to the left side of the mid-channel bar over the riffle. The area of the riffle is 27 m^2.

Between sites 2 and 3, the river is ponded through the zoo area and again just upstream of site 3 by a low-water crossing. A box culvert connected to a storm drain enters the river just downstream from the low-water crossing (fig. 4). The sampled riffle is downstream from this culvert. The riffle has an area of 68 m^2 and extends 21 m down the right side of the channel. A mid-channel bar, overgrown with vegetation, splits the river into two channels. Most of the flow is over the riffle area along the right bank.

Methods

Biological Sampling and Analysis

Biological sampling was conducted for three aquatic-organism communities—benthic macroinvertebrates, periphyton, and phytoplankton. Samples for benthic macroinvertebrate and periphyton analyses were collected during five sampling periods—at the beginning of April; the end of April; the end of June; the end of July; and the end of August. Samples for phytoplankton analysis were collected at the beginning of April, the end of June, and the end of August. Samples were preserved in the field according to methods described by Britton and Greeson (1988). Samples were analyzed by Chadwick and Associates, a private laboratory in Spotwood, Colo.; analyses consisted of species identification and enumeration. A description of the laboratory procedures (Chadwick and Associates, written commun., 1984) is available from the U.S. Geological Survey Office in Austin or Chadwick and Associates upon request. Each organism reported was identified as distinctly different from other individuals in a sample, regardless of the taxonomic level reported. Organisms were identified to the species level whenever possible. In some instances, the actual species could not be identified, but the species was determined to be distinctly different from other species in a sample. When this happened, the species was identified as "sp.," "sp. 1," and so on, for as many unnamed species as were present in a given genus. A library of these organisms is kept by the laboratory so that any of the same organisms found in the future can be matched and identification will remain consistent throughout the study (Chadwick and Associates, oral commun., 1989). Updates will be made as specimens are collected, making it possible to name previously unidentified species. Organisms in the pupal stages were reported, but were not counted as separate species or used in the computation of diversity index.

Benthic macroinvertebrates were collected from each site using a 0.09-m^2 Surber Sampler by cleaning and stirring the bottom substrate to a depth of about 5 cm. Cleaning the bottom substrate consisted of gently

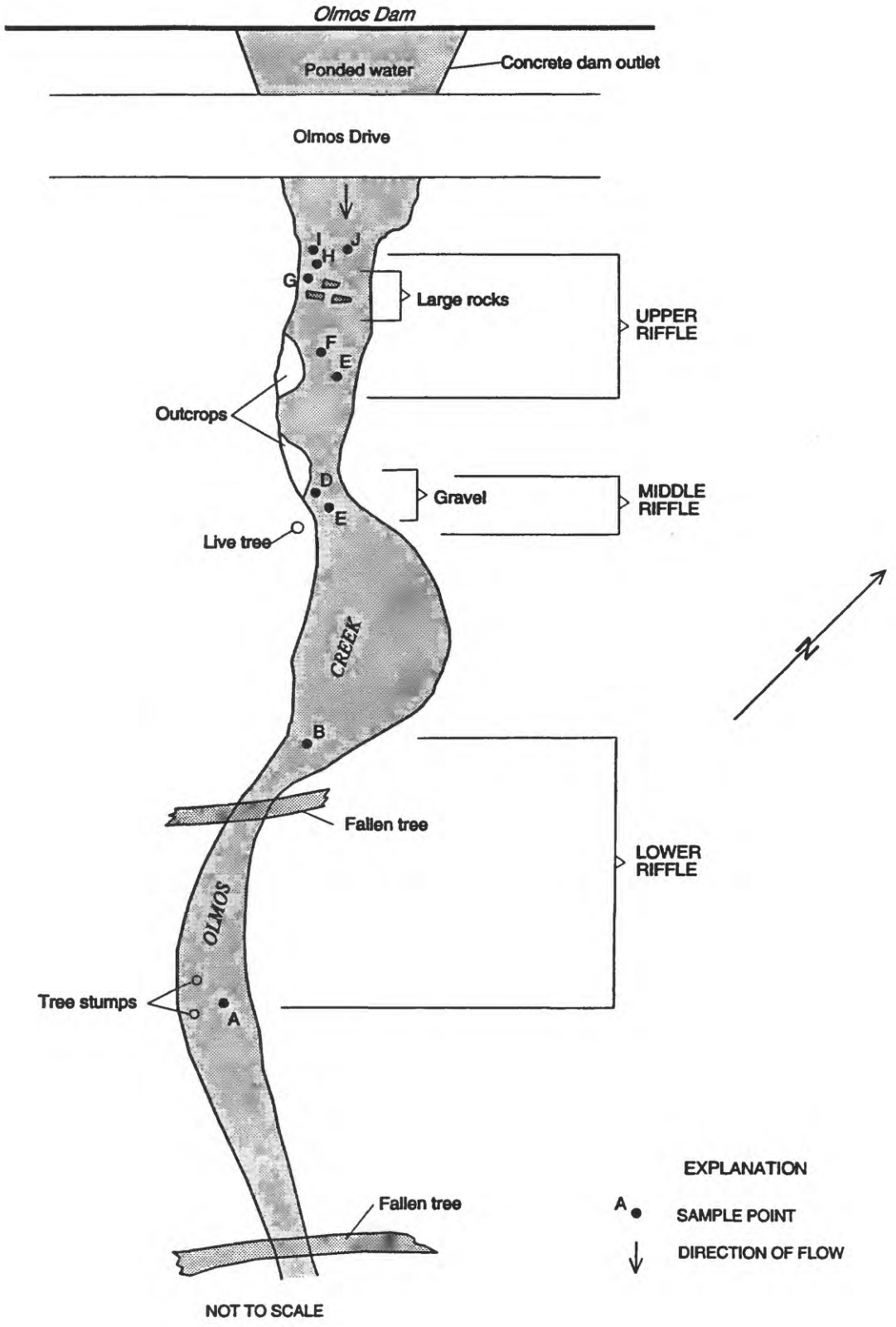


Figure 2. Sample points at site 1, lower Olmos Creek, San Antonio, Texas.

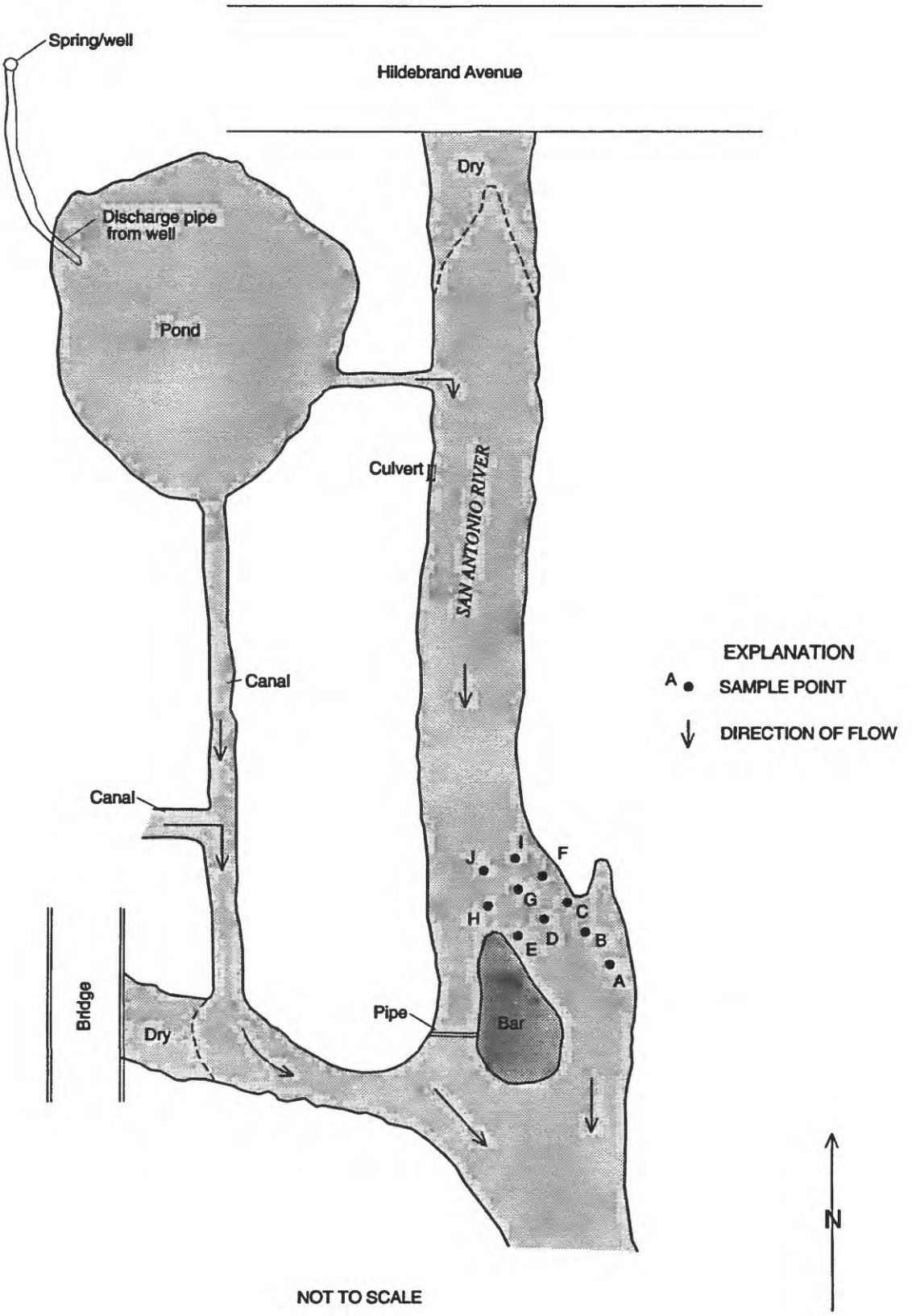


Figure 3. Sample points at site 2, upper San Antonio River, San Antonio, Texas.

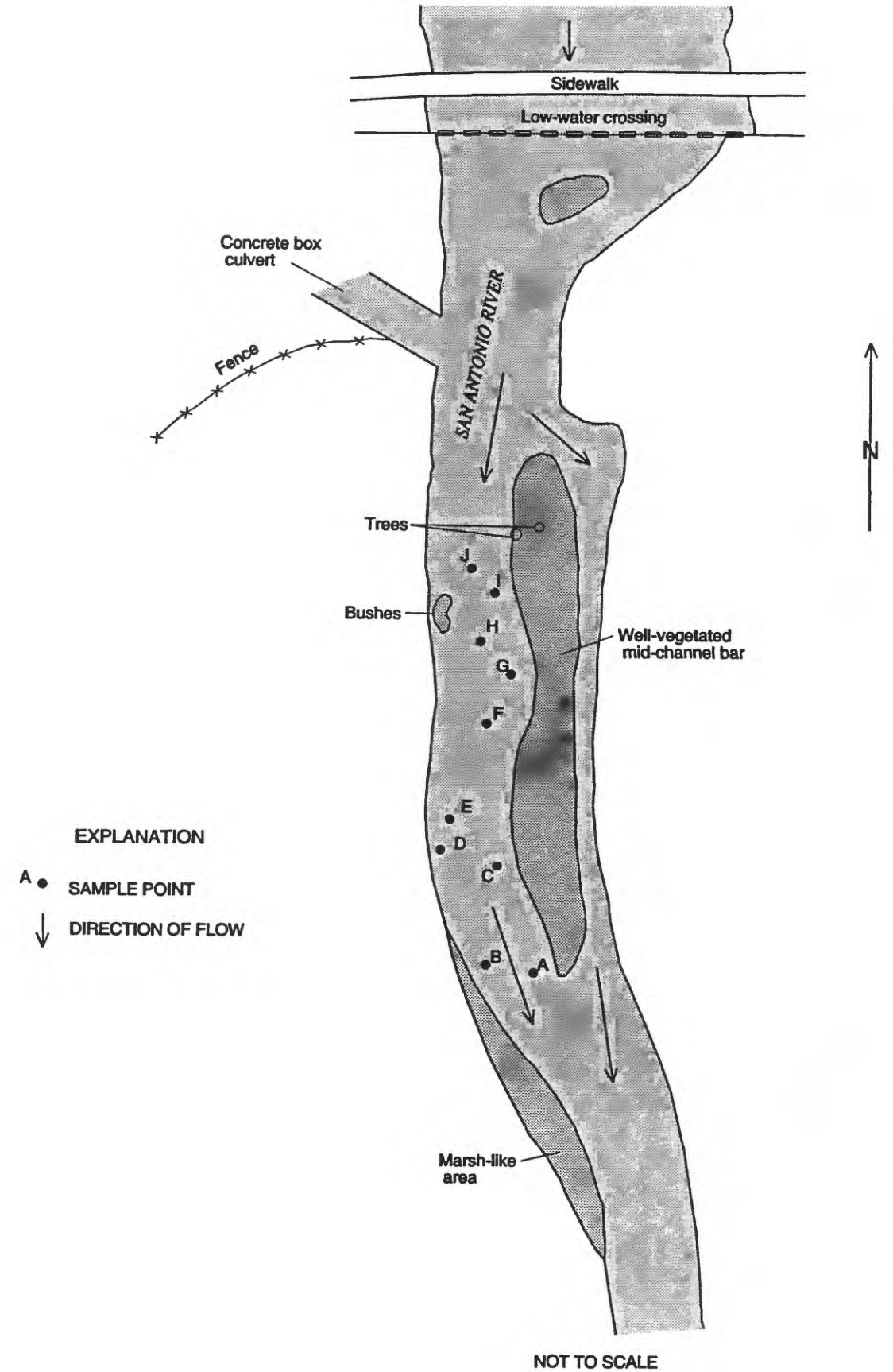


Figure 4. Sample points at site 3, upper San Antonio River, San Antonio, Texas.

scrubbing the larger rocks (larger than 5 cm) by hand at the mouth of the net. The bottom was then stirred up, allowing material to drift into the net. Dislodged organisms were caught in the Surber Sampler net, which had a 212-mm mesh-opening polyester-monofilament screen cloth. Contents of the net were backwashed into a large bucket of water, which was then poured into a U.S. standard 20-cm diameter, no. 70 sieve (210-mm mesh opening). The unsorted sample retained by the sieve was placed in a sample bottle. During each sampling period, data at 10 sample points (labeled A through J) were collected from each site. To avoid disturbing areas upstream of a given sample point, sampling was started at the downstream end of each riffle.

After each benthic macroinvertebrate sample was collected, depth and velocity measurements were made at the center of each sample point. Depths were taken with a wading rod. All samples were collected in areas where water depths generally were less than 0.3 m (the height of the Surber Sampler). Velocities were determined at a depth equal to 0.6 times the depth at each sample point, measured from the surface. Velocities were measured using a pygmy current meter with a standard rating (Smoot and Novak, 1968).

Periphyton samples were collected by scraping a 4-cm^2 area of material from the surface of randomly selected rocks. Transects were sampled at fixed intervals by dividing the stream into four equal sections and randomly choosing sections from which to select rocks. The number of rocks sampled from each transect, and, therefore, the total number of rocks sampled, varied from site to site. All material from each site was composited into a single sample bottle.

Phytoplankton samples were collected as part of the water-quality samples. The equal-width-increment depth-integrated technique (Guy and Norman, 1970; Wells and others, 1990) was used to collect a composite sample. A sample for phytoplankton then was withdrawn from the composite sample.

Riffle bottom-material size distribution of coarse material (1 mm and larger) was determined at each site during the first and last sampling periods. Bottom-material size distribution also was determined whenever there were increased flows that might have moved the riffle material between sampling periods. The method to determine the size distribution of bottom material in the riffles was modified from Wolman (1954). This method involved choosing 100 rocks over the length of a reach and measuring the intermediate axis of the rock. Rocks from the streambed were selected from transects laid out in a grid pattern over the riffles. In each case, the first rock touched without looking down was measured in centimeters. The size of large rocks embedded in the streambed was estimated using a ruler, and particles smaller than 1 mm were reported as less than 0.1 cm. The cumulative-percentage distribution then was computed.

A descriptive statistic called diversity index was computed for each sample. This statistic is a summary of two properties of community structure—the number of different kinds of organisms present and their relative abundance (evenness). For two samples with the same number of taxa, the sample that has the most even distribution of organisms among taxa will have the greatest diversity. Conversely, if the two samples have the same distribution of organisms among taxa, the sample with the most taxa will have the greatest diversity. A modification of Shannon's equation (Shannon and Weaver, 1949) has been used widely (Wilhm and Dorris, 1968) and is presented in this report in the following form:

$$H' = -\sum_{i=1}^{s} \left(\frac{n_i}{n}\right) ln\left(\frac{n_i}{n}\right), \qquad (1)$$

where H' = diversity index or information content of the sample;

s = number of taxa in the sample;

n = total number of individuals in the collection;

n_i = number of individuals in the ith taxa; and

ln = natural logarithm.

The maximum diversity possible for the number of taxa in the sample is given as:

$$H(max) = -\sum_{i=1}^{s} \left(\frac{1}{s}\right) ln\left(\frac{1}{s}\right) = ln(s), \qquad (2)$$

where $H(max)$ = maximum diversity of the sample.

A measure of evenness of distribution of individuals among all the taxa in the sample is:

$$J = \frac{H'}{H(max)}, \qquad (3)$$

where J = evenness of taxa in the sample.

Water-Quality Sampling and Analysis

Water-quality sampling was conducted during five sampling periods—at the beginning of April; the end of April; the end of June; the end of July; and the end of August—using the equal-width-increment depth-integrated technique (Guy and Norman, 1970; Wells and others, 1990). Samples were collected from one cross section, as close as possible to the sampled riffles, where the flow was uniform. Equipment used to obtain samples for chemical analysis was washed with detergent and rinsed thoroughly with tap water and deionized water. Equipment used to collect samples for trace-element analysis was rinsed with a 10-percent hydrochloric acid solution, then with deionized water. All sampling equipment was given a final rinse with native water. Samples were filtered and treated in the field, stored at 4 °C, and shipped within 2 days of collection to the U.S. Geological Survey National Water Quality Laboratory, Arvada, Colo., for chemical analysis. Fixed-endpoint alkalinity and 5-day biochemical oxygen demand were determined at the U.S. Geological Survey office in San Antonio according to methods described by Wells and others (1990).

Stream discharge was measured at or near the sampled riffle using standard U.S. Geological Survey procedures after invertebrate sampling was completed. Water-quality properties, including specific conductance, pH, temperature, and dissolved oxygen, also were determined when discharge was measured.

Fine bottom-material samples were obtained from pools upstream of sampled riffles whenever water-quality samples were obtained. Each bottom-material sample was a composite of four to five scrapings from the top 5 cm of bed material. The bottom material was collected with a wide-mouth plastic jar and composited in a plastic dish. The composited bottom material was mixed, and 50 to 100 g were removed for the sample. Samples for trace-element analysis were shipped to the National Water Quality Laboratory within 2 days of collection.

During the first and last sampling periods, an additional sample was removed from the composited pool bottom material to determine fine bottom-material size distribution. Samples were analyzed at the U.S. Geological Survey office in Austin using a technique modified from Guy (1969). The material was placed in size classes: less than 0.0625 mm, 0.0625 to 0.125 mm, 0.125 to 0.25 mm, 0.25 to 0.5 mm, 0.5 to 1 mm, and larger than 1 mm. The percentage, by weight, of material was determined for each size class, and the cumulative-percentage distribution then was computed.

After the last water-quality sampling period, specific conductance, pH, temperature, and dissolved oxygen also were determined over a 24-hour period. These diel studies were undertaken when flows generally were lowest and temperatures were highest. Site 2 was sampled September 20–21, and site 3 was sampled September 19–20. Site 1 had no flow.

BIOLOGICAL DATA

All benthic macroinvertebrate data collected, except organisms in the pupal stage, are presented in tables 1–12 (at end of report). Total density, at the bottom of each table, is the sum of the organism densities at each sample point. Mean density represents the mean of organisms of that species per square meter for the 10 sample points. Total taxa is the total number of different taxa sampled at each site. The point depth and velocity, modified Shannon-Weaver diversity index, maximum diversity index, and evenness are presented at the bottom of each table. Densities for organisms in the pupal stage are presented in table 13 (at end of report).

Periphyton data are presented in tables 14–16 (at end of report), and phytoplankton data are presented in tables 17–19 (at end of report). The single density listed for each site on each date is a composite of all samples collected. The total density, total taxa, modified Shannon-Weaver diversity index, maximum diversity index, and evenness are summarized at the bottom of tables 14–19.

Site 1 was sampled for benthic macroinvertebrates and periphyton on April 3 and April 26, during only two sampling periods, because there was no surface flow over the riffle areas during the June, July, and August sampling periods. Sampling with Surber nets requires flowing water to wash material into the net area (Britton and Greeson, 1988). Site 1 was sampled for phytoplankton only on April 3, also because of no-flow conditions during other sampling periods.

Benthic Macroinvertebrates

Total mean densities of benthic macroinvertebrates for the three sites ranged from 660 to 10,000 organisms/m^2 (fig. 5, tables 1–12). Sites 1 and 3 had the largest total mean densities during the spring (10,000 organisms/m^2 on April 3 and 5,900 organisms/m^2 on April 7, respectively). Site 3 had the largest total mean

densities during the summer months, ranging from 1,200 organisms/m^2 in July to 1,800 organisms/m^2 in June. Site 2 consistently had the smallest total mean densities for each sampling period, ranging from 660 to 1,400 organisms/m^2. The modified Shannon-Weaver mean diversity index ranged from 0.5 to 2.4 (fig. 6, tables 1–12). Mean diversity index values at site 1 were 1.5 on April 3 and 2.1 on April 26. Mean diversity index ranged from 0.5 to 1.9 at site 2 and from 1.8 to 2.4 at site 3.

The taxonomic structure of macroinvertebrates, broken down by class (except Mollusca) for each site, is shown in figures 7–9. The phylum Mollusca was used to simplify discussions and figures by combining the classes Gastropoda (snails) and Pelecypoda (clams); individual classes of less than 1 percent are not shown. The most abundant macroinvertebrate at sites 1 and 3 was the class Insecta (insects). At site 1 (fig. 7), the majority of the remaining organisms were snails and clams. At site 2 (fig. 8), the most abundant macroinvertebrates were snails and clams, with the remaining organisms mostly insects and Turbellaria (flatworms). Small densities of Oligochaeta (worms) and other classes were present in various samples. At site 3 (fig. 9), the remaining organisms (after insects) were mostly snails, clams, and flatworms.

Depths and velocities at sample points are included with benthic macroinvertebrate data in tables 1–12. Depths were 0.03 to 0.09 m at site 1, 0.09 to 0.27 m at site 2, and 0.15 to 0.46 m at site 3. Velocities were 0.05 to 0.59 m/s at site 1, 0.05 to 0.33 m/s at site 2, and 0.18 to 1.1 m/s at site 3.

Organisms in the pupal stage are presented in table 13. Diptera (true flies) were the only class of organisms for which the pupae could not be identified uniquely. They were, however, present and reported.

Periphyton

The total densities of periphyton for all sites are shown in figure 10 (tables 14–16). Site 1 had total densities of 2,900 cells/mm^2 on April 3 and 5,600 cells/mm^2 on April 26. Total densities ranged from 7,800 to 110,000 cells/mm^2 at site 2, and from 4,300 to 66,000 cells/mm^2 at site 3. The modified Shannon-Weaver diversity index is shown in figure 11 (tables 14–16). Site 1 diversity index values were 1.8 on April 3 and 2.0 on April 26. Diversity index ranged from 1.4 to 2.8 at site 2, and from 2.0 to 2.5 at site 3.

The taxonomic structure of periphyton, broken down by division for each site, is shown in figures 12–14. The predominant periphyton organisms were members of the divisions Cyanophyta (blue-green algae) and Bacillariophyta (diatoms). Organisms in the division Chlorophyta (green algae) also were prevalent in many samples.

At site 1 (fig. 12), blue-green algae were the most abundant periphyton, comprising more than one-half of the total densities. Diatoms accounted for most of the remaining periphyton.

Blue-green algae and diatoms predominated in samples from site 2 (fig. 13). Green algae constituted less than one-fourth of the total densities. The only other division to contribute more than 5 percent of the total density in any sample was Euglenophyta (euglenoids) on August 29.

Site 3 (fig. 14) was dominated by blue-green algae and diatoms, with blue-green algae the predominant organism for most sample dates. Diatoms were the predominant organism on April 7. Green algae accounted for most of the remaining organisms.

Phytoplankton

Total densities of phytoplankton for all sites are shown in figure 15 (tables 17–19). Site 1 had a total density of 35,000 cells/mL on April 3. Total densities at site 2 were 12,000 cells/mL (April 4), 19,000 cells/mL (June 27), and 30,000 cells/mL (August 29). Site 3 had total densities of 5,000 cells/mL (April 7), 40,000 cells/mL (June 26), and 47,000 cells/mL (August 28). The modified Shannon-Weaver diversity index is shown in figure 16 (tables 17–19). The diversity index at site 1 was 2.8 on April 3. Diversity index values at site 2 were 2.5 (April 4), 1.7 (June 27), and 1.6 (August 29). Site 3 diversity index values were 2.1 (April 7), 1.5 (June 26), and 1.4 (August 28).

The taxonomic structure of phytoplankton, broken down by division for each site, is shown in figures 17–19. Blue-green algae predominated, accounting for more than one-half of the total density of phytoplankton in each sample. Diatoms and green algae made up most of the remaining phytoplankton.

At site 1 (fig. 17), blue-green algae were the most abundant phytoplankton, constituting more than one-half of the total density. Green algae were next in abundance with less than one-half of the total density. Diatoms constituted less than one-fourth of the total density.

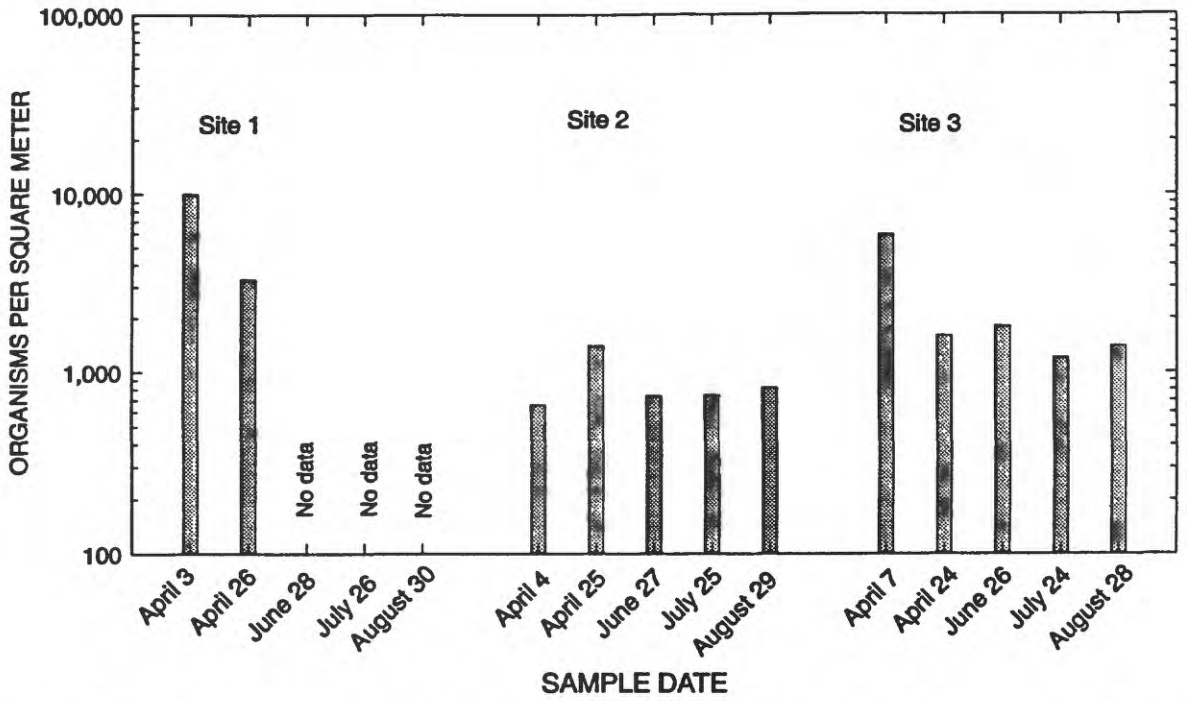


Figure 5. Total mean density of benthic macroinvertebrates for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

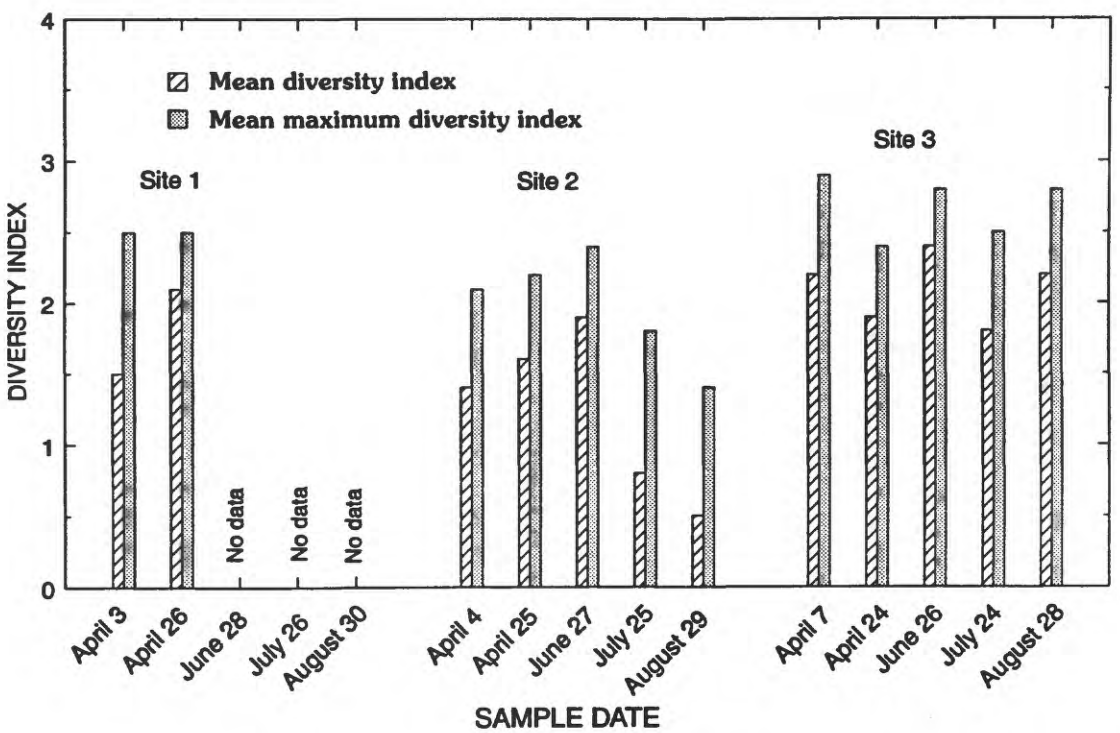
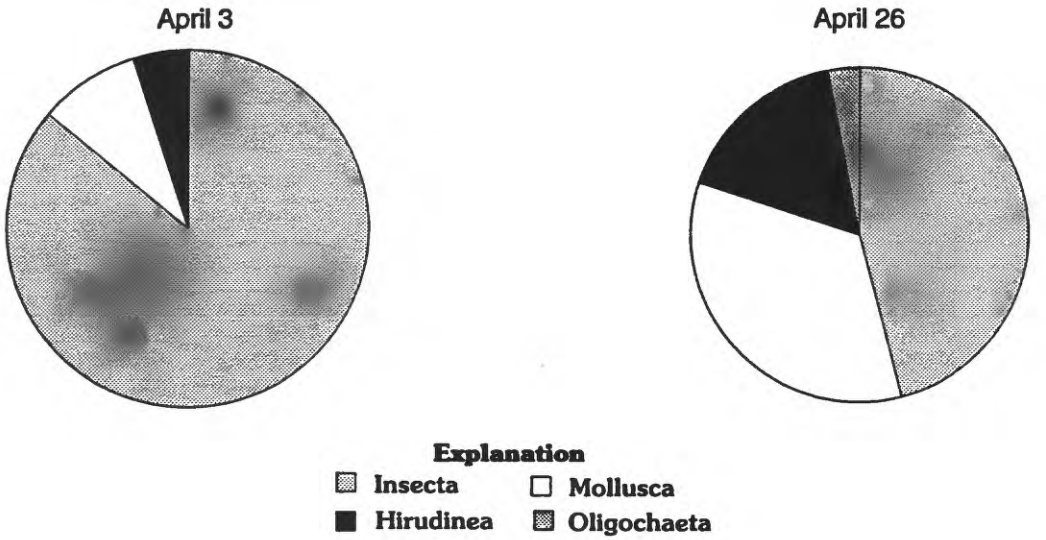


Figure 6. Mean diversity index and mean maximum diversity index of benthic macroinvertebrates for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.



Note: Mollusca is a phylum combining the classes Gastropoda and Pelecypoda

Figure 7. Benthic macroinvertebrate classes for site 1, lower Olmos Creek, San Antonio, Texas, 1989.

At site 2 (fig. 18), blue-green algae ranged from more than one-half to more than three-fourths of the total density (April 4). The remaining phytoplankton organisms at site 2 were mostly diatoms and green algae.

Blue-green algae ranged from more than one-half to more than three-fourths of the total density at site 3 (fig. 19). Diatoms, green algae, and euglenoids constituted most of the remaining phytoplankton. Diatoms accounted for about one-fifth of the total density on June 26 and August 28.

The bottom material in riffles can influence the type of aquatic-organism communities present. Size distributions of bottom material collected from riffles at sites 1–3 are shown in figure 20. Samples were collected during the first sampling period at sites 1 and 2 and during the first and last sampling period at site 3. At site 1, a sample also was collected on April 26 to determine if high flows during April had affected the size distribution of the bottom material. These graphs show that the bottom substrate consisted predominantly of material less than 10 cm along the median axis.

WATER-QUALITY DATA

Results of the chemical analyses are presented in tables 20–22 (at end of report). These tables present water-quality properties and constituents, including specific conductance, pH, temperature, dissolved oxygen, major ions, suspended residue, selected dissolved and total nitrogen and phosphorus species, total organic carbon, and trace elements in water and bottom material. Diel fluctuations of water-quality properties at sites 2 and 3 are presented in tables 23 and 24 (at end of report). Water-quality properties include specific conductance, pH, temperature, and dissolved oxygen.

Measurable stream discharge was 0.01 m^3/s at site 1. During the June, July, and August sampling periods, there was no flow at site 1. Discharge ranged from 0.05 to 0.08 m^3/s at site 2 and from 0.18 to 0.28 m^3/s at site 3 (tables 20–22). The largest biochemical oxygen demand determined was 4.2 mg/L at site 1 on April 3. Biochemical oxygen demand ranged from 0.6 to 1.6 mg/L at site 2 and from 0.9 to 1.9 mg/L at site 3. Hardness ranged from 160 mg/L as $CaCO_3$ at site 1 to 250 mg/L as $CaCO_3$ at site 2. Alkalinity ranged from 130 mg/L as $CaCO_3$ at site 1 to 220 mg/L as $CaCO_3$ at

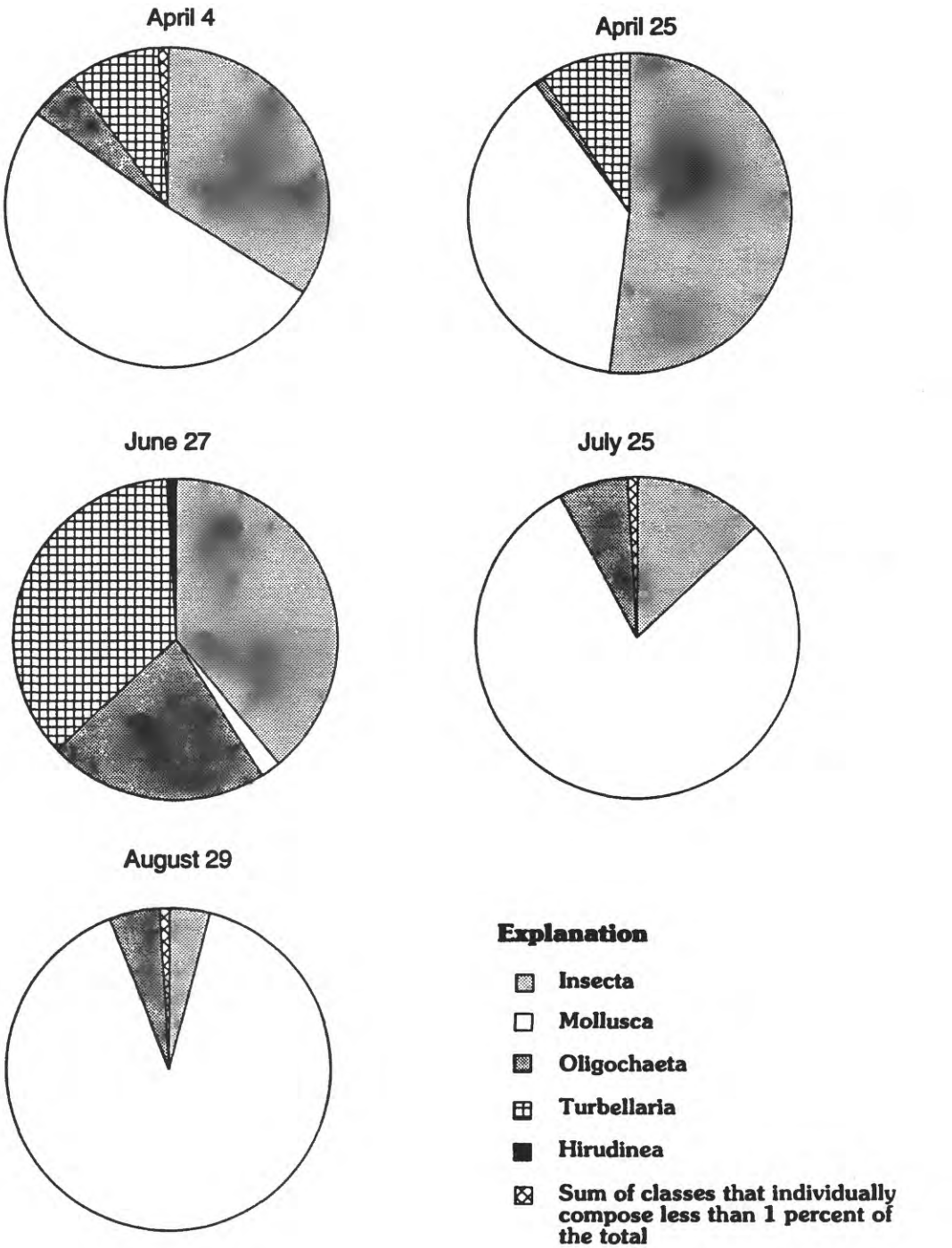


Figure 8. Benthic macroinvertebrate classes for site 2, upper San Antonio River, San Antonio, Texas, 1989.

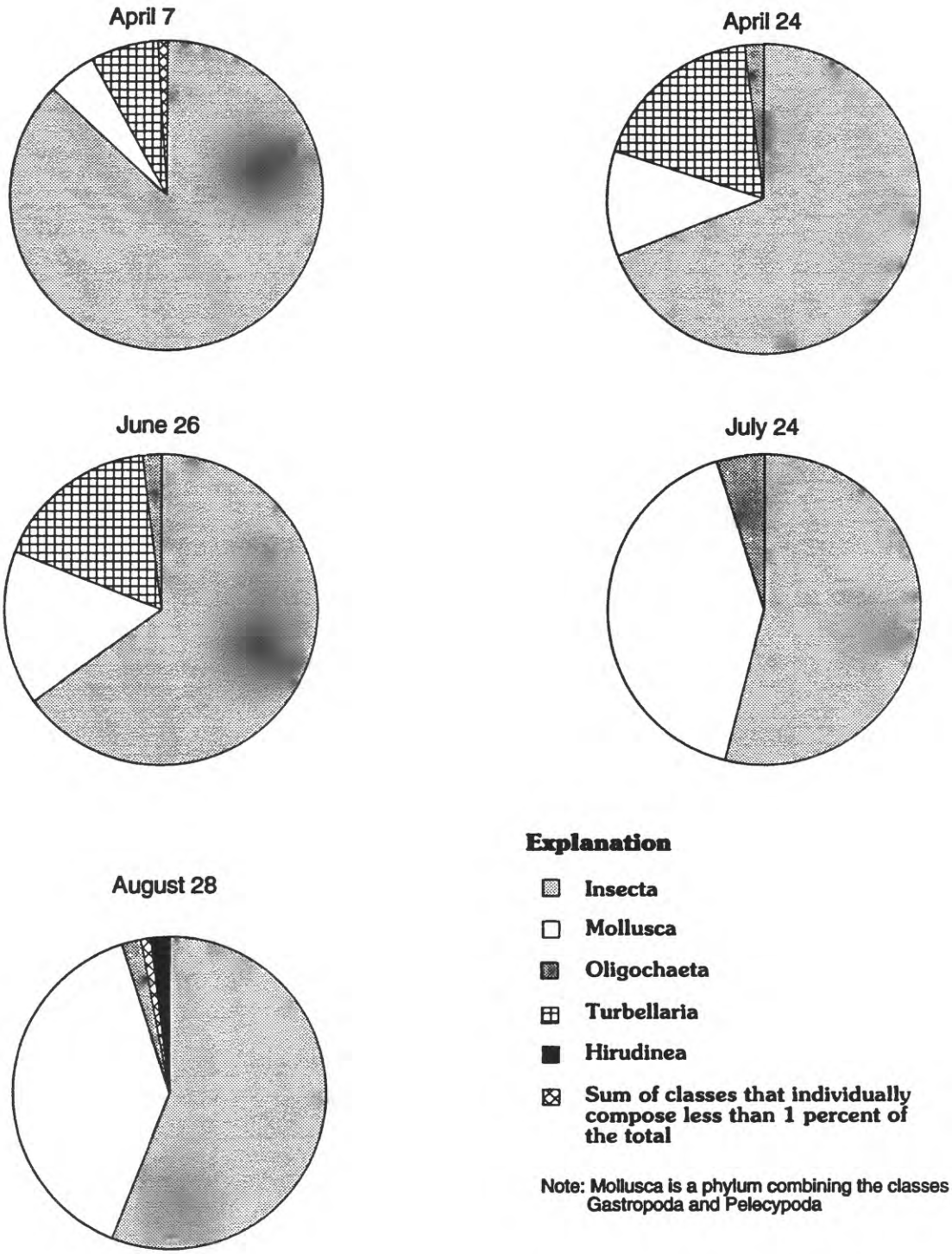


Figure 9. Benthic macroinvertebrate classes for site 3, upper San Antonio River, San Antonio, Texas, 1989.

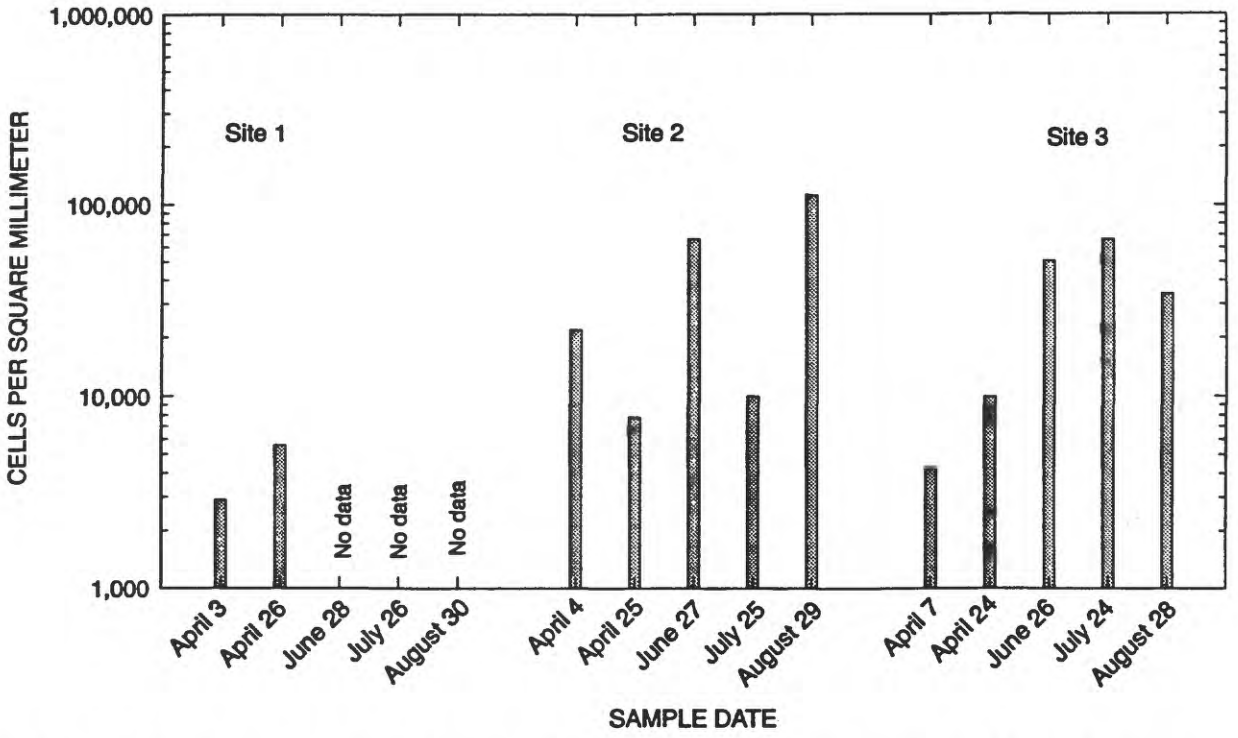


Figure 10. Total density of periphyton for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

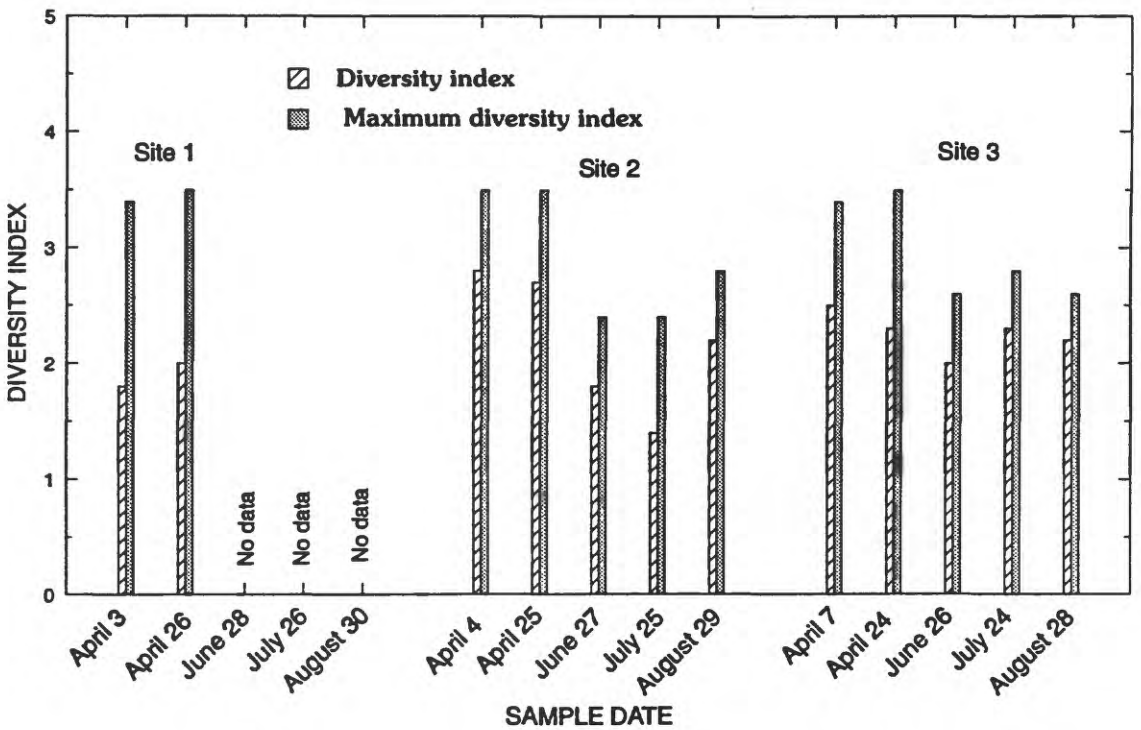


Figure 11. Diversity index and maximum diversity index of periphyton for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

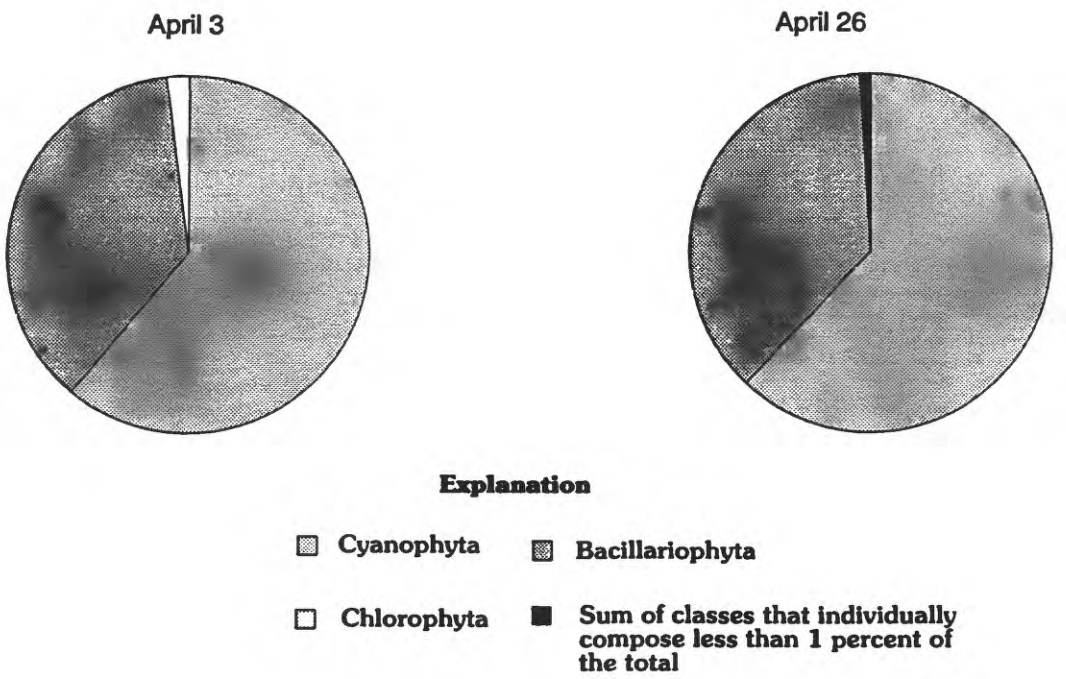


Figure 12. Periphyton divisions for site 1, lower Olmos Creek, San Antonio, Texas, 1989.

site 3. Sites 1 and 3 had the largest dissolved nitrite concentrations, ranging from 0.027 to 0.038 mg/L. Most of the nitrite plus nitrate nitrogen was in the dissolved state. Dissolved ammonia nitrogen generally was less than 0.100 mg/L; however, site 1 had a concentration of 0.132 mg/L on April 3. The total phosphorus concentration at site 1 on April 3 was 0.150 mg/L, more than one-half of which was dissolved orthophosphate. Sites 2 and 3 had total phosphorus concentrations of less than 0.050 mg/L, and in most samples, dissolved orthophosphate was more than one-half of the phosphorus.

Water samples were analyzed for 14 trace elements, most of which were near or less than reporting thresholds. Total aluminum and total iron concentrations were the exceptions at all three sites. Total aluminum concentrations ranged from 70 to 280 µg/L, and total iron concentrations ranged from 70 to 340 µg/L.

Fine bottom-material samples were analyzed for seven trace elements. Most concentrations of trace elements in bottom-material samples were larger than the reporting thresholds. The most prominent was lead, with concentrations ranging from 30 to 70 µg/g at sites 1 and 2 and as much as 230 µg/g at site 3.

Fine bottom-material samples also were collected to determine particle-size distribution. Particle-size distribution of the fine material collected from pooled areas at sites 1–3 are shown in figure 21. Samples were collected during the first sampling period at site 1 and during the first and last sampling periods at sites 2 and 3.

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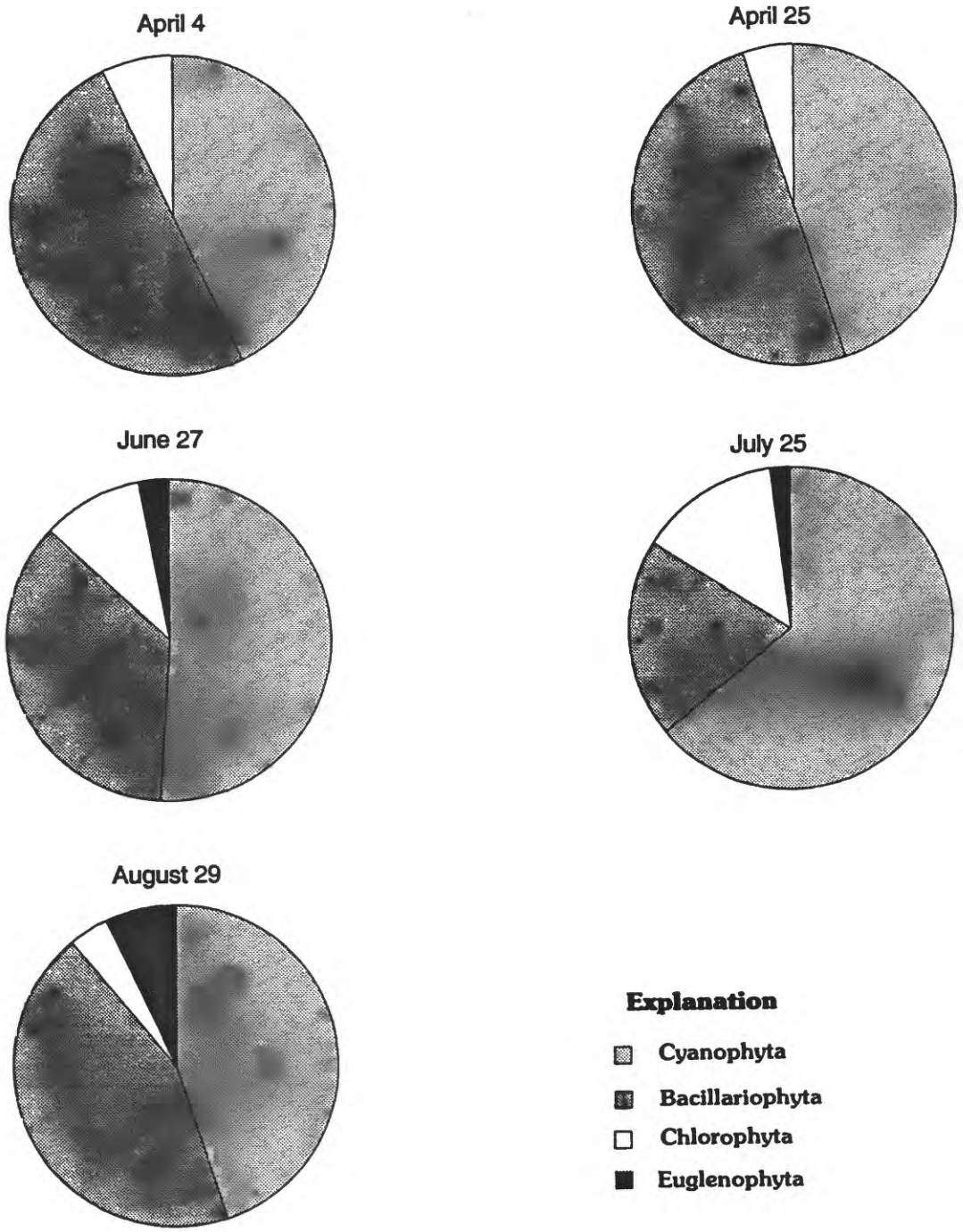

Figure 13. Periphyton divisions for site 2, upper San Antonio River, San Antonio, Texas, 1989.

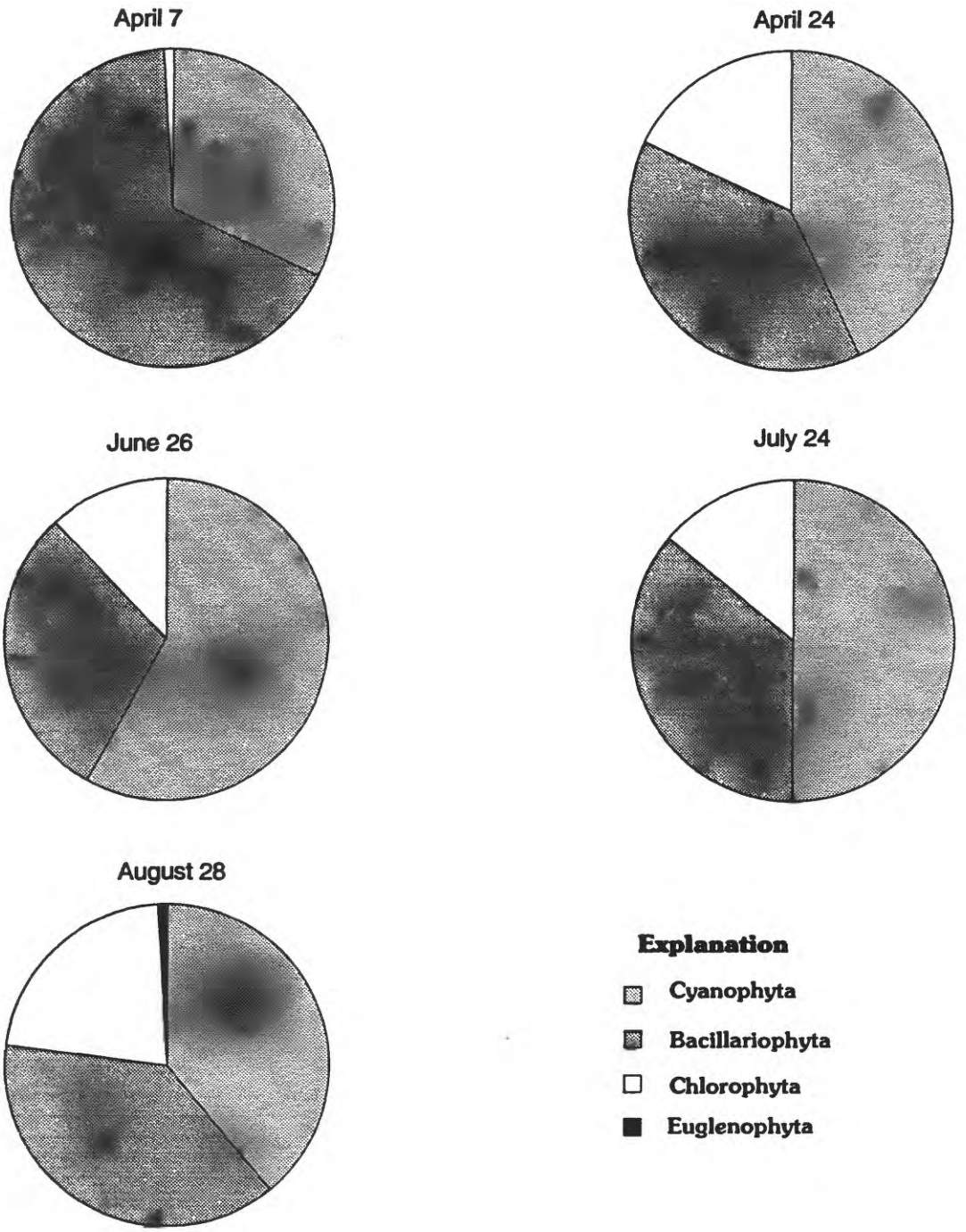

Figure 14. Periphyton divisions for site 3, upper San Antonio River, San Antonio, Texas, 1989.

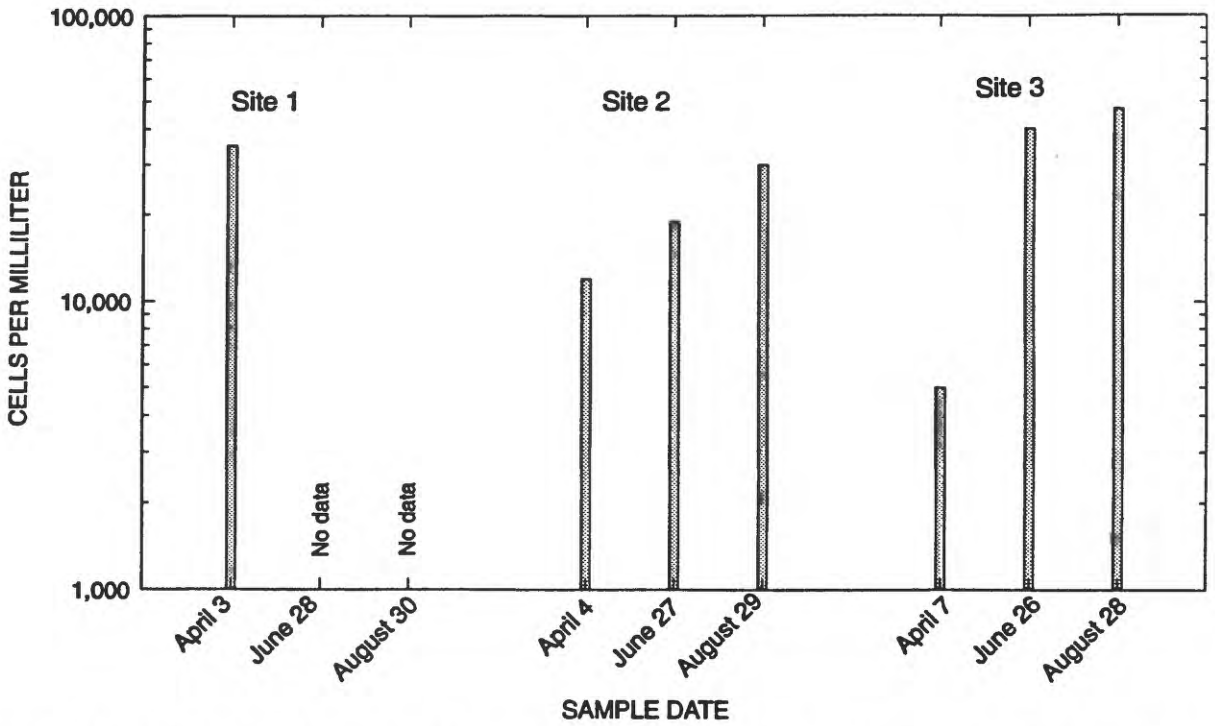

Figure 15. Total density of phytoplankton for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

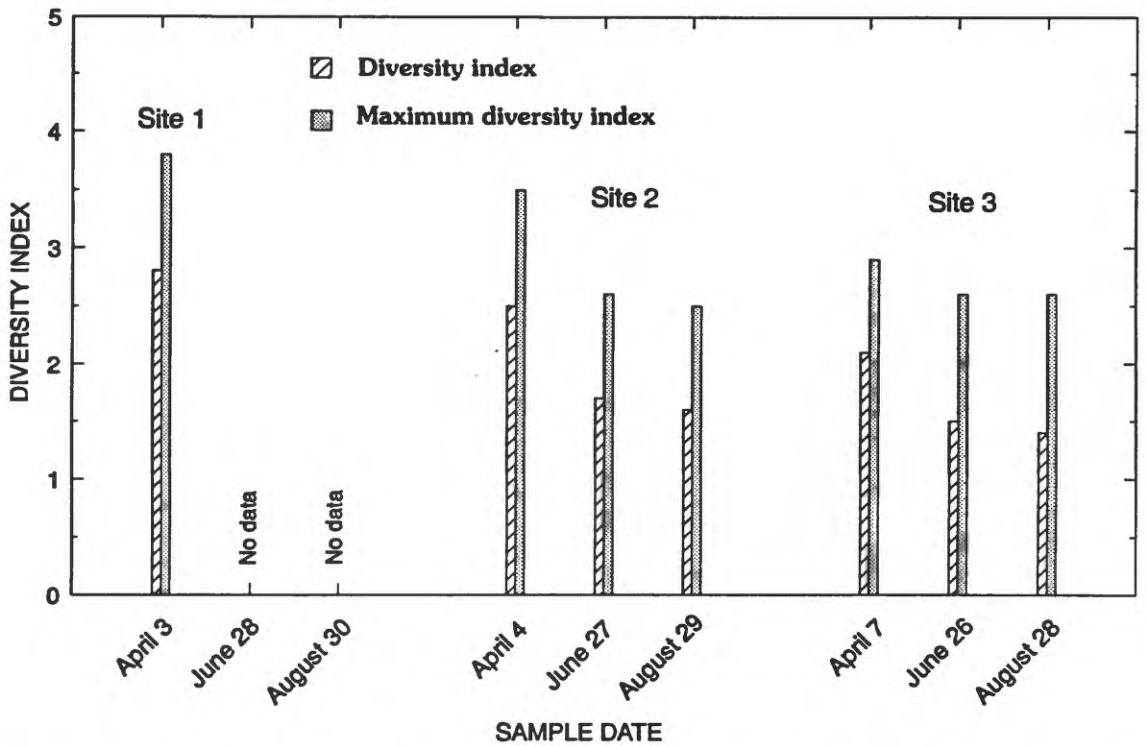

Figure 16. Diversity index and maximum diversity index of phytoplankton for sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

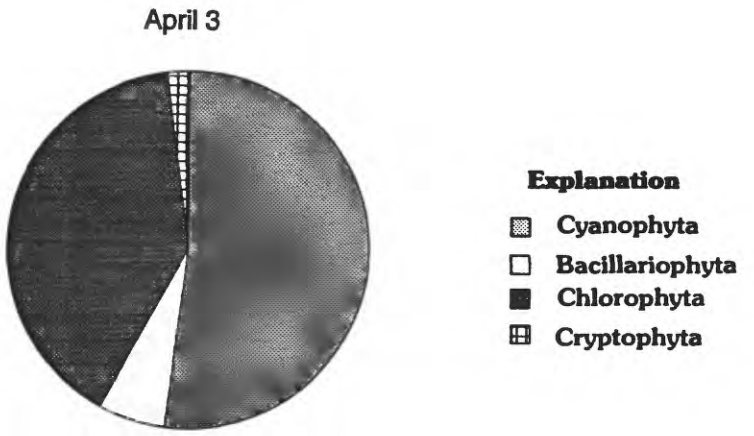

Figure 17. Phytoplankton divisions for site 1, lower Olmos Creek, San Antonio, Texas, 1989.

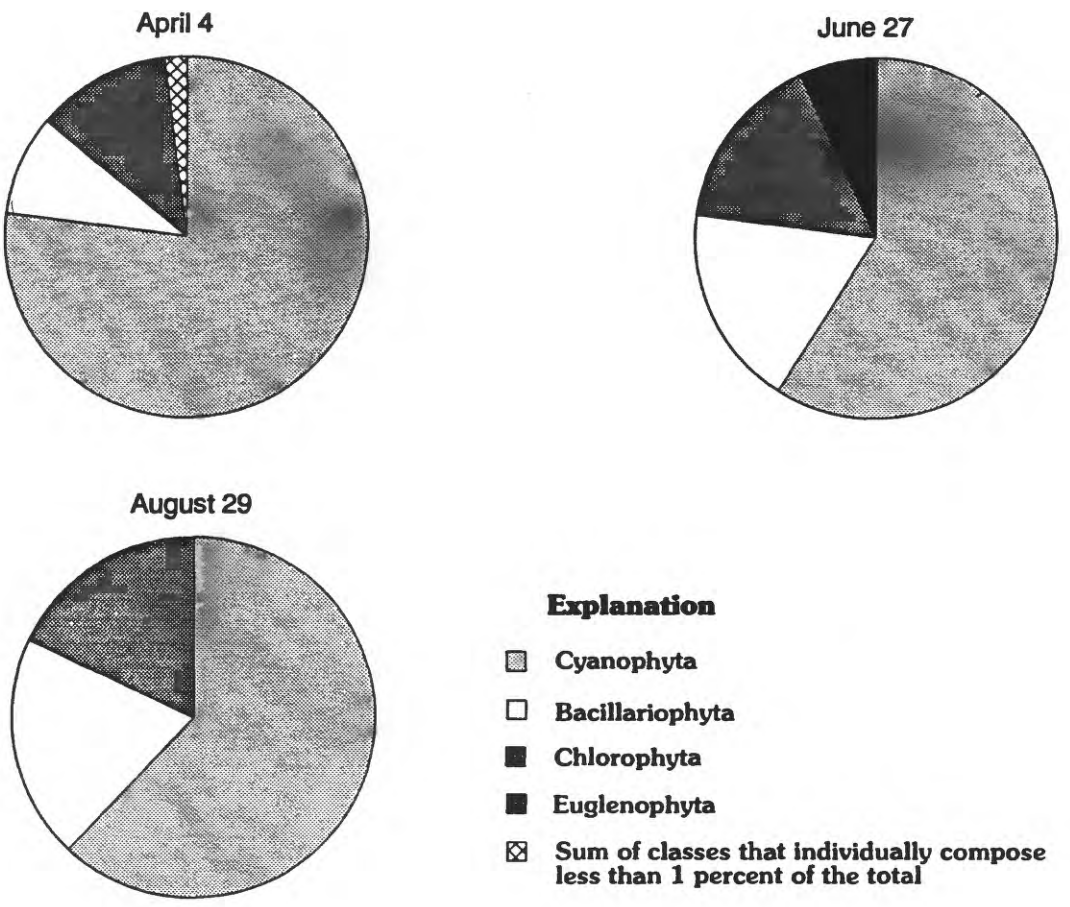

Figure 18. Phytoplankton divisions for site 2, upper San Antonio River, San Antonio, Texas, 1989.

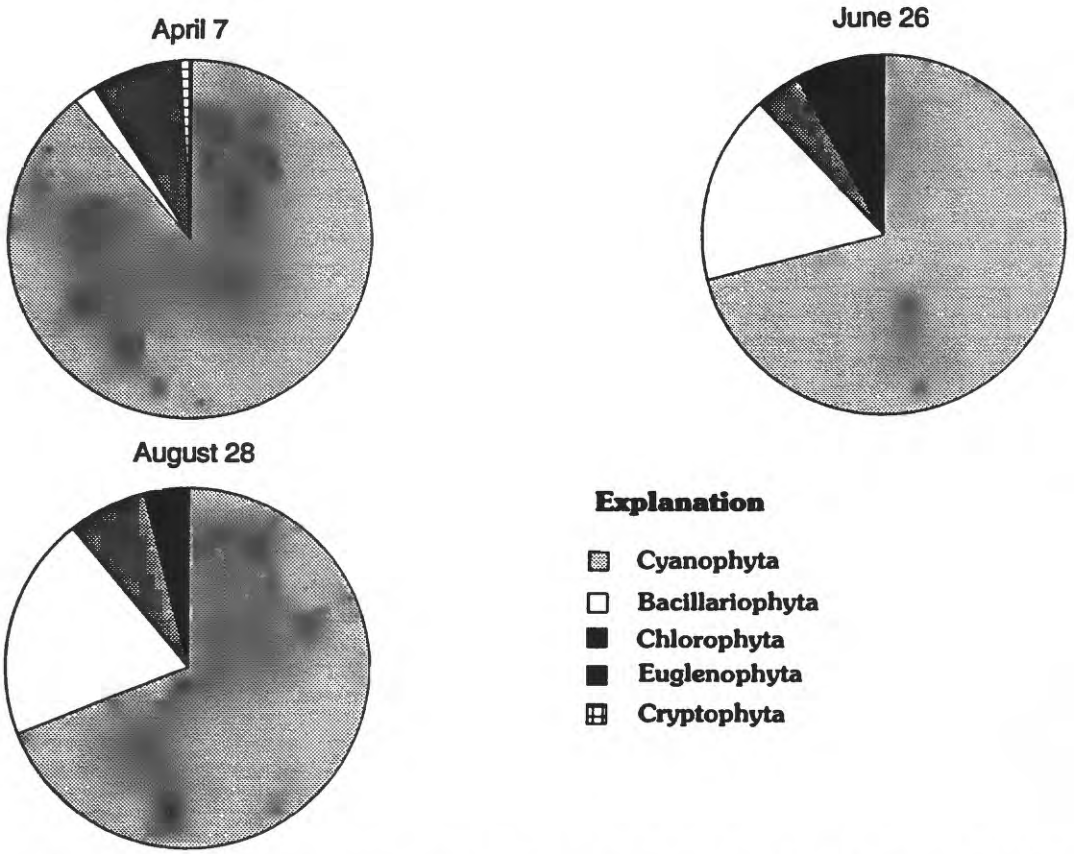

Figure 19. Phytoplankton divisions for site 3, upper San Antonio River, San Antonio, Texas, 1989.

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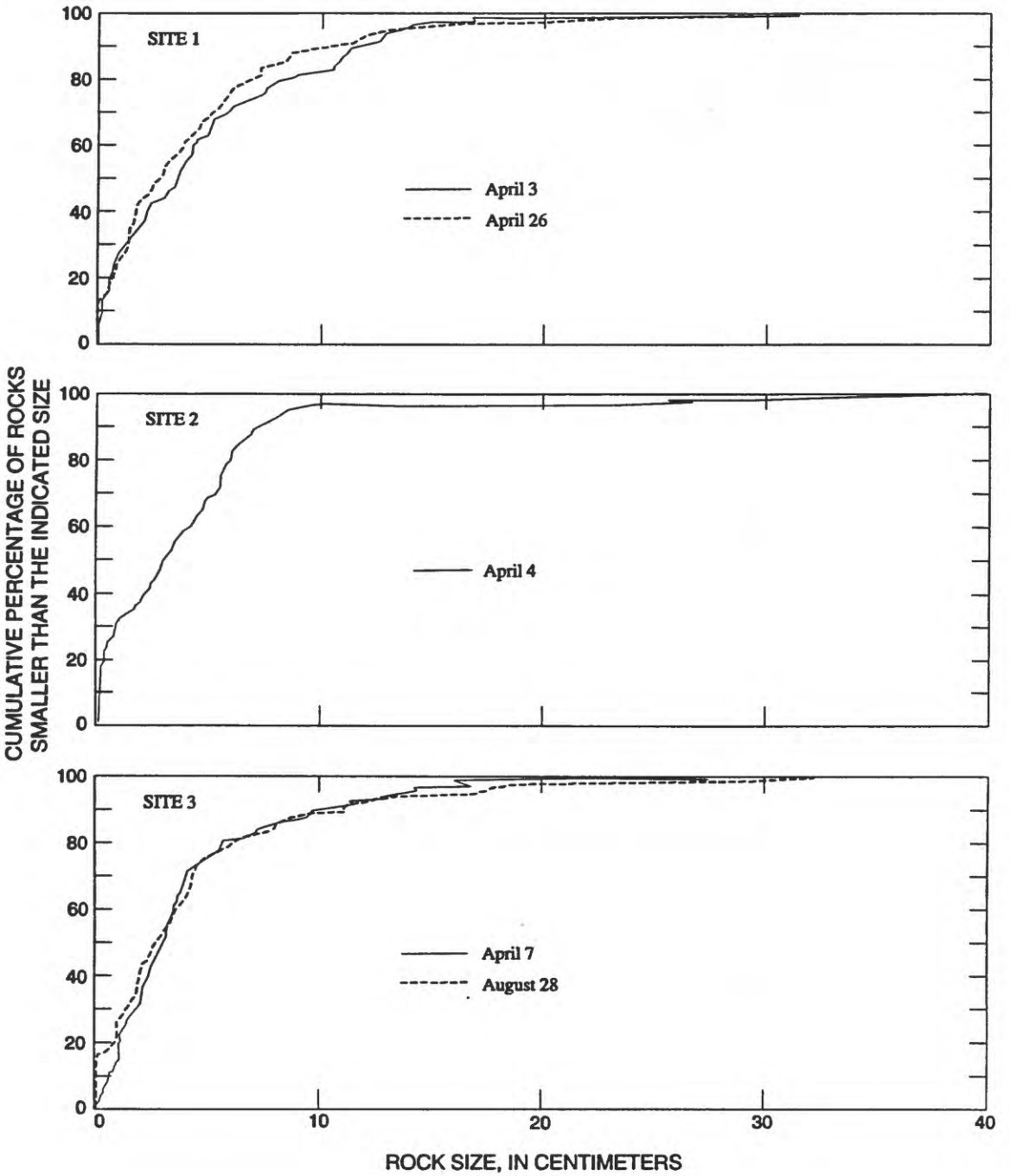

Figure 20. Cumulative-percentage size distribution of bottom material collected from riffles at sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

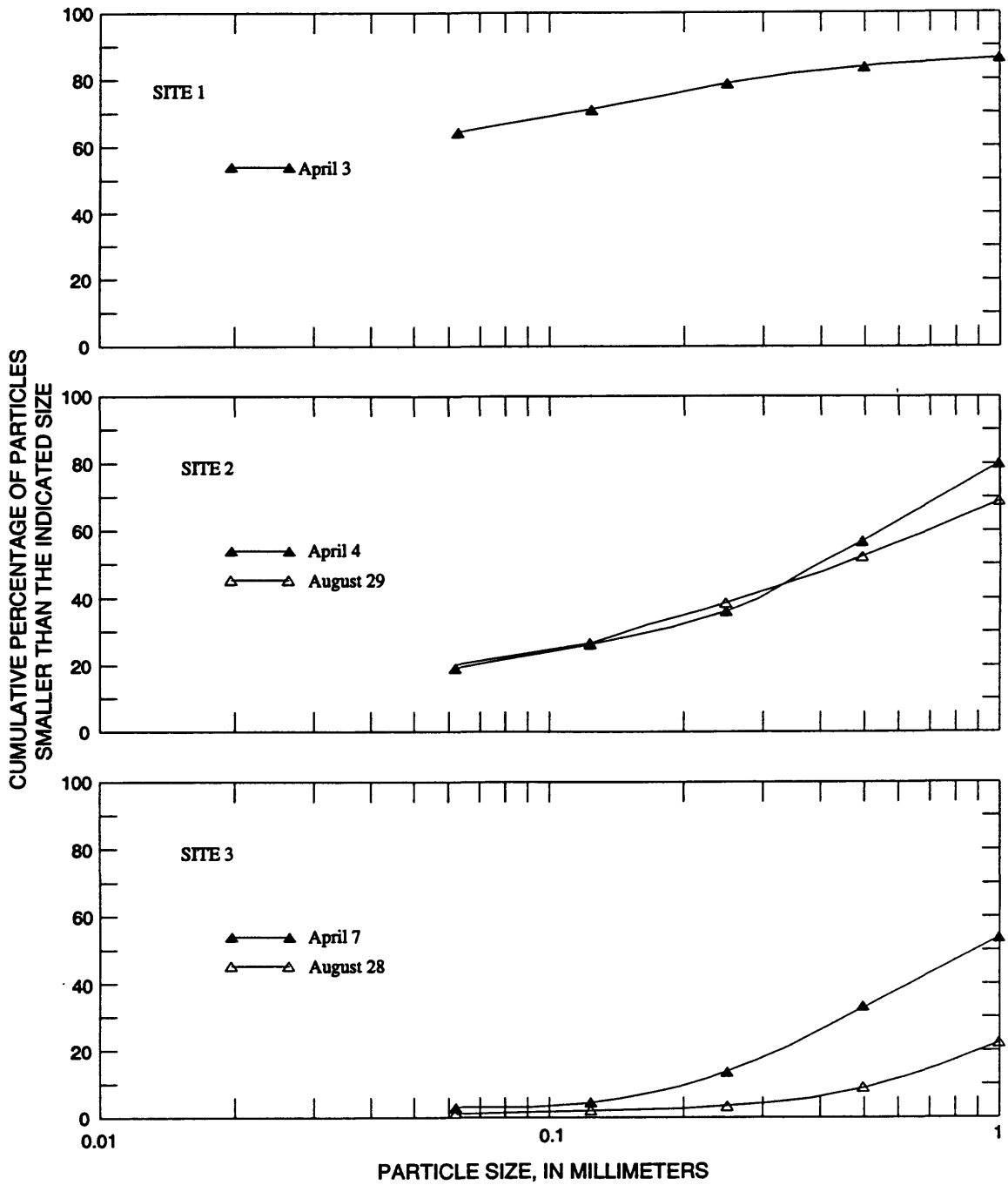

Figure 21. Cumulative-percentage size distribution of bottom material collected from pools at sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989.

Table 1. Benthic macroinvertebrate species list and density for site 1, lower Olmos Creek, San Antonio, Texas, April 3, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; G., genus; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Hebetancylus excentricus	43	11	43	--	--	--	11	--	--	--	11
Physa sp.	97	170	220	75	11	120	130	65	600	120	160
HIRUDINEA (leeches)											
Glossiphonia heteroclita	65	32	560	86	640	480	430	1,200	1,100	54	460
Helobdella triserialis	11	--	11	65	54	11	11	43	--	--	21
INSECTA (insects)											
Coleoptera (beetles)											
Berosus sp.	--	--	--	--	--	--	--	43	--	--	4
Stenelmis sexlineata	22	--	--	--	--	--	--	--	--	--	2
Diptera (true flies)											
Cricotopus sp.	14,000	1,700	820	2,500	2,300	2,300	16,000	4,000	4,500	880	4,900
Dicrotendipes sp.	650	--	--	86	--	--	--	86	170	22	100
Orthocladius sp. 1	650	32	43	130	340	220	340	170	340	22	230
Orthocladius sp. 2	--	32	--	260	340	86	1,000	--	--	--	170
Polypedilum sp.	5,000	650	300	2,300	2,200	1,200	7,900	2,900	5,200	520	2,800
Simulium sp.	1,800	43	43	--	43	--	170	86	--	--	220
Thienemanniella sp.	860	32	--	43	86	43	--	--	--	--	110
Thienemannimyia sp.	--	--	--	--	--	--	--	--	170	32	20
Ephemeroptera (mayflies)											
Caenis sp.	22	--	43	43	--	--	32	--	86	43	27
Lepidoptera (aquatic caterpillars)											
Nepticula sp.	--	--	43	--	--	86	--	--	--	--	13

Footnote at end of table.

Table 1. Benthic macroinvertebrate species list and density for site 1, lower Olmos Creek, San Antonio, Texas, April 3, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Odonata (dragonflies and damselflies)											
Argia bipunctulata	11	--	--	--	--	--	--	--	--	--	1
Argia sp.	22	--	--	--	--	--	11	--	--	--	3
Trichoptera (caddisflies)											
Hydroptila sp.	11	--	--	--	--	--	--	--	--	--	1
OLIGOCHAETA (worms)											
Tubificidae G. sp.	11	11	--	--	--	43	11	86	86	--	25
PELECYPODA (clams)											
Corbicula fluminea	120	140	170	75	110	22	470	11	430	--	150
Musculium sp.	--	--	--	--	--	180	990	260	3,600	300	530
TURBELLARIA (flatworms)											
Phagocata sp.	--	--	--	11	--	--	--	--	--	--	1
Total (rounded)	23,000	2,900	2,300	5,700	6,100	4,800	28,000	9,000	16,000	2,000	10,000
Total taxa	17	11	11	12	10	12	14	12	11	9	--
Point depth, m	.06	.06	.06	.06	.06	.06	.06	.03	.06	.06	--
Point velocity, m/s	.16	.15	.23	.12	.30	.10	.15	.17	.13	.12	--
Diversity index	1.3	1.3	1.8	1.3	1.5	1.6	1.2	1.4	1.7	1.5	1.5
Maximum diversity index	2.8	2.4	2.4	2.5	2.3	2.5	2.6	2.5	2.4	2.2	2.5
Evenness	.5	.5	.8	.5	.7	.6	.5	.6	.7	.7	.6

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 2. Benthic macroinvertebrate species list and density for site 1, lower Olmos Creek, San Antonio, Texas, April 26, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Hebetancylus excentricus	--	--	--	--	--	65	--	--	--	--	6
Physa skinneri	--	--	300	--	43	220	--	690	--	86	130
Physella gyrina	260	32	43	260	430	220	--	86	--	150	150
HIRUDINEA (leeches)											
Helobdella stagnalis	--	--	260	1,100	250	260	1,500	--	--	690	410
Placobdella translucens	--	11	260	170	86	130	950	--	--	--	160
INSECTA (insects)											
Coleoptera (beetles)											
Stenelmis sexlineata	22	--	--	--	--	22	--	43	--	--	9
Diptera (true flies)											
Corynoneura sp. 1	320	--	470	170	65	190	--	--	170	260	160
Corynoneura sp. 2	220	11	130	86	22	--	--	--	43	43	56
Cricotopus sp.	470	11	860	950	240	410	170	300	370	190	400
Dicrotendipes sp.	--	--	--	--	43	--	--	--	22	--	6
Fittkauimyia sp.	--	--	--	43	--	--	--	43	--	22	11
Orthocladius sp.	86	11	130	86	--	22	--	--	22	22	38
Polypedilum illinoisense	600	--	900	1,400	370	150	900	170	240	86	480
Psectrocladius sp.	65	--	86	130	86	150	130	170	130	86	100
Pseudochironomus richardsoni	260	--	340	260	130	--	86	130	43	--	120
Simulium sp.	--	--	--	43	--	--	--	--	--	--	4
Trissopelopia sp.	22	--	170	170	43	43	43	130	43	--	66
Zavrelimyia sp.	--	--	43	86	86	22	--	43	--	65	34
Ephemeroptera (mayflies)											
Ephemerella sp.	22	--	--	--	--	--	--	--	--	--	2
Tricorythodes explicata	240	--	--	--	--	43	--	43	--	22	35

Footnote at end of table.

Table 2. Benthic macroinvertebrate species list and density for site 1, lower Olmos Creek, San Antonio, Texas, April 26, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Odonata (dragonflies and damselflies)											
Enallagma daecki	11	--	--	--	--	--	--	--	--	--	1
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	--	--	43	--	--	--	--	--	--	4
Lumbriculus inconstans	--	--	86	--	--	--	950	--	--	--	100
PELECYPODA (clams)											
Musculium partumeium	450	--	--	130	410	--	--	2,200	--	220	340
Pisidium compressum	65	--	--	--	22	--	86	--	--	--	17
Sphaerium striatinum	22	--	560	--	--	1,100	1,900	1,100	--	--	470
TURBELLARIA (flatworms)											
Dugesia dorotocephala	--	32	43	--	--	--	--	--	--	110	18
Total (rounded)	3,100	110	4,700	5,100	2,300	3,000	6,700	5,100	1,100	2,100	3,300
Total taxa	16	6	16	16	15	15	10	13	9	14	--
Point depth, m	.09	.09	.09	.09	.06	.09	.06	.06	.06	.09	--
Point velocity, m/s	.31	.59	.50	.33	.05	.13	.23	.29	.19	.15	--
Diversity index	2.3	1.6	2.4	2.2	2.3	2.2	1.8	1.8	1.8	2.2	2.1
Maximum diversity index	2.8	1.8	2.8	2.8	2.7	2.7	2.3	2.6	2.2	2.6	2.5
Evenness	.8	.9	.9	.8	.9	.8	.8	.7	.8	.8	.8

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 3. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, April 4, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). sp., species; --, not detected or not applicable; G., genus; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
CRUSTACEA											
Decapoda (crayfish)											
Orconectes sp.	--	--	--	--	--	--	--	32	11	--	4
GASTROPODA (snails)											
Goniobasis sp. 1	150	280	75	120	440	700	780	150	110	310	310
Goniobasis sp. 2	--	--	--	--	--	65	11	--	11	11	10
Hebetancylus excentricus	--	--	--	86	--	--	--	--	--	54	14
Physa sp.	--	--	--	--	--	11	--	--	--	--	1
HIRUDINEA (leeches)											
Helobdella triserialis	--	--	--	--	--	22	--	--	--	--	2
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	--	22	11	220	22	32	65	22	--	32	43
Stenelmis sp.	11	11	22	86	--	140	86	32	--	22	41
Diptera (true flies)											
Atrichopogon sp.	--	--	11	--	--	--	--	--	--	--	1
Cricotopus trifascia	54	11	--	130	310	11	170	120	320	22	110
Dicrotendipes sp.	11	--	--	--	--	--	--	--	--	--	1
Eukiefferiella sp.	--	--	--	--	11	--	--	--	--	--	1
Orthocladius sp. 1	22	--	11	--	43	11	--	--	--	--	9
Polypedilum sp.	--	11	--	--	11	--	--	--	11	--	3
Tanytarsus sp.	--	--	--	--	11	--	--	--	--	--	1
Thienemanniella sp.	--	--	--	43	--	--	--	--	--	--	4
Thienemannimyia sp.	--	--	--	--	11	--	--	11	--	--	2

Footnote at end of table.

Table 3. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, April 4, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Ephemeroptera (mayflies)											
Caenis sp.	--	--	--	--	--	11	--	--	--	11	2
Tricorythodes sp.	--	--	--	--	--	--	11	--	--	--	1
Odonata (dragonflies and damselflies)											
Argia sp.	--	--	--	--	--	--	11	--	--	--	1
Phyllogomphoides sp.	--	--	22	--	--	--	22	--	--	11	6
Trichoptera (caddisflies)											
Hydroptila sp.	--	--	--	--	--	11	--	--	--	--	1
OLIGOCHAETA (worms)											
Tubificidae G. sp.	43	11	32	--	32	75	43	75	22	--	33
PELECYPODA (clams)											
Corbicula fluminea	--	--	--	--	11	11	--	11	--	--	3
TURBELLARIA (flatworms)											
Phagocata sp.	--	--	--	220	--	54	11	120	170	22	60
Total (rounded)	290	350	180	900	900	1,200	1,200	570	660	500	660
Total taxa	6	6	7	7	10	13	10	9	7	9	--
Point depth, m	.18	.18	.15	.24	.21	.15	.12	.15	.12	.12	--
Point velocity, m/s	.08	.08	.18	.25	.31	.19	.18	.22	.16	.22	--
Diversity index	1.4	.8	1.7	1.8	1.4	1.5	1.3	1.9	1.3	1.4	1.4
Maximum diversity index	1.8	1.8	2.0	2.0	2.3	2.6	2.3	2.2	2.0	2.2	2.1
Evenness	.8	.4	.8	.9	.6	.6	.6	.9	.6	.6	.7

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 4. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, April 25, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Hebetancylus excentricus	--	--	--	--	170	--	--	11	11	--	19
Melanoides tuberculata	--	--	--	--	--	--	--	11	--	--	1
Thiara granifera	320	430	--	1,200	860	470	950	450	170	220	510
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	--	86	11	43	54	--	270	32	110	560	120
Stenelmis sexlineata	--	160	--	--	11	--	--	--	43	130	34
Diptera (true flies)											
Corynoneura sp. 1	43	22	32	--	32	260	110	65	--	190	75
Corynoneura sp. 2	32	11	11	--	--	86	32	22	11	32	24
Dicrotendipes sp.	54	--	--	--	--	--	--	--	--	11	6
Orthocladius sp.	86	11	43	--	86	730	260	170	11	240	160
Polypedilum illinoisense	32	--	--	--	--	690	250	110	--	120	120
Psectrocladius sp.	11	11	22	--	--	430	190	54	11	97	83
Pseudochironomus richardsoni	22	--	--	--	43	600	150	75	--	130	100
Stilobezzia sp.	--	--	--	--	--	--	11	--	--	11	2
Trissopelopia sp.	--	--	22	--	--	--	--	--	--	--	2
Ephemeroptera (mayflies)											
Ephemerella sp.	--	--	--	--	--	--	--	22	--	--	2
Odonata (dragonflies and damselflies)											
Enallagma daecki	--	--	--	--	--	--	11	--	--	--	1
Phyllogomphoides stigmata	11	--	--	--	--	--	11	--	--	--	2

Footnote at end of table.

Table 4. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, April 25, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	--	--	22	--	--	--	75	--	--	10
Lumbriculus inconstans	22	43	11	32	--	--	11	--	--	--	12
PELECYPODA (clams)											
Corbicula fluminea	--	--	--	--	--	--	--	--	11	--	1
TURBELLARIA (flatworms)											
Dugesia dorotocephala	32	97	86	11	140	130	11	75	220	470	130
Total (rounded)	660	870	240	1,300	1,400	3,400	2,300	1,200	600	2,200	1,400
Total taxa	11	9	8	5	8	8	13	13	9	12	--
Point depth, m	.21	.21	.21	.24	.15	.15	.18	.09	.12	.12	--
Point velocity, m/s	.16	.13	.15	.05	.28	.23	.10	.20	.19	.26	--
Diversity index	1.8	1.5	1.8	.4	1.3	1.9	1.8	2.0	1.6	2.1	1.6
Maximum diversity index	2.4	2.2	2.1	1.6	2.1	2.1	2.6	2.6	2.2	2.5	2.2
Evenness	.8	.7	.9	.2	.6	.9	.7	.8	.7	.8	.7

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 5. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, June 27, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
CRUSTACEA											
Procambarus blandingi	--	--	--	--	--	--	--	11	11	--	2
GASTROPODA (snails)											
Hebetancylus excentricus	--	--	--	11	--	97	22	22	32	32	22
Thiara granifera	--	--	11	11	--	--	--	--	22	--	4
HIRUDINEA (leeches)											
Placobdella translucens	--	11	11	11	--	--	--	22	--	43	10
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	22	65	22	11	43	22	86	75	180	11	54
Stenelmis sexlineata	--	--	--	--	--	--	--	22	54	--	8
Diptera (true flies)											
Corynoneura sp. 1	--	--	--	22	22	22	43	--	22	11	14
Corynoneura sp. 2	22	22	54	65	54	130	280	--	97	43	77
Cricotopus sp.	11	--	--	54	11	22	--	--	--	11	11
Orthocladius sp.	11	--	--	22	--	22	--	--	32	--	9
Polypedilum illinoisense	--	--	--	22	--	--	22	--	22	11	8
Psectrocladius sp.	--	--	22	--	--	--	--	--	--	--	2
Pseudochironomus richardsoni	--	--	--	--	--	120	65	22	22	75	30
Trissopelopia sp.	--	--	--	11	22	22	22	54	--	11	14
Zavrelimyia sp.	--	--	--	--	54	--	32	11	--	--	10
Ephemeroptera (mayflies)											
Ephemerella sp.	11	--	--	--	--	--	--	--	--	22	3

Footnote at end of table.

Table 5. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, June 27, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Odonata (dragonflies and damselflies)											
Enallagma daecki	--	--	--	--	--	22	--	--	--	--	2
Trichoptera (caddisflies)											
Orthotrichia americana	11	22	11	32	--	54	65	86	160	54	50
Smicridea fasciatella	--	--	--	--	--	22	--	--	--	--	2
OLIGOCHAETA (worms)											
Chaetogaster sp.	120	110	65	--	110	43	220	270	160	220	130
Lumbriculus inconstans	--	32	--	--	54	32	32	110	32	97	39
TURBELLARIA (flatworms)											
Dugesia dorotocephala	--	110	250	160	220	430	320	430	270	170	240
Total (rounded)	210	370	450	430	590	1,100	1,200	1,100	1,100	810	740
Total taxa	7	7	8	12	9	14	12	12	14	14	--
Point depth, m	.21	.18	.18	.24	.18	.12	.12	.18	.12	.12	--
Point velocity, m/s	.12	.15	.19	.19	.19	.30	.27	.20	.22	.22	--
Diversity index	1.4	1.7	1.4	2.0	1.9	2.0	2.0	1.8	2.2	2.2	1.9
Maximum diversity index	2.0	2.0	2.1	2.5	2.2	2.6	2.5	2.5	2.6	2.6	2.4
Evenness	.7	.8	.7	.8	.9	.8	.8	.7	.8	.8	.8

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 6. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, July 25, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
CRUSTACEA											
Procambarus blandingi	--	--	--	--	--	--	11	--	--	--	1
GASTROPODA (snails)											
Hebetancylus excentricus	--	--	--	--	--	11	--	--	--	--	1
Melanoides tuberculata	11	--	--	--	11	--	--	--	--	--	2
Thiara granifera	200	97	180	420	260	420	2,200	430	610	1,100	590
HIRUDINEA (leeches)											
Placobdella translucens	--	--	--	--	11	--	11	--	--	--	2
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	11	--	--	--	--	--	--	43	--	--	5
Stenelmis sexlineata	--	22	--	--	--	--	--	--	--	--	2
Diptera (true flies)											
Corynoneura sp. 1	--	--	--	--	--	--	32	--	--	--	3
Corynoneura sp. 2	--	--	--	--	--	--	130	22	32	11	20
Cricotopus sp.	11	--	--	--	--	--	54	22	22	11	12
Dicrotendipes sp.	--	--	--	--	11	--	32	11	--	--	5
Fittkauimyia sp.	--	--	--	--	--	--	32	11	22	--	6
Orthocladius sp.	11	11	--	--	--	--	65	11	11	11	12
Polypedilum illinoisense	--	--	--	--	--	--	54	22	--	11	9
Psectrocladius sp.	--	--	--	--	--	--	22	--	--	--	2
Pseudochironomus richardsoni	--	--	--	--	--	--	11	--	11	--	2
Zavrelimyia sp. 1	22	11	11	11	--	--	11	22	32	11	13

Footnote at end of table.

Table 6. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, July 25, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Ephemeroptera (mayflies)											
Ephemerella sp.	--	--	--	--	--	--	--	--	--	11	1
Enallagma daecki	22	--	--	--	--	--	11	--	--	--	3
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	--	--	--	43	--	22	22	--	--	9
Lumbriculus inconstans	75	22	22	11	32	--	110	11	11	170	46
TURBELLARIA (flatworms)											
Dugesia dorotocephala	--	--	--	--	11	--	--	--	--	--	1
Total (rounded)	360	160	210	440	380	430	2,800	630	750	1,300	750
Total taxa	8	5	3	3	7	2	16	11	8	8	--
Point depth, m	.09	.12	.24	.18	.24	.27	.12	.12	.15	.12	--
Point velocity, m/s	.09	.15	.14	.22	.13	.33	.32	.28	.26	.27	--
Diversity index	1.4	1.2	.5	.2	1.1	.1	1.0	1.3	.8	.7	.8
Maximum diversity index	2.1	1.6	1.1	1.1	2.0	.7	2.8	2.4	2.1	2.1	1.8
Evenness	.7	.8	.5	.2	.6	.1	.4	.5	.4	.3	.4

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 7. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, August 29, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Melanoides tuberculata	32	--	--	--	--	--	--	--	--	--	3
Thiara granifera	1,200	270	780	400	32	850	1,100	300	1,200	1,300	740
HIRUDINEA (leeches)											
Placobdella translucens	--	11	--	--	--	--	11	22	--	--	4
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	--	--	--	11	--	--	22	11	--	54	10
Stenelmis sexlineata	--	--	--	--	--	--	--	--	11	--	1
Diptera (true flies)											
Fittkauimyia sp.	--	--	--	--	--	11	--	--	--	--	1
Pseudochironomus richardsoni	--	--	--	--	--	--	11	--	--	--	1
Zavrelimyia sp. 1	--	--	11	--	--	11	11	32	--	--	6
Ephemeroptera (mayflies)											
Tricorythodes explicata	--	11	--	--	--	--	--	--	--	--	1
Odonata (dragonflies and damselflies)											
Enallagma daecki	--	--	--	75	--	--	--	--	--	--	8
Phyllogomphoides stigmata	11	--	--	--	--	--	--	--	--	--	1
Trichoptera (caddisflies)											
Orthotrichia americana	--	--	--	--	--	--	11	--	--	--	1
Smicridea fasciatella	--	--	--	--	--	11	--	--	--	11	2

Footnote at end of table.

Table 7. Benthic macroinvertebrate species list and density for site 2, upper San Antonio River, San Antonio, Texas, August 29, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	11	--	--	11	--	--	11	--	75	11
Lumbriculus inconstans	11	11	65	--	--	--	65	32	43	75	30
PELECYPODA (clams)											
Corbicula fluminea	--	--	--	11	--	--	--	--	--	--	1
TURBELLARIA (flatworms)											
Dugesia dorotocephala	--	11	--	--	--	--	--	--	--	--	1
Total (rounded)	1,300	320	860	500	43	880	1,200	410	1,300	1,500	820
Total taxa	4	6	3	4	2	4	7	6	3	5	--
Point depth, m	.18	.15	.15	.15	.21	.18	.15	.18	.12	.12	--
Point velocity, m/s	.15	.11	.13	.09	.17	.21	.18	.21	.23	.19	--
Diversity index	.2	.7	.3	.6	.6	.2	.5	1.0	.2	.6	.5
Maximum diversity index	1.4	1.8	1.1	1.4	.7	1.4	2.0	1.8	1.1	1.6	1.4
Evenness	.1	.4	.3	.4	.9	.1	.2	.6	.2	.4	.4

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 8. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, April 7, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; G., genus; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
COLLEMBOLA (springtails)	--	--	43	--	--	--	--	--	--	--	4
GASTROPODA (snails)											
Goniobasis sp. 1	11	--	--	--	--	180	140	220	--	--	55
Hebetancylus excentricus	11	22	86	370	22	--	11	--	--	75	60
HIRUDINEA (leeches)											
Helobdella fusca	--	--	--	22	--	--	--	--	--	--	2
INSECTA (insects)											
Coleoptera (beetles)											
Heterelmis sp.	--	--	--	--	--	--	--	--	--	11	1
Microcylloepus sp.	1,200	75	650	110	340	340	260	--	1,300	250	450
Narpus sp.	--	11	--	--	--	--	--	--	--	--	1
Psephenus herricki	--	--	--	11	22	--	--	--	--	--	3
Stenelmis sexlineata	950	290	170	170	730	340	190	130	520	120	360
Diptera (true flies)											
Cricotopus trifascia	1,600	150	600	22	130	43	65	43	--	140	280
Dicrotendipes sp.	--	22	--	--	--	--	--	--	--	--	2
Eukiefferiella sp.	86	--	--	--	--	--	--	--	--	--	9
Hemerodromia sp.	86	--	--	--	--	43	22	--	86	54	29
Orthocladius sp. 1	260	110	170	--	--	130	22	--	86	43	82
Orthocladius sp. 2	--	--	--	--	43	--	22	--	---	11	8
Orthocladius sp. 3	86	--	--	--	--	--	--	--	--	--	9
Polypedilum sp.	--	22	86	--	--	--	--	--	--	--	11
Simulium sp.	340	--	--	--	43	--	--	--	--	--	38

Footnote at end of table.

Table 8. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, April 7, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Tanytarsus sp.	1,400	1,500	2,700	22	1,300	340	580	600	2,100	670	1,100
Thienemanniella sp.	--	120	220	--	86	--	22	--	--	65	51
Thienemannimyia sp.	86	32	86	--	130	86	43	43	260	--	77
Ephemeroptera (mayflies)											
Baetis alius	950	390	560	86	390	300	320	86	860	790	470
Caenis sp.	--	--	--	--	--	--	--	--	86	11	10
Rhithrogena sp.	--	--	--	22	--	--	--	--	--	--	2
Stenonema sp.	--	--	--	22	--	--	--	--	--	--	2
Tricorythodes sp.	1,200	2,100	2,400	340	2,500	690	670	1,400	3,400	390	1,500
Hemiptera (true bugs)											
Saldidae	--	--	43	--	--	--	--	--	--	--	4
Lepidoptera (aquatic caterpillars)											
Petrophila sp.	--	11	43	--	--	--	--	--	--	22	8
Megaloptera (alderflies and dobson flies)											
Corydalus cornutus	--	--	--	--	--	43	22	--	--	--	6
Odonata (dragonflies and damselflies)											
Argia bipunctulata	--	--	--	--	--	--	11	--	--	11	2
Argia sp.	86	54	11	11	22	--	22	43	86	150	48
Dythemis sp.	--	--	11	--	--	--	11	--	--	--	2
Trichoptera (caddisflies)											
Cheumatopsyche sp.	--	--	--	--	43	--	--	--	--	--	4
Hydroptila sp.	--	86	170	--	--	43	22	--	--	65	39
Hydroptillidae pupae	--	--	--	--	--	--	--	--	86	--	9
Leptonema sp.	1,000	320	300	--	340	860	1,100	54	520	97	460
Leucotrichia sp.	--	--	--	--	--	43	--	--	170	43	26
Ochrotrichia tarsialis	260	32	86	--	43	--	--	--	--	--	42

Footnote at end of table.

Table 8. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, April 7, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
OLIGOCHAETA (worms)											
Tubificidae G. sp.	97	150	--	43	--	--	32	--	--	54	38
PELECYPODA (clams)											
Corbicula fluminea	32	97	380	120	290	65	54	170	54	130	140
Musculium sp.	--	--	240	--	--	--	--	86	--	--	33
TURBELLARIA (flatworms)											
Phagocata sp.	1,300	150	170	710	86	390	--	340	690	220	410
Total (rounded)	11,000	5,700	9,200	2,100	6,600	3,900	3,600	3,200	10,000	3,400	5,900
Total taxa	20	21	22	15	18	16	21	12	15	22	--
Point depth, m	.15	.18	.24	.24	.18	.18	.18	.27	.21	.18	--
Point velocity, m/s	1.0	.46	.51	.34	.48	.77	.50	1.1	.43	.23	--
Diversity index	2.5	2.0	2.2	2.0	2.0	2.4	2.2	1.8	2.0	2.5	2.2
Maximum diversity index	3.0	3.0	3.1	2.7	2.9	2.8	3.0	2.5	2.7	3.1	2.9
Evenness	.8	.7	.7	.7	.7	.9	.7	.7	.7	.8	.8

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 9. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, April 24, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Hebetancylus excentricus	--	--	--	--	--	43	--	--	--	22	6
Melanoides tuberculata	54	--	--	43	--	--	--	11	--	110	22
Thiara granifera	75	--	11	43	97	--	22	11	--	--	26
HIRUDINEA (leeches)											
Placobdella translucens	--	--	11	22	--	--	--	--	--	11	4
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	560	600	220	240	180	160	260	320	160	260	300
Stenelmis sexlineata	--	--	--	--	22	32	--	22	--	--	8
Diptera (true flies)											
Corynoneura sp. 1	86	32	--	43	--	--	--	--	--	22	18
Corynoneura sp. 2	260	65	--	--	--	32	43	--	--	22	42
Cricotopus sp.	43	22	--	--	--	32	22	--	--	--	12
Orthocladius sp.	--	11	--	--	--	--	--	--	--	--	1
Psectrocladius sp.	43	11	--	--	--	--	--	--	--	--	5
Pseudochironomus richardsoni	--	--	11	--	--	11	--	--	--	22	4
Trissopelopia sp.	43	--	--	--	--	22	65	--	--	--	13
Zavrelimyia sp.	43	11	11	22	--	--	22	11	--	22	14
Ephemeroptera (mayflies)											
Ephemerella sp.	170	220	110	43	110	110	110	32	--	130	100
Tricorythodes explicata	810	520	190	580	32	170	430	11	--	470	320
Megaloptera (alderflies and dobson flies)											
Corydalus cornutus	--	--	--	43	--	--	22	--	--	--	6

Footnote at end of table.

Table 9. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, April 24, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Odonata (dragonflies and damselflies)											
Argia extranea	--	--	--	--	--	--	--	--	--	22	2
Brechmorhoga mendax	--	--	--	--	--	--	43	--	--	11	5
Enallagma daecki	--	11	--	--	--	--	--	--	--	--	1
Trichoptera (caddisflies)											
Orthotrichia americana	--	--	--	22	--	--	--	--	--	--	2
Smicridea fasciatella	650	430	320	22	--	150	860	11	--	170	260
OLIGOCHAETA (worms)											
Chaetogaster sp.	43	22	--	22	--	11	--	--	--	11	11
Lumbriculus inconstans	--	11	22	65	54	22	22	11	--	11	22
PELECYPODA (clams)											
Corbicula fluminea	75	340	65	86	150	22	300	110	22	--	120
TURBELLARIA (flatworms)											
Dugesia dorotocephala	650	540	130	750	170	110	65	22	220	320	300
Total (rounded)	3,600	2,800	1,100	2,000	820	930	2,300	570	400	1,600	1,600
Total taxa	15	15	11	15	8	14	14	11	3	16	--
Point depth, m	.15	.15	.18	.15	.27	.24	.15	.27	.30	.18	--
Point velocity, m/s	.74	.48	.59	.26	.40	.29	.63	.45	.33	.44	--
Diversity index	2.2	2.0	1.9	1.9	1.9	2.3	1.9	1.5	.9	2.1	1.9
Maximum diversity index	2.7	2.7	2.4	2.7	2.1	2.6	2.6	2.4	1.1	2.8	2.4
Evenness	.8	.7	.8	.7	.9	.9	.7	.6	.8	.8	.8

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 10. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, June 26, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
GASTROPODA (snails)											
Hebetancylus excentricus	22	--	--	--	--	--	--	11	--	--	3
Melanoides tuberculata	--	43	43	--	--	11	--	--	--	75	17
Thiara granifera	--	300	43	11	--	--	--	11	54	--	42
HIRUDINEA (leeches)											
Placobdella translucens	--	22	--	--	--	22	--	--	--	--	4
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	170	43	650	54	65	43	22	160	11	11	120
Psephenus texanus	--	--	--	11	22	--	--	--	11	--	4
Stenelmis sexlineata	--	--	--	--	--	--	--	--	11	22	3
Diptera (true flies)											
Corynoneura sp. 1	86	86	170	43	22	43	11	22	--	--	48
Corynoneura sp. 2	340	430	950	220	110	86	65	54	43	--	230
Cricotopus sp.	450	430	220	240	120	54	22	250	32	--	180
Dicrotendipes sp.	--	--	--	22	--	--	--	--	--	--	2
Fittkauimyia sp.	--	--	--	--	--	--	--	11	--	--	1
Hemerodromia sp.	--	--	--	--	--	--	--	22	--	--	2
Orthocladius sp.	260	170	220	65	54	--	22	75	65	--	93
Polypedilum illinoisense	220	340	86	22	22	75	22	32	75	--	89
Psectrocladius sp.	65	--	43	22	11	--	--	32	--	--	17
Pseudochironomus richardsoni	260	43	300	22	11	32	--	75	54	--	80
Simulium sp.	22	43	43	--	11	11	--	11	--	--	14
Trissopelopia sp.	43	86	86	43	11	--	--	43	22	--	33
Zavrelimyia sp.	--	220	170	65	22	22	--	43	--	11	55

Footnote at end of table.

Table 10. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, June 26, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Ephemeroptera (mayflies)											
Ephemerella sp.	22	170	--	43	11	97	22	97	65	22	55
Tricorythodes explicata	--	22	--	11	54	22	11	170	--	65	36
Odonata (dragonflies and damselflies)											
Argia extranea	--	--	--	43	--	--	--	--	--	--	4
Brechmorhoga mendax	--	--	11	--	--	--	--	--	--	--	1
Enallagma daecki	--	--	--	--	--	--	11	--	--	--	1
Trichoptera (caddisflies)											
Orthotrichia americana	--	--	130	32	97	32	11	75	22	11	41
Smicridea fasciatella	430	11	190	11	--	--	--	140	65	--	85
OLIGOCHAETA (worms)											
Chaetogaster sp.	65	--	--	11	43	22	--	22	--	22	18
Lumbriculus inconstans	--	--	43	11	43	43	43	--	--	65	25
PELECYPODA (clams)											
Corbicula fluminea	32	520	130	97	54	120	120	120	130	86	140
TURBELLARIA (flatworms)											
Dugesia dorotocephala	650	540	860	110	270	11	--	320	540	--	330
Total (rounded)	3,100	3,500	4,400	1,200	1,100	750	380	1,800	1,200	390	1,800
Total taxa	16	18	19	22	19	17	12	22	15	10	--
Point depth, m	.21	.15	.24	.27	.34	.37	.40	.18	.27	.27	--
Point velocity, m/s	.49	.42	.65	.38	.46	.43	.52	.48	.46	.26	--
Diversity index	2.3	2.5	2.4	2.6	2.5	2.6	2.2	2.7	2.0	2.0	2.4
Maximum diversity index	2.8	2.9	2.9	3.1	2.9	2.8	2.5	3.1	2.7	2.3	2.8
Evenness	.8	.9	.8	.8	.9	.9	.9	.9	.7	.9	.9

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 11. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, July 24, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
CRUSTACEA											
Procambarus blandingi	--	32	--	--	--	--	--	--	--	--	3
GASTROPODA (snails)											
Melanoides tuberculata	11	75	11	75	220	75	43	11	75	290	89
Thiara granifera	170	97	120	400	420	250	160	140	97	220	210
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	97	--	22	--	32	22	300	65	54	120	71
Stenelmis sexlineata	--	54	32	--	--	11	--	--	--	--	10
Diptera (true flies)											
Corynoneura sp. 1	--	--	--	--	--	--	--	11	--	--	1
Corynoneura sp. 2	11	22	--	--	11	22	--	22	--	11	10
Cricotopus sp.	11	--	--	11	--	--	--	--	--	--	2
Fittkauimyia sp.	22	--	--	11	11	22	--	11	--	11	9
Orthocladius sp.	--	--	--	--	--	--	--	11	--	--	1
Polypedilum illinoisense	--	--	--	--	--	--	43	43	--	--	9
Simulium sp.	--	11	--	--	--	--	--	--	--	--	1
Trissopelopia sp.	32	22	11	--	--	54	22	22	22	22	21
Zavrelimyia sp.	43	32	11	11	22	97	32	54	43	43	39
Ephemeroptera (mayflies)											
Ephemerella sp.	43	11	22	11	32	11	43	11	--	11	20
Tricorythodes explicata	32	--	86	--	--	--	--	--	11	22	15
Megaloptera (alderflies and dobson flies)											
Corydalus cornutus	22	--	--	--	--	--	--	--	--	--	2

Footnote at end of table.

Table 11. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, July 24, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Odonata (dragonflies and damselflies)											
Acanthagrion quadratum	--	11	--	--	--	--	--	--	--	--	1
Argia extranea	75	97	11	--	--	--	32	--	--	--	22
Brechmorhoga mendax	--	--	32	--	--	22	--	--	--	--	5
Enallagma daecki	43	32	43	22	86	65	65	140	86	65	65
Miathyria marcella	--	--	--	--	--	--	--	11	--	--	1
Trichoptera (caddisflies)											
Smicridea fasciatella	2,000	86	54	--	--	--	460	990	--	43	360
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	--	--	--	22	--	54	--	--	--	8
Lumbriculus inconstans	--	--	11	11	--	11	230	--	--	270	53
PELECYPODA (clams)											
Corbicula fluminea	32	200	--	540	260	220	160	190	390	110	210
Total (rounded)	2,600	780	470	1,100	1,100	880	1,600	1,700	780	1,200	1,200
Total taxa	15	14	13	9	10	13	13	15	8	13	--
Point depth, m	.21	.18	.34	.30	.37	.21	.24	.21	.27	.15	--
Point velocity, m/s	.95	.54	.60	.18	.18	.48	.71	.51	.36	.28	--
Diversity index	1.1	2.3	2.2	1.2	1.7	2.1	2.1	1.6	1.6	2.1	1.8
Maximum diversity index	2.7	2.6	2.6	2.2	2.3	2.6	2.6	2.7	2.1	2.6	2.5
Evenness	.4	.9	.8	.5	.7	.8	.8	.6	.8	.8	.7

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 12. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, August 28, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected or not applicable; sp., species; m, meters; m/s, meters per second]

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
CRUSTACEA											
Procambarus blandingi	--	--	11	--	--	--	--	--	--	--	1
GASTROPODA (snails)											
Melanoides tuberculata	32	340	440	65	120	75	97	230	86	32	150
Thiara granifera	310	330	170	380	43	720	650	65	43	97	280
HIRUDINEA (leeches)											
Placobdella translucens	--	--	22	--	32	43	86	11	22	11	23
INSECTA (insects)											
Coleoptera (beetles)											
Microcylloepus sp.	970	75	54	54	97	22	86	22	54	110	150
Psephenus texanus	--	--	--	--	32	--	11	--	--	--	4
Stenelmis sexlineata	140	22	11	--	--	130	320	--	54	170	85
Diptera (true flies)											
Corynoneura sp. 1	22	--	--	--	--	--	--	--	--	--	2
Corynoneura sp. 2	65	--	22	--	32	--	--	--	--	--	12
Cricotopus sp.	22	--	--	--	22	22	--	11	11	--	9
Fittkauimyia sp.	--	11	11	11	11	--	--	--	22	--	7
Hemerodromia sp.	22	--	--	--	--	--	--	--	--	--	2
Orthocladius sp.	--	--	11	--	11	--	--	--	--	--	2
Polypedilum illinoisense	--	--	32	11	140	--	--	--	--	--	18
Pseudochironomus richardsoni	11	11	--	--	54	--	--	--	--	--	8
Simulium sp.	11	--	--	--	--	--	--	--	--	--	1
Trissopelopia sp.	11	--	22	65	150	65	22	32	11	22	40
Zavrelimyia sp.	11	--	97	54	180	65	11	54	22	11	50

Footnote at end of table.

Table 12. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, August 28, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)—Continued										
Ephemeroptera (mayflies)											
Ephemerella sp.	75	43	97	--	32	54	--	--	11	--	31
Tricorythodes explicata	290	97	22	--	97	32	--	--	32	11	58
Megaloptera (alderflies and dobson flies)											
Corydalus cornutus	22	--	--	--	--	--	--	--	--	--	2
Odonata (dragonflies and damselflies)											
Acanthagrion quadratum	--	32	--	--	--	--	--	32	--	--	6
Argia extranea	75	--	190	--	--	32	54	--	--	--	35
Brechmorhoga mendax	11	--	--	11	--	--	--	--	--	--	2
Enallagma daecki	22	54	130	--	54	65	160	11	22	32	55
Hetaerina americana	160	--	75	--	11	--	--	--	--	--	25
Miathyria marcella	--	--	--	--	22	--	--	--	--	--	2
Phyllogomphoides stigmata	--	--	--	--	--	--	11	--	11	--	2
Pseudoleon supurbus	--	--	--	--	--	--	--	11	--	--	1
Trichoptera (caddisflies)											
Smicridea fasciatella	560	110	300	--	320	140	330	--	--	43	180
OLIGOCHAETA (worms)											
Chaetogaster sp.	--	--	--	54	22	--	11	22	11	--	12
Lumbriculus inconstans	--	22	--	11	11	11	11	22	54	32	17
PELECYPODA (clams)											
Corbicula fluminea	32	540	32	150	75	65	150	54	54	54	120
TURBELLARIA (flatworms)											
Dugesia dorotocephala	11	--	--	--	--	11	--	--	11	--	3
Total (rounded)	2,900	1,700	1,700	870	1,600	1,600	2,000	580	530	620	1,400

Footnote at end of table.

Table 12. Benthic macroinvertebrate species list and density for site 3, upper San Antonio River, San Antonio, Texas, August 28, 1989—Continued

CLASS Order *Genus species*	Sample point										Mean[1]
	A	B	C	D	E	F	G	H	I	J	
Total taxa	22	13	19	11	22	16	15	13	17	12	--
Point depth, m	.18	.21	.21	.46	.34	.24	.15	.30	.30	.15	--
Point velocity, m/s	1.1	.63	.47	.37	.25	.71	.46	.40	.21	.45	--
Diversity index	2.2	1.9	2.4	1.8	2.7	2.0	2.1	2.1	2.6	2.1	2.2
Maximum diversity index	3.1	2.6	2.9	2.4	3.1	2.8	2.7	2.6	2.8	2.5	2.8
Evenness	.7	.7	.8	.8	.9	.7	.8	.8	.9	.8	.8

[1] Mean total computed using mean densities of organisms. Mean evenness computed using mean diversity index and mean maximum diversity index.

Table 13. Pupae densities at sites 1–3, lower Olmos Creek and upper San Antonio River, San Antonio, Texas, 1989

[--, not detected]

Organism Sample date	Sample point										Mean
	A	B	C	D	E	F	G	H	I	J	
	Density (organisms per square meter)										
Site 1											
Chironomidae pupae April 3	--	22	43	220	260	43	170	43	260	43	110
Site 2											
Chironomidae pupae April 4	--	--	--	--	--	--	--	--	11	--	1
Site 3											
Diptera pupae April 7	--	--	--	--	--	--	22	--	--	--	2
Chironomidae pupae April 7	--	--	--	--	--	--	22	--	--	22	4

Table 14. Periphyton species list and density for site 1, lower Olmos Creek, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected; ND, no data collected because of no-flow conditions; sp., species]

DIVISION *Genus species*	Sample date				
	April 3	April 26	June 28	July 26	August 30
	Density (cells per square millimeter)				
BACILLARIOPHYTA (diatoms)					
Achnanthes lanceolata	--	14	ND	ND	ND
Achnanthes minutissima	200	300	ND	ND	ND
Amphora ovalis	--	29	ND	ND	ND
Cocconeis placentula	29	--	ND	ND	ND
Cyclotella sp.	--	320	ND	ND	ND
Cymatopleura solea	7	--	ND	ND	ND
Cymbella minuta	14	85	ND	ND	ND
Cymbella sp.	--	14	ND	ND	ND
Fragilaria sp.	7	--	ND	ND	ND
Gomphonema brasiliense	--	14	ND	ND	ND
Gomphonema parvulum	64	43	ND	ND	ND
Gomphonema sp.	7	--	ND	ND	ND
Gomphonema subclavatum	7	--	ND	ND	ND
Navicula accomoda	--	29	ND	ND	ND
Navicula capitata	--	14	ND	ND	ND
Navicula cryptocephala	36	14	ND	ND	ND
Navicula cuspidata	7	14	ND	ND	ND
Navicula lateropunctata	--	14	ND	ND	ND
Navicula orbiculata	36	--	ND	ND	ND
Navicula pupula	7	--	ND	ND	ND
Navicula rhychocephala	--	29	ND	ND	ND
Navicula rhyncocephala	7	--	ND	ND	ND
Navicula sp.	21	71	ND	ND	ND
Navicula texana	--	14	ND	ND	ND
Navicula tripunctata	7	85	ND	ND	ND
Nitzschia acicularis	14	14	ND	ND	ND
Nitzschia amphibia	71	--	ND	ND	ND
Nitzschia dissipata	110	230	ND	ND	ND
Nitzschia filiformis	29	--	ND	ND	ND
Nitzschia frustulum	150	130	ND	ND	ND
Nitzschia hungarica	--	130	ND	ND	ND
Nitzschia linearis	--	14	ND	ND	ND
Nitzschia microcephala	--	85	ND	ND	ND
Nitzschia palea	93	300	ND	ND	ND
Nitzschia sp.	36	--	ND	ND	ND
Rhoicosphenia curvata	29	43	ND	ND	ND
Stephanodiscus sp.	52	--	ND	ND	ND
Surirella ovata	--	14	ND	ND	ND
Synedra ulna	7	14	ND	ND	ND

Table 14. Periphyton species list and density for site 1, lower Olmos Creek, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date				
	April 3	April 26	June 28	July 26	August 30
	Density (cells per square millimeter)—Continued				
CHLOROPHYTA (green algae)					
Actinastrum hantzschii	52	–	ND	ND	ND
Chlorococcum sp.	17	–	ND	ND	ND
Unknown chlorococcum	–	41	ND	ND	ND
CYANOPHYTA (blue-green algae)					
Gongrosira sp.	–	82	ND	ND	ND
Lyngbya sp.	44	–	ND	ND	ND
Lyngbya subtilis	–	350	ND	ND	ND
Oscillatoria	1,700	3,000	ND	ND	ND
Spirulina sp.	–	41	ND	ND	ND
XANTHOPHYTA (yellow-green algae)					
Vaucheria sp.	–	21	ND	ND	ND
Total (rounded)	2,900	5,600	ND	ND	ND
Total taxa	29	33	ND	ND	ND
Diversity index	1.8	2.0	ND	ND	ND
Maximum diversity index	3.4	3.5	ND	ND	ND
Evenness	.5	.6	ND	ND	ND

Table 15. Periphyton species list and density for site 2, upper San Antonio River, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected; sp., species]

DIVISION *Genus species*	Sample date				
	April 4	April 25	June 27	July 25	August 29
	Density (cells per square millimeter)				
BACILLARIOPHYTA (diatoms)					
Achnanthes exigua	--	36	--	--	--
Achnanthes microcephala	120	--	--	--	--
Achnanthes minutissima	1,400	640	--	--	--
Amphipleura pellucida	--	--	--	100	--
Amphora ovalis	120	--	--	--	--
Bacillaria paradoxa	--	--	650	--	1,100
Caloneis lewisii	120	--	--	--	--
Caloneis ventricosa	230	--	--	--	--
Cocconeis diminuta	--	--	6,500	--	11,000
Cocconeis placentula	--	210	--	--	--
Cyclotella sp.	--	43	--	--	--
Cymatopleura elliptica	--	--	--	--	1,100
Cymbella affinis	--	71	--	--	1,100
Cymbella cymbiformis	470	--	--	--	--
Cymbella sp.	120	180	--	--	--
Diploneis sp.	350	--	--	--	--
Fragilaria leptostauron	120	--	--	--	--
Fragilaria sp.	230	--	--	--	--
Gomphonema angustatum	--	--	--	400	--
Gomphonema constrictum	--	--	3,900	810	5,600
Gomphonema olivaceum	--	460	--	--	--
Gomphonema parvulum	230	36	--	--	--
Gomphonema sp.	230	--	--	--	--
Gyrosigma obtusatum	--	36	2,000	--	3,400
Melosira sp.	300	86	--	--	--
Meridion circulare	--	--	7,800	--	11,000
Navicula amphibia	--	140	--	--	--
Navicula capitata	--	36	--	--	--
Navicula cryptocephala	--	110	--	--	--
Navicula lateropunctata	--	36	--	--	--
Navicula minuscula	120	140	--	--	--
Navicula orbiculata	--	36	--	--	--
Navicula radiosa	--	--	--	--	2,200
Navicula rhynchocephala	350	--	--	--	--
Navicula sp.	470	140	--	--	--
Navicula texana	120	--	--	--	--
Navicula tripunctata	230	140	--	--	--
Nitzschia acicularis	120	36	--	--	--
Nitzschia amphibia	940	--	--	--	--
Nitzschia dissipata	1,200	280	--	--	--

Table 15. Periphyton species list and density for site 2, upper San Antonio River, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date				
	April 4	April 25	June 27	July 25	August 29
	Density (cells per square millimeter)—Continued				
Nitzschia filiformis	700	--	--	--	--
Nitzschia flexa	--	36	--	--	--
Nitzschia frustulum	120	360	--	--	--
Nitzschia microcephala	350	--	--	--	--
Nitzschia palea	820	360	--	--	--
Nitzschia paradoxa	350	--	--	--	--
Nitzschia sp.	820	180	--	--	--
Pinnularia biceps	--	--	--	--	9,000
Pinnularia flexuosa	120	--	--	--	--
Stephanodiscus sp.	--	43	--	--	--
Surirella biseriata	--	--	--	--	1,100
Surirella patella	--	36	--	100	1,100
Synedra fasicula	--	36	650	510	--
Synedra ulna	--	--	2,000	100	1,100
CHLOROPHYTA (green algae)					
Chlorella	--	--	6,500	1,400	4,500
Chlorococcum sp.	74	--	--	--	--
Cladophora glomerata	--	260	--	--	--
Cylindrocapsa geminella	590	--	--	--	--
Rhizoclonium sp.	740	--	--	--	--
Tetraedron minimum	--	43	--	--	--
Unknown chlorococcoid	--	87	--	--	--
CYANOPHYTA (blue-green algae)					
Anabaena	--	--	4,600	100	3,400
Lyngbya aeruginea-caerulea	--	910	--	--	--
Lyngbya digueti	1,700	--	--	--	--
Microcystis aeruginosa	--	--	29,000	6,300	44,000
Oscillatoria	7,000	2,400	--	100	3,400
Phormidium sp.	590	--	--	--	--
Spirulina sp.	--	170	--	--	--
EUGLENOPHYTA (euglenoids)					
Trachelomonas	--	--	2,000	200	7,800
Total (rounded)	22,000	7,800	66,000	10,000	110,000
Total taxa	34	33	11	11	17
Diversity index	2.8	2.7	1.8	1.4	2.2
Maximum diversity index	3.5	3.5	2.4	2.4	2.8
Evenness	.8	.8	.8	.6	.8

Table 16. Periphyton species list and density for site 3, upper San Antonio River, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected; sp., species]

DIVISION *Genus species*	Sample date				
	April 7	April 24	June 26	July 24	August 28
	Density (cells per square millimeter)				
BACILLARIOPHYTA (diatoms)					
Achnanthes microcephala	--	19	--	--	--
Achnanthes minutissima	570	600	--	--	--
Achnanthes sp.	--	57	--	--	--
Amphipleura pellucida	--	19	--	--	--
Bacillaria paradoxa	--	--	--	660	--
Biddulphia laevis	--	--	1,000	--	--
Cocconeis diminuta	--	--	5,700	6,600	4,500
Cocconeis pediculus	30	--	--	--	--
Cocconeis placentula	600	620	--	--	--
Cymbella affinis	--	19	--	--	--
Cymbella gracilis	--	--	--	660	--
Cymbella minuta	15	--	--	--	--
Cymbella sp.	15	--	--	--	--
Epithema sp.	--	19	--	--	--
Fragilaria construens	15	--	--	--	--
Fragilaria sp.	90	130	--	--	--
Gomphonema brasiliense	--	38	--	--	--
Gomphonema constrictum	--	--	2,600	2,600	690
Gomphonema olivaceum	230	150	--	--	--
Gomphonema parvulum	90	300	--	--	--
Gomphonema subclavatum	15	19	--	--	--
Gyrosigma obtusatum	30	--	2,600	3,300	1,000
Melosira sp.	180	440	--	--	--
Meridion circulare	--	--	1,500	2,000	4,200
Navicula capitata	60	--	--	--	--
Navicula cryptocephala	30	76	--	--	--
Navicula decussis	--	38	--	--	--
Navicula lateropunctata	60	76	--	--	--
Navicula minuscula	120	38	--	--	--
Navicula orbiculata	120	76	--	--	--
Navicula radiosa	--	--	520	1,300	690
Navicula rhynchocephala	75	170	--	--	--
Navicula sp.	110	94	--	--	--
Navicula tripunctata	--	38	--	--	--
Nitzschia acicularis	--	19	--	--	--
Nitzschia dissipata	150	360	--	--	--
Nitzschia fonticola	15	--	--	--	--
Nitzschia frustulum	75	76	--	--	--

Table 16. Periphyton species list and density for site 3, upper San Antonio River, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date				
	April 7	April 24	June 26	July 24	August 28
	Density (cells per square millimeter)—Continued				
Nitzschia linearis	60	38	--	--	--
Nitzschia microcephala	--	19	--	--	--
Nitzschia palea	90	150	--	--	--
Nitzschia sp.	30	38	--	--	--
Pinnularia biceps	--	--	520	2,000	690
Rhoicosphenia curvata	--	38	--	--	--
Surirella angustata	--	--	--	2,000	--
Surirella ovata	--	38	--	--	--
Surirella patella	--	--	--	--	1,000
Surirella tenera	--	--	--	--	350
Synedra ulna	--	76	1,000	2,600	--
CHLOROPHYTA (green algae)					
Chaetophora elegans	--	1,800	--	--	--
Chlamydomonas	--	--	2,100	3,300	3,800
Chlorella	--	--	4,100	4,600	3,800
Rhizoclonium	--	--	--	1,300	--
Unknown chlorococcoid	23	--	--	--	--
CYANOPHYTA (blue-green algae)					
Anabaena	45	560	3,600	4,000	2,800
Microcystis aeruginosa	--	--	20,000	22,000	10,000
Oscillatoria	1,300	3,800	6,200	6,600	350
Synechococcus sp.	68	--	--	--	--
EUGLENOPHYTA (euglenoids)					
Trachelomonas	--	--	--	--	350
Total (rounded)	4,300	10,000	51,000	66,000	34,000
Total taxa	29	34	13	16	14
Diversity index	2.5	2.3	2.0	2.3	2.2
Maximum diversity index	3.4	3.5	2.6	2.8	2.6
Evenness	.7	.7	.8	.8	.8

Table 17. Phytoplankton species list and density for site 1, lower Olmos Creek, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). ND, no data collected because of no-flow conditions; sp., species]

DIVISION *Genus species*	Sample date		
	April 3	June 28	August 30
	Density (cells per milliliter)		
BACILLARIOPHYTA (diatoms)			
Achnanthes deflexa	60	ND	ND
Achnanthes minutissima	220	ND	ND
Cocconeis placentula	20	ND	ND
Cyclotella ocellata	620	ND	ND
Gomphonema sp.	60	ND	ND
Navicula cryptocephala	20	ND	ND
Navicula cuspidata	20	ND	ND
Navicula jaernefeltii	40	ND	ND
Navicula minima	40	ND	ND
Navicula radiosa	40	ND	ND
Navicula texana	40	ND	ND
Navicula sp.	60	ND	ND
Nitzschia amphibia	20	ND	ND
Nitzschia angustata	40	ND	ND
Nitzschia dissipata	60	ND	ND
Nitzschia hungarica	80	ND	ND
Nitzschia linearis	20	ND	ND
Nitzschia microcephala	20	ND	ND
Nitzschia palea	120	ND	ND
Nitzschia sp.	100	ND	ND
Stephanodiscus sp.	310	ND	ND
Synedra ulna	40	ND	ND
CHLOROPHYTA (green algae)			
Ankistrodesmus falcatus	190	ND	ND
Chlamydomonas sp.	2,400	ND	ND
Chodatella quadriseta	940	ND	ND
Elakatothrix viridis	380	ND	ND
Franceia droescheri	2,100	ND	ND
Gloeocystis ampla	4,100	ND	ND
Kirchneriella subsolitaria	380	ND	ND
Nannochloris sp.	190	ND	ND
Oocystis sp.	750	ND	ND
Tetraedron trigonum	190	ND	ND
Tetraspora lacustris	190	ND	ND
Treubaria setigerum	190	ND	ND
Unknown coccoid	2,100	ND	ND

Table 17. Phytoplankton species list and density for site 1, lower Olmos Creek, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date		
	April 3	June 28	August 30
	Density (cells per milliliter)—Continued		
CHRYSOPHYTA (golden-brown algae)			
Kephyrion sp.	190	ND	ND
CRYPTOPHYTA (cryptophytes)			
Cryptomonas erosa	190	ND	ND
Rhodomonas minuta	380	ND	ND
CYANOPHYTA (blue-green algae)			
Aphanocapsa delicatissima	2,400	ND	ND
Chroococcus dispersus	7,100	ND	ND
Chroococcus limneticus	1,100	ND	ND
Chroococcus minutus	4,900	ND	ND
Dactylococcopsis fascicularis	1,500	ND	ND
Gloeothece linearis	190	ND	ND
Oscillatoria	940	ND	ND
Total (rounded)	35,000	ND	ND
Total taxa	45	ND	ND
Diversity index	2.8	ND	ND
Maximum diversity index	3.8	ND	ND
Evenness	.7	ND	ND

Table 18. Phytoplankton species list and density for site 2, upper San Antonio River, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected; sp., species]

DIVISION *Genus species*	Sample date		
	April 4	June 27	August 29
	Density (cells per milliliter)		
BACILLARIOPHYTA (diatoms)			
Achnanthes minutissima	82	--	--
Achnanthes sp.	21	--	--
Asterionella formosa	21	--	--
Cocconeis placentula	41	--	--
Cyclotella ocellata	110	--	--
Cyclotella stelligera	--	--	300
Cymbella affinis	21	190	--
Cymbella turgidula	120	--	--
Navicula cryptocephala	42	--	--
Navicula hambergii	41	--	--
Navicula minima	21	--	--
Navicula pupula	--	380	--
Navicula radiosa	--	570	2,700
Navicula sp.	61	--	--
Navicula tripunctata	82	--	--
Nitzschia acicularis	21	--	--
Nitzschia filiformis	21	--	--
Nitzschia fonticola	21	--	--
Nitzschia palea	270	--	--
Pinnularia biceps	--	1,100	600
Surirella ovata	21	--	--
Surirella patella	--	190	--
Surirella robusta	--	--	900
Synedra ulna	--	950	1,800
CHLOROPHYTA (green algae)			
Chlamydomonas sp.	560	--	1,200
Chlorella sp.	--	2,300	2,700
Closterium sp.	--	380	--
Cosmarium denticulatum	--	--	900
Cosmarium ovale	--	190	--
Oocystis pusilla	450	--	--
Tetraedron gracile	--	--	600
Tetraedron muticum	110	--	--
Unknown coccoid	340	--	--
CRYPTOPHYTA (cryptophytes)			
Cryptomonas erosa	110	--	--

Table 18. Phytoplankton species list and density for site 2, upper San Antonio River, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date April 4	 June 27	 August 29
	Density (cells per milliliter)—Continued		
CYANOPHYTA (blue-green algae)			
Anabaena flos-aquae	--	950	1,200
Aphanocapsa delicatissima	2,500	--	--
Aphanothece sp.	1,000	--	--
Chroococcus dispersus	560	--	--
Chroococcus minutus	2,700	--	--
Chroococcus sp.	110	--	--
Dactylococcopsis sp.	110	--	--
Gloeothece linearis	680	--	--
Microcystis aeruginosa	--	10,000	17,000
Oscillatoria sp.	1,100	--	300
Spirulina sp.	110	--	--
Synechococcus sp.	110	--	--
EUGLENOPHYTA (euglenoids)			
Euglena acus	--	380	--
Phacus sp.	--	190	--
Trachelomonas sp.	110	760	--
Total (rounded)	12,000	19,000	30,000
Total taxa	33	14	12
Diversity index	2.5	1.7	1.6
Maximum diversity index	3.5	2.6	2.5
Evenness	.7	.7	.6

Table 19. Phytoplankton species list and density for site 3, upper San Antonio River, San Antonio, Texas, 1989

[Diversity index computed using a modified version of Shannon's equation (Shannon and Weaver, 1949). --, not detected; sp., species]

DIVISION *Genus species*	Sample date		
	April 7	June 26	August 28
	Density (cells per milliliter)		
BACILLARIOPHYTA (diatoms)			
Bacillaria paradoxa	--	--	940
Cocconeis diminuta	--	1,200	940
Cocconeis placentula	19	--	--
Cyclotella stelligera	--	--	1,400
Cymatopleura solea	9	400	--
Gomphonema constrictum	--	1,600	--
Gomphonema subclavatum	9	--	--
Melosira ambigua	--	--	470
Meridion circulare	--	400	--
Navicula grimmei	9	--	--
Navicula radiosa	--	800	1,400
Navicula sp.	19	--	--
Nitzschia dissipata	28	--	--
Nitzschia fonticola	--	--	940
Nitzschia palea	19	400	--
Pinnularia biceps	--	--	2,800
Pinnularia latevittata	--	--	470
Surirella angustata	--	800	--
Surirella robusta	--	400	--
Synedra ulna	--	800	--
CHLOROPHYTA (green algae)			
Chlamydomonas sp.	220	--	--
Chlorella sp.	--	1,600	3,300
Franceia ovalis	56	--	--
Unknown coccoid	110	--	--
CRYPTOPHYTA (cryptophytes)			
Cryptomonas sp.	56	--	--
CYANOPHYTA (blue-green algae)			
Anabaena flos-aquae	--	2,000	470
Aphanocapsa delicatissima	1,400	--	--
Aphanothece sp.	390	--	--
Chroococcus minutus	1,200	--	--
Chroococcus sp.	680	--	--
Gloeothece linearis	56	--	--
Lyngbya sp.	280	--	--
Microcystis aeruginosa	--	26,000	32,000
Oscillatoria sp.	220	--	--

Table 19. Phytoplankton species list and density for site 3, upper San Antonio River, San Antonio, Texas, 1989—Continued

DIVISION *Genus species*	Sample date April 7	 June 26	 August 28
	Density (cells per milliliter)—Continued		
Synechococcus sp.	170	--	--
EUGLENOPHYTA (euglenoids)			
Euglena sp.	--	--	940
Euglena acus	--	1,200	--
Trachelomonas sp.	--	2,000	940
Total (rounded)	5,000	40,000	47,000
Total taxa	19	14	13
Diversity index	2.1	1.5	1.4
Maximum diversity index	2.9	2.6	2.6
Evenness	.7	.6	.5

Table 20. Water-quality data for site 1, lower Olmos Creek, San Antonio, Texas, 1989

[m^3/s, cubic meters per second; µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mm, millimeters; Hg, mercury; $CaCO_3$, calcium carbonate; --, not determined; N, nitrogen; NO_2+NO_3, nitrite plus nitrate; P, phosphorus; µg/L, micrograms per liter; µg/g micrograms per gram; <, less than]

Date	Time	Discharge, instantaneous (m^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Color (platinum-cobalt units)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Barometric pressure (mm of Hg)	Oxygen, dissolved (percent saturation)	Oxygen demand, biochemical, 5 day (mg/L)	Hardness, total (mg/L as $CaCO_3$)
Apr												
03...	1310	0.01	404	7.7	26.0	30	12	7.1	741	90	4.2	160
26...	1120	.01	545	7.4	23.0	--	--	3.2	747	38	--	--

Date	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium (percent)	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
Apr											
03...	56	6.0	16	17	0.5	5.6	130	44	15	0.30	7.9
26...	--	--	--	--	--	--	--	--	--	--	--

Table 20. Water-quality data for site 1, lower Olmos Creek, San Antonio, Texas, 1989—Continued

Date	Solids, sum of constituents, dissolved (mg/L)	Residue, total at 105 °C, suspended (mg/L)	Residue, volatile, suspended (mg/L)	Residue, fixed nonfilterable (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
Apr											
03...	231	34	5	29	0.038	0.300	0.292	0.132	0.80	0.150	0.082
26...	--	--	--	--	--	--	--	--	--	--	--

Date	Carbon organic, total (mg/L)	Cyanide, total (mg/L)	Aluminum, total recoverable (µg/L)	Arsenic, total (µg/L)	Arsenic, total, in bottom material (µg/g)	Barium, total recoverable (µg/L)	Barium, recoverable from bottom material (µg/g)	Cadmium, total recoverable (µg/L)	Cadmium, recoverable from bottom material (µg/g)	Chromium, total recoverable (µg/L)	Chromium, recoverable from bottom material (µg/g)
Apr											
03...	9.4	<0.010	280	2	7	100	60	<1	2	2	10
26...	--	--	--	--	--	--	--	--	--	--	--

Date	Copper, total recoverable (µg/L)	Copper, recoverable from bottom material (µg/g)	Iron, total recoverable (µg/L)	Lead, total recoverable (µg/L)	Lead, recoverable from bottom material (µg/g)	Mercury, total recoverable (µg/L)	Mercury, recoverable from bottom material (µg/g)	Nickel, total recoverable (µg/L)	Selenium, total (µg/L)	Silver, total recoverable (µg/L)	Zinc, total recoverable (µg/L)
Apr											
03...	3	10	340	<5	30	<0.10	0.06	6	<1	<1	10
26...	--	--	--	--	--	--	--	--	--	--	--

Table 21. Water-quality data for site 2, upper San Antonio River, San Antonio, Texas, 1989

[m^3/s, cubic meters per second; µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mm, millimeters; Hg, mercury; $CaCO_3$, calcium carbonate; --, not determined; <, less than; N, nitrogen; NO_2+NO_3, nitrite plus nitrate; P, phosphorus; µg/L, micrograms per liter; µg/g micrograms per gram]

Date	Time	Discharge, instantaneous (m^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Color (platinum-cobalt units)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Barometric pressure (mm of Hg)	Oxygen, dissolved (percent saturation)	Oxygen demand, biochemical, 5 day (mg/L)	Hardness, total (mg/L as $CaCO_3$)
Apr												
04...	1300	0.08	494	7.4	25.0	2	1.2	7.8	747	97	1.2	220
25...	1020	.08	487	7.4	24.0	--	--	7.0	745	85	--	--
June												
27...	1200	.07	480	7.3	25.0	5	2.6	7.8	752	96	.6	250
July												
25...	1115	.07	446	7.3	25.0	--	--	6.5	749	80	--	--
Aug												
29...	1130	.05	475	7.3	24.5	<1	.60	7.4	748	91	1.6	230

Date	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium (percent)	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
Apr											
04...	65	15	8.8	8	0.3	1.3	200	21	16	0.20	11
25...	--	--	--	--	--	--	--	--	--	--	--
June											
27...	72	16	9.8	8	.3	1.7	190	21	17	.20	13
July											
25...	--	--	--	--	--	--	--	--	--	--	--
Aug											
29...	66	15	9.2	8	.3	1.1	200	16	15	.20	12

Date	Solids, sum of constituents, dissolved (mg/L)	Residue, total at 105 °C, suspended (mg/L)	Residue, volatile, suspended (mg/L)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
Apr										
04...	269	8	<1	0.005	2.50	1.80	0.008	<0.20	0.020	0.011
25...	--	--	--	--	--	--	--	--	--	--
June										
27...	273	9	<1	.005	1.80	1.70	.024	.30	<.010	<.001
July										
25...	--	--	--	--	--	--	--	--	--	--
Aug										
29...	260	<1	<1	.002	1.70	1.70	.008	<.20	<.010	.008

Table 21. Water-quality data for site 2, upper San Antonio River, San Antonio, Texas, 1989—Continued

Date	Carbon, organic, total (mg/L)	Cyanide, total (mg/L)	Aluminum, total recoverable (µg/L)	Arsenic, total (µg/L)	Arsenic, total, in bottom material (µg/g)	Barium, total recoverable (µg/L)	Barium, recoverable from bottom material (µg/g)	Cadmium, total recoverable (µg/L)	Cadmium, recoverable from bottom material (µg/g)	Chromium, total recoverable (µg/L)	Chromium, recoverable from bottom material (µg/g)
Apr											
04...	0.8	<0.010	70	<1	3	100	40	1	2	1	7
25...	--	--	--	--	--	--	--	--	--	--	--
June											
27...	.6	<.010	150	1	3	100	20	<1	3	2	8
July											
25...	--	--	--	--	--	--	--	--	--	--	--
Aug											
29...	.6	<.010	140	<1	3	<100	<100	<1	2	1	10

Date	Copper, total recoverable (µg/L)	Copper, recoverable from bottom material (µg/g)	Iron, total recoverable (µg/L)	Lead, total recoverable (µg/L)	Lead, recoverable from bottom material (µg/g)	Mercury, total recoverable (µg/L)	Mercury, recoverable from bottom material (µg/g)	Nickel, total recoverable (µg/L)	Selenium, total (µg/L)	Silver, total recoverable (µg/L)	Zinc, total recoverable (µg/L)
Apr											
04...	2	7	70	<5	50	<0.10	0.04	4	<1	<1	10
25...	--	--	--	--	--	--	--	--	--	--	--
June											
27...	2	7	120	2	40	.10	.03	<1	<1	<1	10
July											
25...	--	--	--	--	--	--	--	--	--	--	--
Aug											
29...	5	9	80	3	70	.10	.06	3	<1	<1	<10

Table 22. Water-quality data for site 3, upper San Antonio River, San Antonio, Texas, 1989

[m^3/s, cubic meters per second; µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; NTU, nephelometric turbidity unit; mg/L, milligrams per liter; mm, millimeters; Hg, mercury; $CaCO_3$, calcium carbonate; --, not determined; <, less than; N, nitrogen; NO_2+NO_3, nitrite plus nitrate; P, phosphorus; µg/L, micrograms per liter; µg/g micrograms per gram]

Date	Time	Discharge, instantaneous (m^3/s)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Color (platinum-cobalt units)	Turbidity (NTU)	Oxygen, dissolved (mg/L)	Barometric pressure (mm of Hg)	Oxygen, dissolved (percent saturation)	Oxygen demand, biochemical, 5 day (mg/L)	Hardness, total (mg/L as $CaCO_3$)
Apr												
07...	1400	0.28	500	7.9	23.5	3	3.0	8.0	748	96	0.9	240
24...	1215	.27	502	7.6	24.0	--	--	6.6	747	80	--	--
June												
26...	1230	.18	492	7.5	25.0	5	3.3	6.5	751	80	.9	230
July												
24...	1145	.23	485	7.5	26.0	--	--	6.8	750	85	--	--
Aug												
28...	1400	.21	485	7.6	27.0	<1	2.6	6.5	745	84	1.9	230

Date	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium (percent)	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L)	Chloride, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
Apr											
07...	68	16	9.0	8	0.3	1.7	200	--	16	0.20	12
24...	--	--	--	--	--	--	--	--	--	--	--
June											
26...	69	15	9.0	8	.3	1.1	220	17	16	.20	12
July											
24...	--	--	--	--	--	--	--	--	--	--	--
Aug											
28...	69	15	10	8	.3	2.1	210	20	15	.20	12

Date	Solids, sum of constituents, dissolved (mg/L)	Residue, total at 105 °C, suspended (mg/L)	Residue, volatile, suspended (mg/L)	Residue, fixed nonfilterable (mg/L	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3, total (mg/L as N)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, ammonia + organic, total (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, ortho, dissolved (mg/L as P)
Apr											
07...	--	3	2	1	0.029	1.40	1.40	0.006	0.40	0.030	0.020
24...	--	--	--	--	--	--	--	--	--	--	--
June											
26...	276	3	<1	--	.035	1.60	1.60	.062	.50	.033	.023
July											
24...	--	--	--	--	--	--	--	--	--	--	--
Aug											
28...	277	6	5	1	.027	1.50	1.50	.057	.40	.030	.016

Table 22. Water-quality data for site 3, upper San Antonio River, San Antonio, Texas, 1989—Continued

Date	Carbon, organic, total (mg/L)	Cyanide, total (mg/L)	Aluminum, total recoverable (µg/L)	Arsenic, total (µg/L)	Arsenic, total, in bottom material (µg/g)	Barium, total recoverable (µg/L)	Barium, recoverable from bottom material (µg/g)	Cadmium, total recoverable (µg/L)	Cadmium, recoverable from bottom material (µg/g)	Chromium, total recoverable (µg/L)	Chromium, recoverable from bottom material (µg/g)
Apr											
07...	1.1	<0.010	100	<1	3	100	80	<1	2	2	10
24...	--	--	--	--	--	--	--	--	--	--	--
June											
26...	1.7	<.010	200	<1	3	100	70	<1	3	2	10
July											
24...	--	--	--	--	--	--	--	--	--	--	--
Aug											
28...	1.3	<.010	200	<1	2	<100	100	<1	2	1	7

Date	Copper, total recoverable (µg/L)	Copper, recoverable from bottom material (µg/g)	Iron, total recoverable (µg/L)	Lead, total recoverable (µg/L)	Lead, recoverable from bottom material (µg/g)	Mercury, total recoverable (µg/L)	Mercury, recoverable from bottom material (µg/g)	Nickel, total recoverable (µg/L)	Selenium, total (µg/L)	Silver, total recoverable (µg/L)	Zinc, total recoverable (µg/L)
Apr											
07...	2	30	120	<5	230	<0.10	0.05	<1	<1	<1	20
24...	--	--	--	--	--	--	--	--	--	--	--
June											
26...	2	10	150	3	230	.10	.02	1	<1	<1	30
July											
24...	--	--	--	--	--	--	--	--	--	--	--
Aug											
28...	4	10	120	3	220	.10	.05	1	<1	<1	<10

Table 23. Diel fluctuations in water-quality properties at site 2, upper San Antonio River, San Antonio, Texas, September 20–21, 1989

[µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; mg/L, milligrams per liter; --, not determined]

Time (hour)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Dissolved oxygen (mg/L)
1100	490	7.4	24.0	6.6
1200	--	7.4	24.5	6.8
1300	--	7.4	24.5	6.9
1400	--	7.5	25.0	7.0
1500	--	7.5	25.0	7.1
1600	--	7.5	25.5	7.2
1700	--	7.5	25.0	7.1
1800	--	7.5	25.0	7.0
1900	--	7.5	25.0	6.9
2000	--	7.5	25.0	6.8
2100	--	7.4	24.5	6.7
2200	--	7.4	24.5	6.6
2300	--	7.4	24.5	6.6
2400	--	7.4	24.5	6.5
0100	--	7.4	24.5	6.5
0200	--	7.4	24.0	6.5
0300	--	7.4	24.0	6.5
0400	--	7.4	24.0	6.4
0500	--	7.4	24.0	6.4
0600	--	7.4	24.0	6.4
0700	--	7.4	24.0	6.4
0800	--	7.4	24.0	6.5
0900	--	7.4	24.0	6.5
1000	--	7.4	24.0	6.6
1100	--	7.4	24.0	6.8
1200	546	7.4	24.5	7.1
Minimum	--	7.4	24.0	6.4
Maximum	--	7.5	25.5	7.2

Table 24. Diel fluctuations in water-quality properties at site 3, upper San Antonio River, San Antonio, Texas, September 19–20, 1989

[µS/cm, microsiemens per centimeter at 25 °C; °C, degrees Celsius; mg/L, milligrams per liter]

Time (hour)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Dissolved oxygen (mg/L)
0700	477	7.7	24.5	5.8
0800	481	7.7	24.5	5.8
0900	483	7.7	24.5	5.8
1000	485	7.7	24.5	6.0
1100	486	7.7	24.5	6.1
1200	487	7.8	24.5	6.2
1300	488	7.8	25.0	6.4
1400	488	7.8	25.0	6.5
1500	489	7.8	25.0	6.6
1600	490	7.8	25.0	6.6
1700	491	7.8	25.0	6.7
1800	491	7.8	24.5	6.7
1900	492	7.8	24.5	6.6
2000	493	7.8	24.5	6.5
2100	493	7.8	24.5	6.5
2200	495	7.8	24.5	6.4
2300	496	7.8	24.5	6.4
2400	496	7.8	24.5	6.5
0100	497	7.8	24.5	6.4
0200	498	7.8	24.5	6.4
0300	499	7.8	24.5	6.3
0400	500	7.8	24.5	6.2
0500	501	7.8	24.5	6.1
0600	502	7.8	24.5	6.0
0700	503	7.8	24.5	5.9
0800	504	7.8	24.5	5.9
Minimum	477	7.7	24.5	5.8
Maximum	504	7.8	25.0	6.7

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