Stormflow Chemistry in the Santa Ana River below Prado Dam and at the Diversion Downstream from Imperial Highway, Southern California, 1995–98

By John A. Izbicki, Gregory O. Mendez, *and* Carmen A. Burton

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
Placer Hall, Suite 2012
6000 J Street
Sacramento, CA 95819-6129

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CONTENTS

FIGURES

Appendix A:

TABLES

Appendix Tables:

CONVERSION FACTORS, VERTICAL DATUM, WATER-CHEMISTRY UNITS, AND ABBREVIATIONS AND ACRONYMS

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Volume	
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
	Flow Rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F=1.8(°C)+32.$$

Vertical Datum

*Sea leve*l: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Chemistry Units

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations and Acronyms.

AFX, automated segmented flow
DOC, dissolved organic carbon
GS/MS, gas chromatography/mass spectrometry
HPLC, high performance liquid chromatography
kg, kilogram
MCL, Maximum Contaminant Level (U.S. Environmental Protection Agency)
MTBE, methyl tert-butyl ether (a volatile organic compound used as a gasoline additive)
nm, nanometer (one-billionth of a meter)
OCWD, Orange County Water District
PAH, polycyclic aromatic hydrocarbon
SARWQHS, Santa Ana River Water Quality and Health Study (Orange County Water District)
SMCL, Secondary Maximum Contaminant Level (U.S. Environmental Protection Agency)
SOC, suspended organic carbon
USEPA, U.S. Environmental Protection Agency
µS/cm, microsiemen per centimeter
USGS, U.S. Geological Survey
UV, ultraviolet
VOC, volatile organic compound

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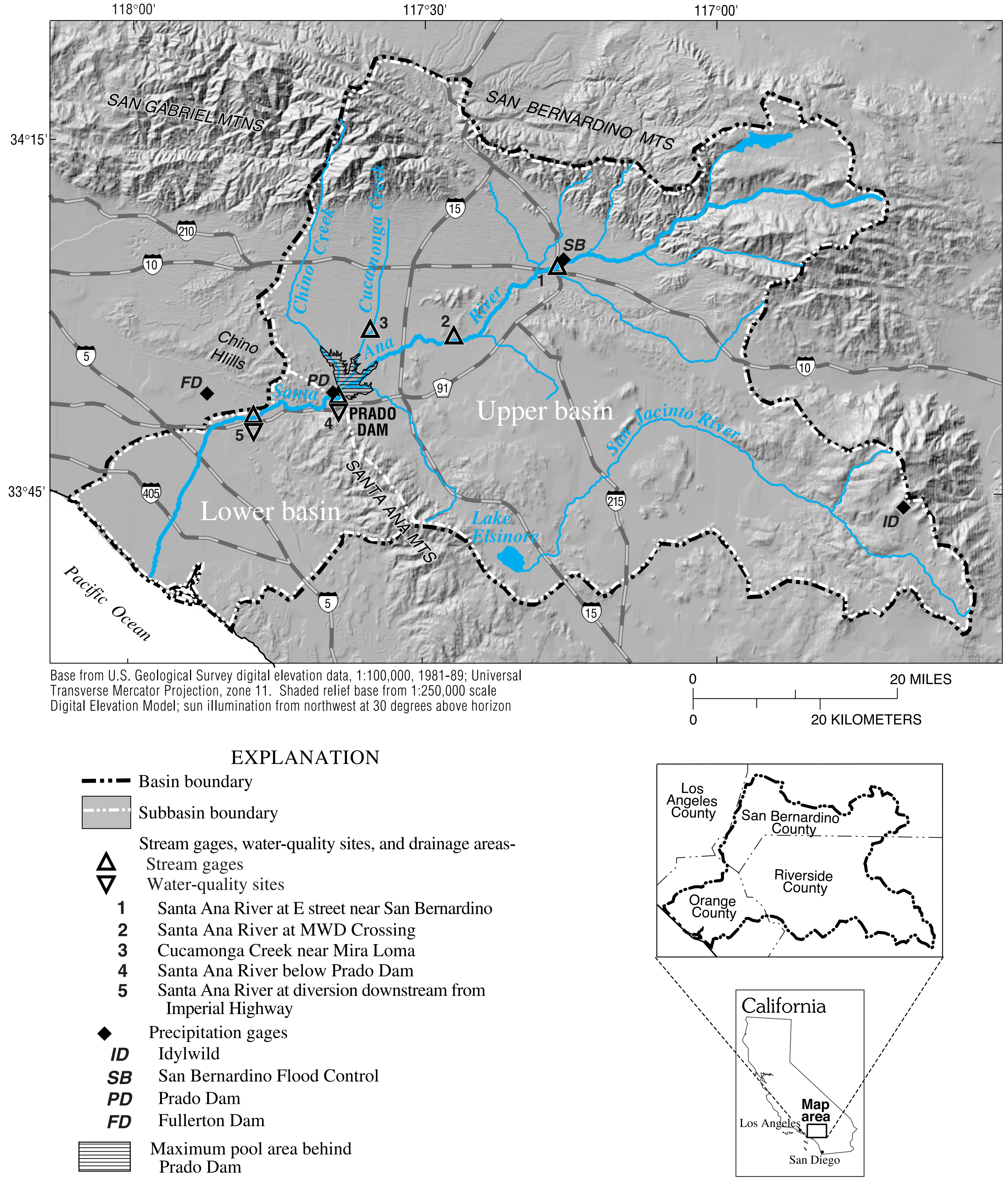
ABSTRACT

The Santa Ana River drains about 2,670 square miles of the densely populated coastal area of southern California, near Los Angeles. Almost all the flow in the river, more than 200,000 acre-feet annually, is diverted into ponds where it infiltrates and recharges underlying aquifers. About 2 million people are dependent on these aquifers for water supply. Stormflow in the Santa Ana River is considered a source of "high-quality" water suitable for use as a source of ground-water recharge. To test this assumption, stormflow samples were collected at two locations—below Prado Dam and at the diversion point downstream from Imperial Highway—for 12 winter storms between 1995 and 1998.

Nitrate concentrations decreased during stormflow from a median concentration of 7.8 milligrams per liter in base flow to concentrations less than 1 milligram per liter in some large storms. Concentrations of chemically reduced forms of nitrogen (nitrite, ammonia, and organic nitrogen) increased during stormflow and are the predominant forms of nitrogen in large stormflows. Dissolved organic carbon (DOC) concentrations increased from a median concentration of 4.6 milligrams per liter in base flow to more than 20 milligrams per liter in some stormflows. Concentrations of DOC were especially high during the first storm of the rainy season, and large increases in DOC concentrations were measured even as a result of small early season storms that did not cause large increases in streamflow. DOC present during early season stormflow had less ultraviolet absorbance at 254 nanometers (UV_{254}) per unit of carbon than did DOC from late season stormflows. DOC in water held in storage behind Prado Dam had the highest UV_{254} absorbance per unit of carbon. Maximum pesticide concentrations in stormflow did not exceed U.S. Environmental Protection Agency Maximum Contaminant Levels. Most pesticide concentrations were less than 1 microgram per liter and less than the detection limits obtained using standard drinking water analyses. Increases in concentrations of pesticides such as diazinon, malathion, and chlorpyrifos in stormflow result from runoff from urban areas downstream from Prado Dam. In general, large late season stormflows have the most pesticide detections of all stormflows sampled. Concentrations of methyl tert-butyl ether (MTBE), a gasoline additive, during base flow were as high as 0.9 microgram per liter and concentrations decreased during stormflow. Like pesticides, the concentrations did not exceed the U.S. Environmental Protection Agency Maximum Contaminant Levels for MTBE.

INTRODUCTION

The Santa Ana River drains about 2,670 square miles (mi^2) of the densely populated coastal area of southern California near Los Angeles (fig. 1). Almost all flow in the Santa Ana River, more than 200,000 acre-feet (acre-ft) of water annually, is diverted to ponds where it is allowed to infiltrate and recharge underlying aquifers (Orange County Water District,



Base from U.S. Geological Survey digital elevation data, 1:100,000, 1981-89; Universal Transverse Mercator Projection, zone 11. Shaded relief base from 1:250,000 scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Figure 1. Santa Ana River basin and location of stream gages, water-quality sites, and precipitation gages, southern California.

1996a). Pumpage from these aquifers is the primary source of supply for about 2 million people in Orange County, California (Orange County Water District, 1996a).

Base flow in the Santa Ana River is maintained almost entirely by discharges of treated municipal wastewater (Burton and others, 1998). At present (2000), the assumption guiding ground-water recharge operations is that stormflow in the Santa Ana River is "high-quality" water suitable to recharge aquifers pumped as a source of public supply. Large quantities of water recharged during stormflows in the winter are believed to improve the overall quality of water recharged from the Santa Ana River. However, stormflows include runoff from urban and agricultural areas and may contain high concentrations of inorganic and organic constituents that can degrade water quality. In the past, few data were available to address these concerns.

In 1995, the Orange County Water District (OCWD) began a series of studies to characterize the quality of the Santa Ana River water, the effects of recharge from the river on ground-water quality, and the potential health effects associated with using water from the Santa Ana River to recharge aquifers that are pumped for water supply. These studies are collectively known as the Santa Ana River Water Quality and Health Study (SARWQHS) (Orange County Water District, 1996b). This report is part of the SARWQHS and was funded by the Orange County Water District in cooperation with the U.S. Geological Survey (USGS). As part of the SARWQHS, historical changes in water chemistry in the Santa Ana River were evaluated by the USGS (Burton and others, 1998). Data from that report serve as a benchmark to evaluate changes in water chemistry that occur during stormflow.

Purpose and Scope

The purpose of this report is to evaluate changes in the concentrations of selected water-quality constituents in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway during stormflow. The first storm of the rainy season was of special interest because of potentially large changes in water chemistry if soluble material that accumulated in the basin during the dry season was washed into the Santa Ana River or its tributaries. The scope of the study included collection and analysis of water samples during 12 stormflows between December 1995 and February 1998 for dissolved nutrients, dissolved organic carbon, selected dissolved pesticides and volatile organic compounds, and selected dissolved trace elements.

Acknowledgments

The authors thank Greg Peacock of the U.S. Army Corps of Engineers for precipitation and stage data for Prado Dam; and Alan Flowers, Chris McConaghy, and John Vandenburgh of the Orange County Water District for data on the surface flow and diversion of water by the Orange County Water District downstream from Imperial Highway. The authors thank the scientific review panel of the SARWQHS for sharing their expertise and for their input throughout this study.

DESCRIPTION OF THE SANTA ANA RIVER BASIN

The Santa Ana River hydrologic unit, which includes the Santa Ana River drainage basin and a few small streams near the coast that discharge into the ocean, is about 2,670 mi^2. The area includes parts of San Bernardino, Riverside, Los Angeles, and Orange Counties (fig. 1). The river flows to the west and discharges into the Pacific Ocean. The topography of the basin ranges from steep, rugged mountains, with peaks as high as 11,500 feet (ft) above sea level, to broad alluvial valleys and a coastal plain to the west. The climate is characterized by warm, dry summers and cool, moist winters. Average annual precipitation ranges from about 12 inches (in.) near the coast to about 18 in. in the inland valleys. In the higher mountains, cool summers and cold winters prevail. Average annual precipitation can exceed 40 in. in some of the higher mountains. Most precipitation occurs between November and March (U.S. Army Corps of Engineers, 1994), but in some years the rainy season may begin as early as September and (or) end as late as June.

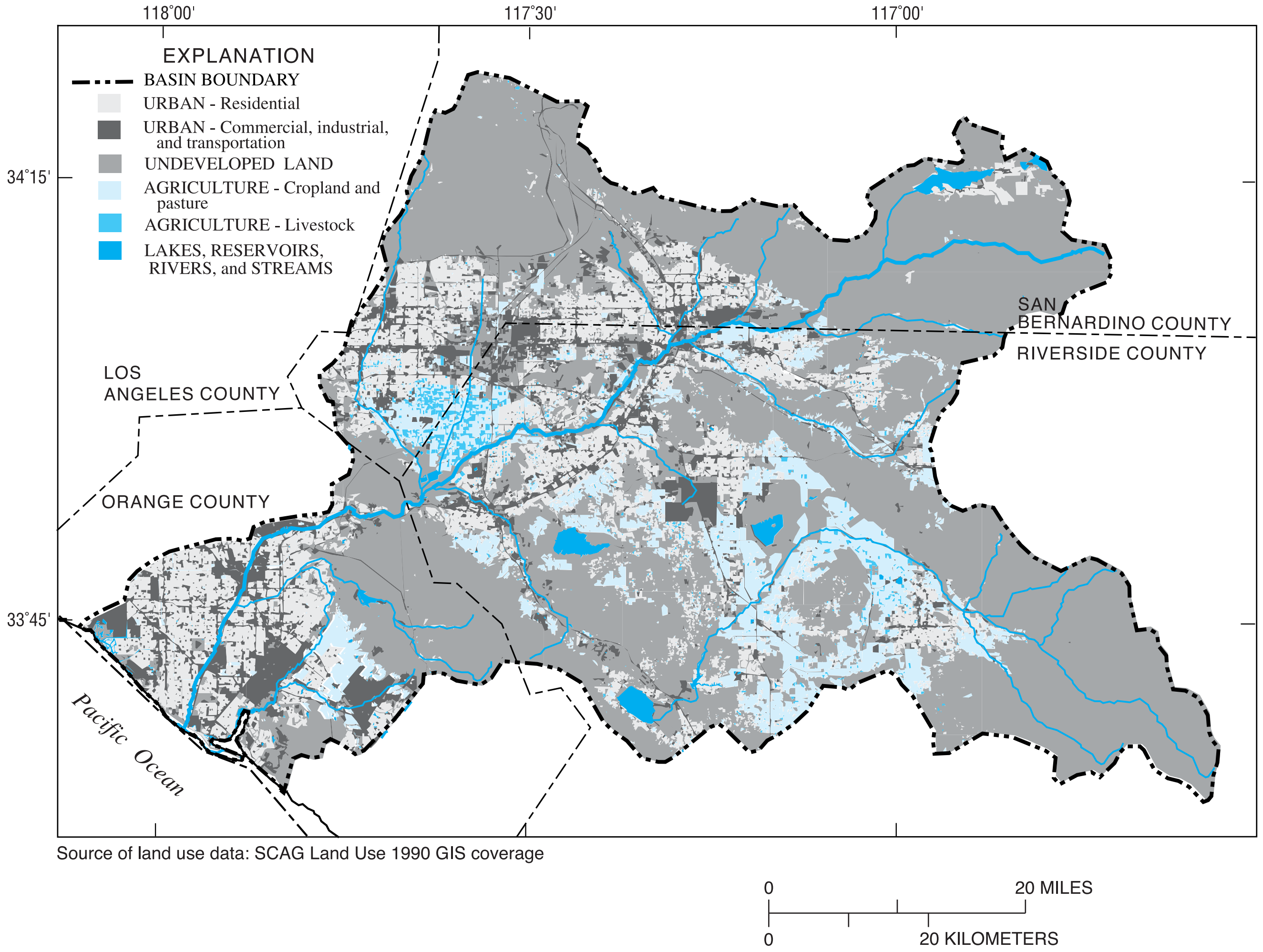
Population, Land Use, and Water Use

Since the 1940's, the population in the Santa Ana River basin has increased rapidly, and agricultural and undeveloped land uses have decreased while urban land uses have increased. In 1990, the population in the

Santa Ana River basin was more than 4.5 million (Santa Ana Regional Water Quality Control Board, 1995), and land use ranged from dense urban development in the coastal plain and inland valleys to undeveloped wilderness in the high mountains (fig. 2). In 1990, land use in the study area was 32 percent urban, 11 percent agricultural, and 57 percent undeveloped. Agricultural land use was largely cropland and pastures but also included orchards and dairies.

In 1995, there were about 340 animal-confinement facilities and more than 340,000 animals (primarily dairy cows) within the Santa Ana River basin (Santa Ana Regional Water Quality Control Board, 1996). About 300 of these facilities and most of the animals (about 300,000) are in the area drained by Chino and Cucamonga Creeks to the north of Prado Dam (fig. 1).

Local water is extensively managed for public supply and additional water is imported from northern California and the Colorado River through aqueducts. Most of the water used for public supply is eventually discharged to the Santa Ana River, its larger tributaries, or adjacent shallow ground water as treated municipal wastewater. To meet water-quality objectives established for the basin by the Santa Ana Regional Water Quality Control Board (1995), almost all municipal wastewater discharged to the river is tertiary treated. Storm and sanitary sewers are separate in communities within the Santa Ana River basin, and combined sewer overflows to the river are not a problem (Burton and others, 1998). In addition to the tertiary treatment of municipal wastewater, about half of the base flow of the Santa Ana River is treated to remove nitrate by a series of artificial wetlands upstream from Prado Dam (O'Connor, 1995; Brian



Source of land use data: SCAG Land Use 1990 GIS coverage

Figure 2. Land use in the Santa Ana River basin, southern California, 1990.

Baharie, Orange County Water District, oral commun., 1996).

Almost all flow in the Santa Ana River, more than 200,000 acre-ft annually, is diverted by the Orange County Water District (1996a) for ground-water recharge downstream from Imperial Highway (fig. 1). Only water from the larger stormflows, which exceed the capacity of the diversion facility, is not diverted for ground-water recharge.

Water rights to the Santa Ana River have been the subject of much litigation. The April 17, 1969, Stipulation for Judgement in Orange County Water District versus City of Chino, et. al. provides for a regional allocation of water supply among the major public water districts in the Santa Ana River basin; this decision covers both the quantity and the quality of streamflow in the Santa Ana River below Prado Dam (Santa Ana River Watermaster, 1996).

Streamflow Characteristics

For the purposes of this report, the Santa Ana River basin was divided into an upper basin and a lower basin (fig. 1). The upper basin is that part of the basin upstream from the Chino Hills and the Santa Ana Mountains. The upper basin drains the headwater areas in the mountains in the northern and eastern part of the basin and the inland alluvial valleys; the upper basin is about 2,470 mi^2, including 768 mi^2 in the San Jacinto River/Lake Elsinore drainage. The San Jacinto River/Lake Elsinore drainage does not normally contribute flow to the Santa Ana River, and in most years Lake Elsinore (a naturally occurring graben lake) is the terminus for flow in the San Jacinto River. However, flow from the San Jacinto River/Lake Elsinore drainage into Temescal Wash and the Santa Ana River occurred in 1917, 1980, and 1995 (California Department of Water Resources, 1982; O'Connor, 1995; Santa Ana River Watermaster, 1996). The lower basin is that part of the Santa Ana River basin downstream from the Chino Hills and the Santa Ana Mountains—an area of about 200 mi^2. The lower basin drains the western slopes of the Chino Hills and Santa Ana Mountains and the coastal plain.

Base flow in the Santa Ana River is maintained by discharges of treated municipal sewage. In 1995, base flow in the Santa Ana River below Prado Dam averaged 180 cubic feet per second (ft^3/s), almost equaling the combined discharge from upstream wastewater-treatment plants (Burton and others, 1998). Streamflow in the Santa Ana River also is supplemented by releases of imported water from northern California and from the Colorado River. Unlike wastewater discharges, these releases are intermittent and are intended to supplement local water supply.

High flows in the Santa Ana River occur during the rainy season as a result of precipitation and subsequent runoff. Most precipitation falls between November and March (U.S. Army Corps of Engineers, 1994), but in some years the rainy season may begin as early as September and (or) end as late as June. The largest historical flow in the Santa Ana River occurred in January 1862 and was estimated to be about 320,000 ft^3/s at Riverside Narrows, near MWD crossing (fig. 1) (U.S. Army Corps of Engineers, 1994).

Since 1940, streamflow between the upper and lower parts of the Santa Ana River basin has been regulated by Prado Dam. Regulation of streamflow has reduced peak flows during the winter by releasing stormwater gradually over a period of several days, weeks, or months (U.S. Army Corps of Engineers, 1994). Since the construction of the dam, peak flows have been smaller in magnitude and have not exceeded 7,500 f^3/s below Prado Dam or 10,600 ft^3/s at Imperial Highway. In recent years, increased urbanization may have resulted in increased runoff and larger peak flows (U.S. Army Corps of Engineers, 1994): peak flows greater than 1,000 ft^3/s can occur at Imperial Highway as a result of runoff from urban areas downstream from Prado Dam, even when only small quantities of water are being released by the dam (Alan Flowers, Orange County Water District, oral commun., 1996).

Prado Dam is operated according to a complex set of procedures intended to minimize flood damage in the lower part of the Santa Ana River basin and to maximize availability of surface water for ground-water recharge by OCWD (U.S. Army Corps of Engineers, 1994). To help minimize flood damage, the channel of the Santa Ana River downstream from Prado Dam has been extensively modified to serve as an urban floodway. To minimize adverse effects on endangered species in wetland areas behind Prado Dam, water is not stored behind the dam during the dry season (U.S. Army Corps of Engineers, 1994).

APPROACH

Stormflows were sampled at two sites along the Santa Ana River, below Prado Dam and at the diversion downstream from Imperial Highway; the latter site is hereafter referred to as "Imperial Highway" (fig. 3). Imperial Highway is about 11 miles (mi) downstream from Prado Dam. Stormflow data from Imperial Highway reflects the quality of water diverted for recharge and is a combination of runoff from urban areas downstream from Prado Dam; runoff from areas upstream from Prado Dam; and, during the later part of the rainy season, runoff from previous storms that was stored behind Prado Dam. Data from both sites were combined to estimate water quality during base flow, and early season and late season stormflow. Data from the two sites were compared and contrasted to provided an estimate of the quantity and quality of runoff from urban areas between Prado Dam and Imperial Highway. One emphasis of the study was evaluation of possible "first flush" effects on water chemistry. Therefore, it was necessary that stormflow from the first storm of each rainy season be sampled.

Characterization of changes in water quality during stormflow required sample collection prior to the beginning of the stormflow and across the entire stormflow hydrograph, including the rising limb, peak flow, and recessional flow. Typical weather forecasts are not accurate enough to determine when to begin sample collection. Commercially available doppler radar was used to supplement weather forecasts and facilitate sample collection by providing advanced warning of storms (fig. 4). These data provided 4 to 6 hours warning for storms from the northwest. They provided less warning and less accurate predictions of precipitation originating from the southwest or southeast. Doppler radar also provided real-time data on the current precipitation, and real-time data estimates of the expected amount and duration of precipitation from each storm. These data were used during storms to determine sample-collection frequency. The doppler radar record also was used with data from a tipping-bucket rain gage network operated by the U.S. Army Corps of Engineers to provide a record of the timing and distribution of precipitation during each storm.

Detailed sample collection across the stormflow hydrograph is labor intensive and prohibitively expensive if done using conventional techniques, such as depth-integrated sampling. Automated samplers were used to collect many samples during a single stormflow and reduce costs. However, these samples collected are not depth-integrated and may not necessarily be representative of suspended sediment or sorbed constituents. Most samples were analyzed for a small number of constituents, such as nitrate or ultraviolet (UV) absorbance that are relatively inexpensive to analyze. Fewer samples were analyzed for other constituents, such as pesticides, that are more expensive to analyze. Automated samplers were not used for the collection of volatile organic carbon samples. Quality-assurance procedures are described in Appendix A. Sample collection, preservation, and analytical methods are described in Appendix B.

SAMPLED STORMFLOWS

Twelve stormflows were sampled between December 1995 and February 1998: two were sampled during the rainy season of 1995–96, and five were sampled during each of the two following rainy seasons (fig. 5). The sampled stormflows included the first stormflows of each rainy season. Precipitation at Prado Dam for sampled stormflows ranged from 0.03 to 4.55 in. (table 1). The largest storm (December 5–9, 1997) produced almost 10 in. of rain at some sites in the basin and caused flooding in parts of coastal Orange County.

The 1995–96 rainy season was drier than average and the 1996–97 rainy season was about average. The last storm of the 1996–97 rainy season occurred near the end of January, several months earlier than usual, and was followed by one of the driest periods on record—197 days with no precipitation in parts of the upper basin and 207 days with no precipitation in the lower basin. The 1997–98 rainy season was much wetter than average because of "El Niño," a warming of the tropical Pacific Ocean that can result in extreme weather throughout the world and greater than average precipitation in southern California. As a result of El Niño, February 1998 was one of the wettest Februarys on record in southern California.

Peak stormflows sampled as part of this study were as great as 5,830 ft^3/s below Prado Dam and 5,960 ft^3/s at Imperial Highway (table 1). The largest stormflow occurred January 25–30, 1997, and included water that had been stored behind the dam. The inclusion of stored water occurred during many of the large, late season stormflows sampled as part of this study (fig. 5).

A. Below Prado Dam, looking upstream (September 5, 1996, streamflow is approximately 173 cubic feet per second).

B. Diversion downstream from Imperial Highway, looking across from left bank [flow is to the left] (November 7, 1996, streamflow is approximately 190 cubic feet per second).

Figure 3. Santa Ana River ***(A)*** below Prado Dam, and ***(B)*** at the diversion downstream from Imperial Highway, southern California.

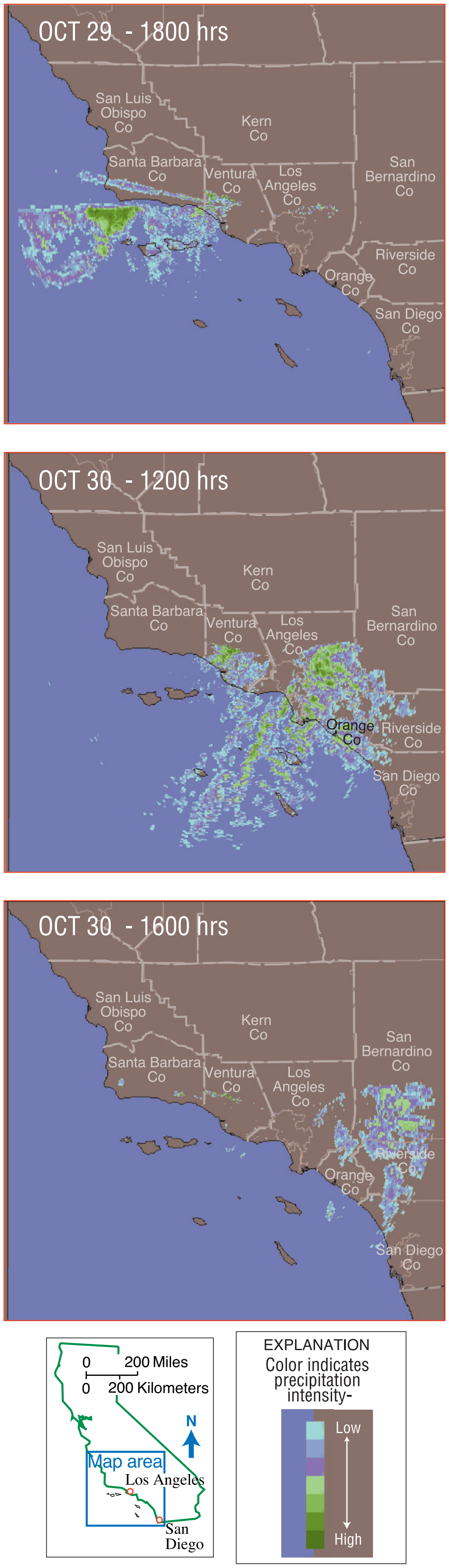


Figure 4. Doppler radar images of precipitation in southern California, October 29–30, 1996.

Comparison and contrast of precipitation and runoff during 3 of the 12 storms, and resulting stormflows (fig. 6), were used to simplify the presentation of stormflow-chemistry data in this report. The three storms selected are representative of the types of storms that occur in the Santa Ana basin. Data from these three storms and stormflows will be used throughout this report to evaluate changes in stormflow water chemistry.

The storm that produced the October 30–November 1, 1996, stormflow (fig. 6A) was the first storm of the 1996–97 rainy season. This storm was from the northwest and yielded 0.89 in. of rain at Prado Dam (table 1). This precipitation, although large in quantity and relatively intense for a first storm of the rainy season, is typical of early season winter storms in southern California in that precipitation began near the coast and moved inland (figs. 4 and 6A).

The storm that produced the January 25–30, 1997, stormflow (fig. 6B) occurred later in the rainy season. This storm was from the northwest and yielded 1.7 in. of rain at Prado Dam. The quantity of precipitation was not exceptionally large; however, the stormflow was one of the largest sampled as part of this study because it included the release of water stored behind Prado Dam (table 1). Although this storm was from the northwest, analysis of regional satellite and doppler radar images show that this storm included precipitation from warm, moist air drawn into the basin from the southwest. These storms, which typically occur later in the rainy season, produced many of the larger magnitude, longer duration storms and stormflows sampled during this study. The “El Niño” storms that caused record precipitation during the 1997–98 rainy season were similar to this storm. The large stormflows during the 1997–98 rainy season also included water released from behind Prado Dam.

The storm that produced the September 25–27, 1997, stormflow (fig. 6C) was the second storm of the 1997–98 rainy season, but the first to include runoff from the lower basin and the first significant stormflow of the 1997–98 rainy season. This storm was a hurricane that originated from the southeast and yielded 0.75 in. of rain at Prado Dam (table 1). Although not usually destructive, precipitation from hurricanes is not unusual in the study area and two hurricanes occurred (September 14–16 and 25–27, 1997) during the study. It was flooding from a hurricane in 1936 that prompted the construction of Prado Dam (U.S. Army Corps of Engineers, 1994).

Timing and Distribution of Precipitation and Runoff

The timing and distribution of precipitation and subsequent runoff during most storms causes some tributary streams, such as Cucamonga Creek, to produce more runoff, more quickly, than does the main stem of the Santa Ana River. Cucamonga Creek is in the

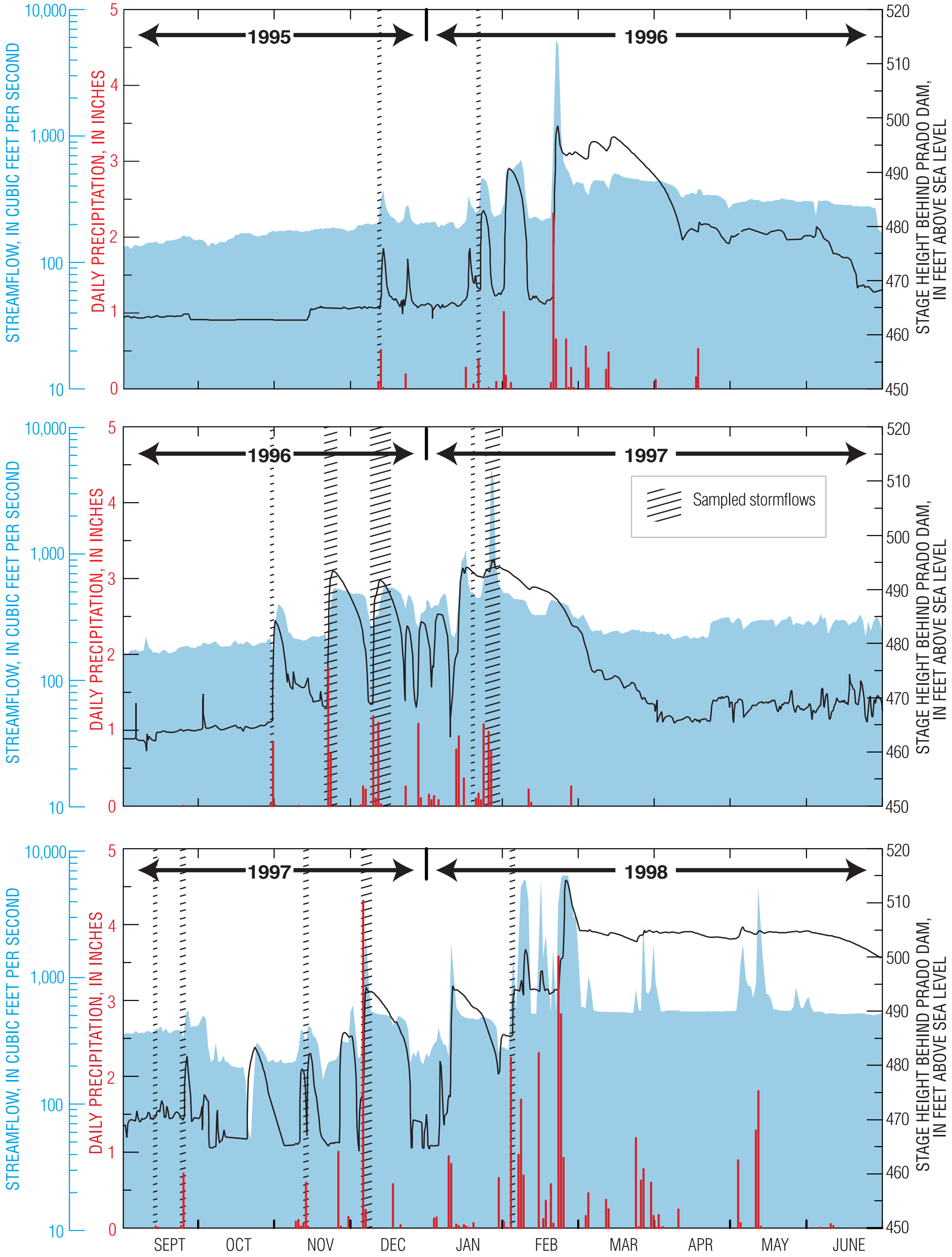


Figure 5. Sampled stormflows, precipitation, and stage at Prado Dam and streamflow in the Santa Ana River below Prado Dam during the 1995–96, 1996–97, and 1997–98 rainy seasons.

northwestern part of the basin, which is closer to the coast than are other parts of the upper basin. As a result, during many storms it rains here first and runoff begins earlier here (fig. 6A). In addition, Cucamonga Creek is concrete-lined throughout much of its length and stormflow is flashy. Peak flows are larger and the water flows more rapidly to downstream sites in concrete-lined channels than in natural channels. This flashy response to rainfall in Cucamonga Creek produced runoff quicker than did the main stem of the Santa Ana River upstream from Prado Dam even when precipitation began in the southeastern part of the basin—as in the September 25–27, 1997, storm (fig. 6C). Although the data are not shown in figure 6, the timing and distribution of runoff in Chino Creek (fig. 1) is similar to the timing and distribution of runoff in Cucamonga Creek. As a result of their location, the timing and distribution of precipitation, flashy runoff, and infiltration of stormflow into the channel along the main stem of the Santa Ana River, Cucamonga and Chino Creeks have a larger effect on downstream stormflow than would be expected on the basis of their drainage areas—especially during the early part of the rainy season.

Table 1. Summary of stormflow sample collection in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California

[OCWD, Orange County Water District; USGS, U.S. Geological Survey; ft^3/s, cubic feet per second]

Sample dates	Precipitation at Prado Dam (inches)	Peak streamflow: Below Prado Dam (ft^3/s)	Peak streamflow: Diversion downstream from Imperial Highway [1] (ft^3/s)	Laboratory	Classification
1995–96					
(September-April precipitation 9.24 inches))					
December 12–13	0.61	401	349	OCWD	Early season storm
January 21–22	.38	470	467	OCWD	Late season storm
1996–97					
(September-April precipitation 13.95 inches)					
October 30– November 1	0.89	799	799	USGS	Early season storm
November 21–26	2.53	540	595	USGS	Late season storm
December 9–17	2.42	561	970	USGS	Late season storm
January 19–22	.26	500	565	USGS	Late season storm
January 25–30	1.7	5,830	[2]5,960	USGS	Late season storm
1997–98					
(September-April precipitation 32.49 inches)					
September 14–16	0.03	[3]405	[3]406	USGS	Early season storm
September 25–27	.75	655	717	USGS	Early season storm
November 10–12	.58	379	413	USGS	Early season storm
December 5–9	4.55	4,630	[2]3,600	USGS	Late season storm
February 3–5	2.25	3,060	[2]2,080	USGS	Late season storm

[1] Calculated from data reported by OCWD.

[2] Accuracy of flow data is poor at high flows when diversion dam is deflated.

[3] Base flow was augmented by releases of imported water to the Santa Ana River; only a small increase in streamflow, about 20 ft^3/s, occurred during this storm.

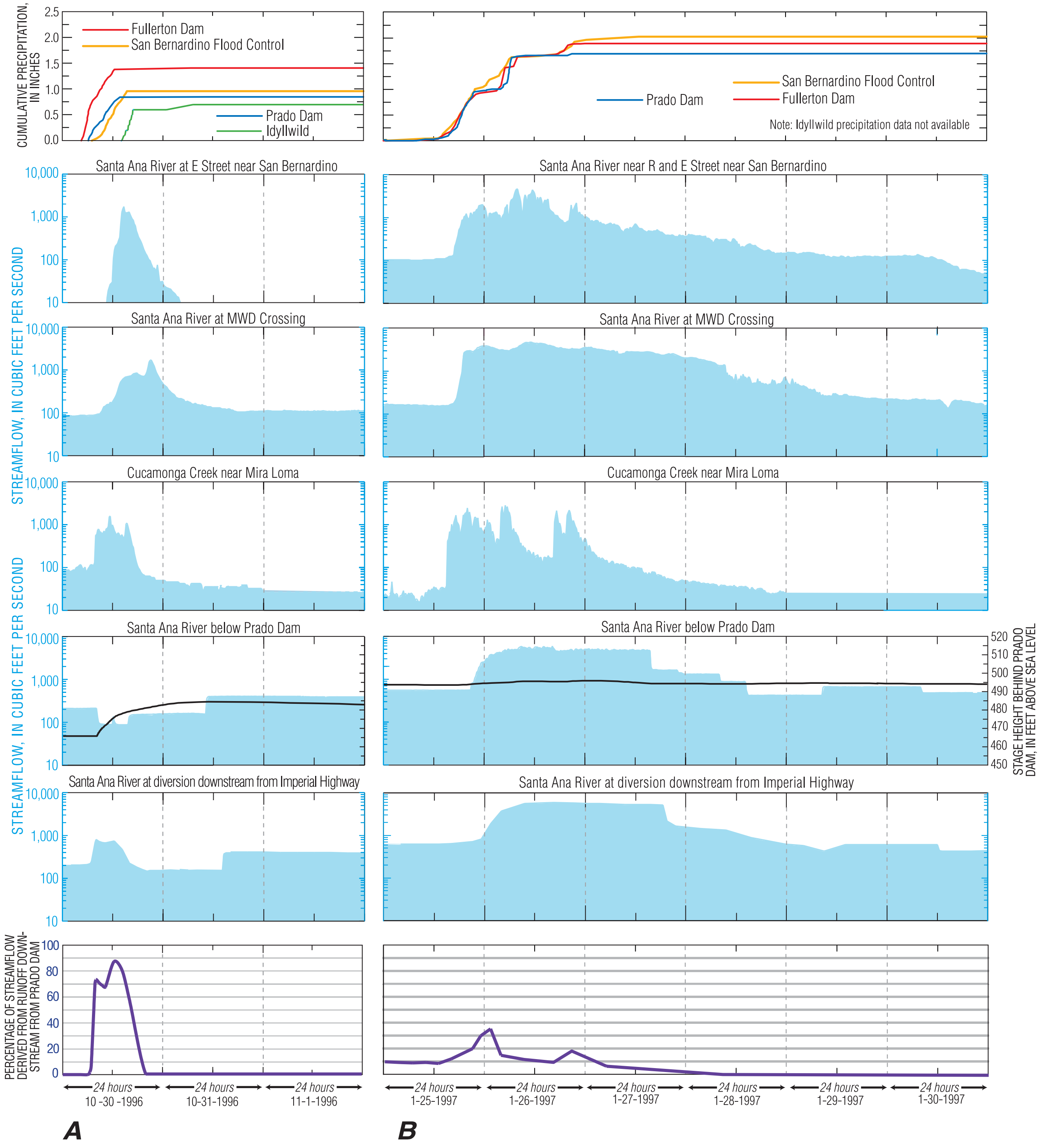


Figure 6. Precipitation and stormflow for selected sites in the Santa Ana River basin, southern California: ***(A)*** October 30–November 1, 1996; ***(B)*** January 25–30, 1997; and ***(C)*** September 25–27, 1997.

In contrast to the flashy conditions along Cucamonga and Chino Creeks, dry conditions at the beginning of the rainy season can reduce the amount of stormflow from upstream parts of the basin near San Bernardino. Although much of the main stem of the Santa Ana River is perennial, some infiltration capacity exists along the river channel prior to the first storm of the season. During the early part of the 1996–97 and 1997–98 rainy seasons, infiltration of stormflow resulted in the reduction of peak flows between the Santa Ana River at E Street and MWD Crossing, and delayed the arrival of peak stormflows at downstream sites (figs. 6A,C). Later in the rainy season, less bank storage was available for stormflow, and infiltration along the channel of the Santa Ana River had less effect on peak flows and the timing of stormflows (fig. 6B).

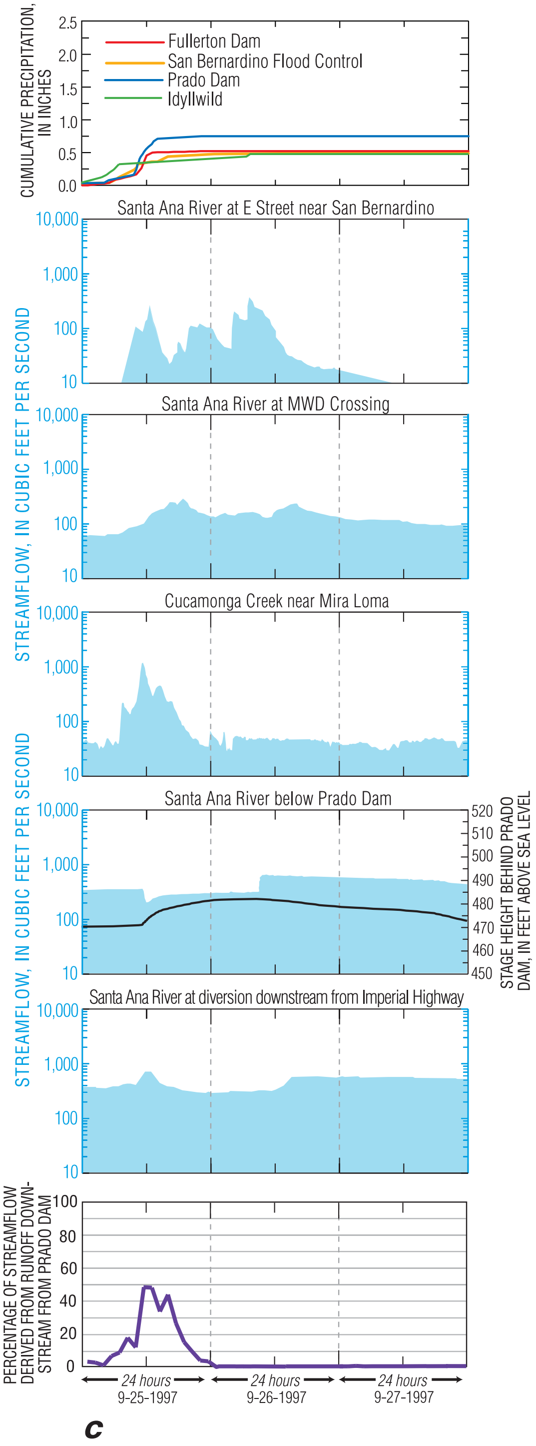


Figure 6. Continued.

In most years, infiltration into dry stream channels and diversion for ground-water recharge reduce the contribution of runoff from mountain areas to near zero during the early part of the rainy season. However, runoff from mountain areas does contribute to stormflow at downstream sites later in the rainy season.

Regulation of Streamflow at Prado Dam

Regulation at Prado Dam has a direct effect on stormflow in the Santa Ana River below the dam and at Imperial Highway by reducing peak flows and by the storage and subsequent release of stormwater gradually over a period of several days, weeks, or months (U.S. Army Corps of Engineers, 1994; Burton and others, 1998).

When peak flows are reduced by regulation, stormflow at Imperial Highway may be composed primarily of runoff from urban areas downstream from Prado Dam. For example, on October 30, 1996, while regulation reduced streamflow below Prado Dam to about 80 ft^3/s, downstream runoff produced peak flows as high as 800 ft^3/s in the Santa Ana River at Imperial Highway (fig. 6A). Regulation reduced streamflow below Prado Dam during the beginning of both the January 25–30, 1997, and September 25–27, 1997, storms in a similar manner but to a lesser extent (figs. 6B,C).

Under some conditions, stormflow below Prado Dam and at Imperial Highway may be dominated by water from previous storms that had been held in storage behind Prado Dam. The chemistry of stormflow stored behind the dam may be altered by mixing with subsequent baseflow, chemical and biochemical reactions, or dissolution of soluble material from soils and plants. Furthermore, stormflow entering the reservoir may either replace or mix with previously stored water. The storage dynamics, mixing, and chemical reactions that may occur in the flooded wetlands behind Prado Dam were not studied; however, all these factors influence the composition of stormflow below Prado Dam and at Imperial Highway when water is impounded and later released from the dam.

STORMFLOW CHEMISTRY

Under most conditions, stormflow water chemistry in the Santa Ana River, as in most streams, is dominated by inputs of nutrients, dissolved organic carbon (DOC), pesticides, and other organic compounds from sources outside the stream (Cole, 1983). As a result, the concentrations of these constituents can change rapidly during stormflow as different parts of the basin contribute runoff to downstream sampling sites at different times.

To facilitate interpretation, data from below Prado Dam and from Imperial Highway were grouped into base flow, early season stormflow, and late season stormflow.

Base-flow samples were defined as samples collected prior to precipitation and runoff. At least one sample was collected prior to the beginning of precipitation and runoff for each storm. Base-flow data collected below Prado Dam and at Imperial Highway were consolidated for summary statistics presented in this report. However, samples composed primarily of water from previous stormflows that was stored behind Prado Dam and subsequently released were not included in statistics describing base flow. Similarly, samples from the September 14–16, 1997, stormflow that included a high percentage of imported water were not included in statistics describing base flow.

Early season stormflows included the first stormflow of each rainy season. During the 1997–98 rainy season, early season stormflows also included the second and third stormflows. This was done because the first stormflow of the 1997–98 rainy season (September 14–16) was small, with precipitation and subsequent runoff restricted to the upper basin. The second storm was the first storm that produced runoff across the entire Santa Ana River basin (September 24–27) and was, in fact, the first stormflow of the season in the lower basin. Many water-quality changes common to the first stormflow of the season also were present in the third stormflow of the 1997–98 rainy season (November 10–12). Factors that may have contributed to this are (1) a large amount of material may have accumulated in the basin during the record dry period before the start of the 1997–98 rainy season and the first and second stormflows of the season may not have washed all the accumulated material from the basin, or (2) the relatively long time between the second and third stormflows (almost 2 months) may have allowed additional material to accumulate in the basin.

Late season stormflows include all other stormflow. Many of these stormflows typically include water from previous stormflows that was released from storage behind Prado Dam.

To determine if there are differences in water chemistry between base flow, early season stormflows, and late season stormflows, water-chemistry data were evaluated on the basis of the median test (Neter and Wasserman, 1974), with a confidence criterion of $\alpha=0.05$.

Imperial Highway is only a short distance downstream from Prado Dam. During base flow, and during parts of some storms, water below Prado Dam flows downstream to Imperial Highway with little additional inflow. Hydrograph separation was used to determine the percentage of water that originated as runoff from urban areas downstream from Prado Dam and facilitate comparison between stormflow water chemistry at the two sites. Travel time between Prado Dam and Imperial Highway is about 4 hours (Alan Flowers, Orange County Water District, oral commun., 1996) but may be less at high flows and greater at low flows. Three and one-half hours was used as the travel time for hydrograph separations presented in this report. Travel times may be greater for smaller stormflows. A more precise separation incorporating changes in travel time with changes in streamflow and dispersion within the stream channel was beyond the scope of this report.

Changes in Nutrient Concentrations During Stormflow

Nutrients sampled as part of this study include nitrogen and phosphorus. Forms of nitrogen analyzed during stormflow were dissolved nitrate and more reduced forms of nitrogen such as dissolved nitrite, dissolved ammonia, and dissolved organic nitrogen. Forms of phosphorus analyzed include dissolved phosphate and dissolved orthophosphate.

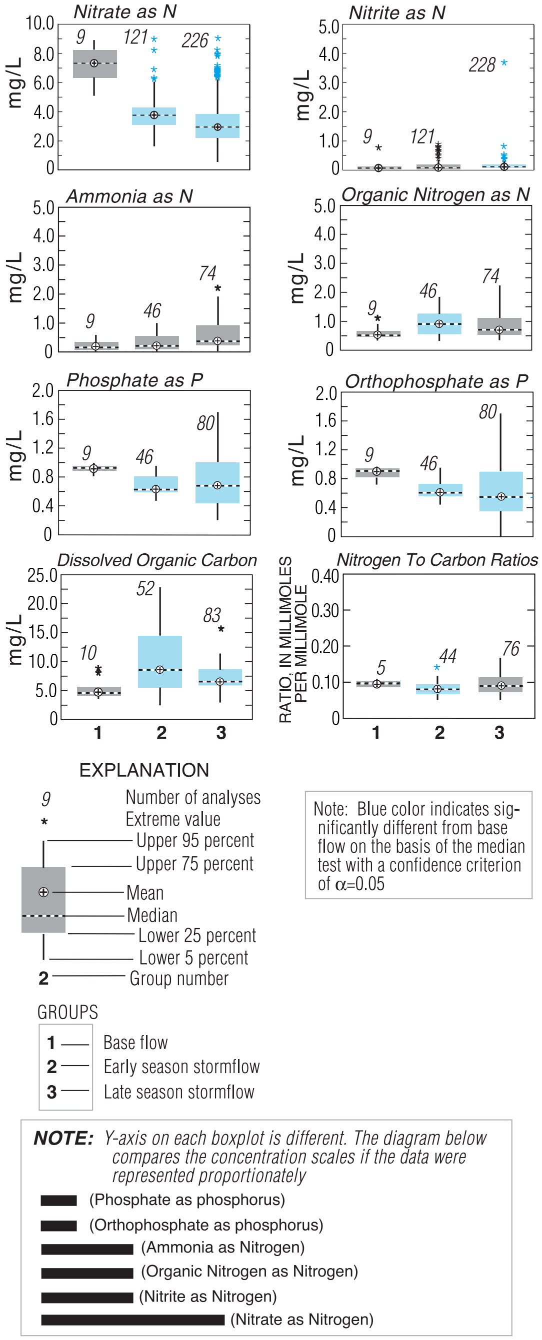
Nitrate

Median dissolved-nitrate concentration in base flow (sampled prior to the stormflows during 1995–98) in the Santa Ana River below Prado Dam and at Imperial Highway was 7.3 milligrams per liter (mg/L) as nitrogen (fig. 7). The maximum concentration of 9.1 mg/L (Appendix C) as nitrogen is only slightly less than the U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for nitrate of 10 mg/L as nitrogen. High nitrate concentrations in base flow result from the discharge of treated municipal wastewater to the river. Nitrate concentrations in the Santa Ana River below Prado Dam increased at a rate of 0.15 mg/L as nitrogen per year over the last 25 years (Burton and others, 1998). Similar trends were observed in rivers and streams receiving large amounts of treated municipal wastewater throughout the United States, because the more reduced forms of nitrogen in wastewater are converted to nitrate by advanced wastewater-treatment technologies (Muller and Helsel, 1996).

In general, dissolved-nitrate concentrations decrease during stormflow (fig. 7). Median nitrate concentrations in early season and late season stormflows below Prado Dam and at Imperial Highway were 3.7 and 2.9 mg/L as nitrogen, respectively. These values are statistically different from concentrations in base flow at these sites. Decreases in nitrate concentrations during stormflow are consistent with dilution of nitrate from point sources, such as wastewater-treatment plants (Muller and others, 1995). The largest decreases in nitrate concentration were observed at Imperial Highway when stormflow was dominated by runoff from urban areas downstream from Prado Dam (fig. 8). Similar decreases also were observed below Prado Dam.

Although dissolved-nitrate concentrations generally decrease during stormflow in the Santa Ana River, concentrations increased during the recessional flows of some early season storms below Prado Dam and at Imperial Highway (fig. 8C). These increases may be associated with the arrival of runoff from Cucamonga and Chino Creeks. In other areas, increases in nitrate concentrations during stormflow have been associated with nonpoint sources of nitrate such as fertilizer applications or animal confinement facilities (Muller and others, 1995).

The lowest dissolved-nitrate concentrations below Prado Dam and at Imperial Highway occurred during large, late season stormflows that replaced water held in storage behind Prado Dam. For example, during the January 25–30, 1997, stormflow (fig. 8B), nitrate concentrations initially decreased at Imperial Highway as a result of runoff from urban areas downstream from Prado Dam and then increased after



Note: Blue color indicates significantly different from base flow on the basis of the median test with a confidence criterion of α=0.05

NOTE: *Y-axis on each boxplot is different. The diagram below compares the concentration scales if the data were represented proportionately*

Figure 7. Concentrations of dissolved nitrate, nitrite, ammonia, organic nitrogen, phosphate, orthophosphate, and organic carbon and nitrogen-to-carbon ratios in base flow and in early season and late season stormflows in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1995–98. (mg/l, milligram per liter)

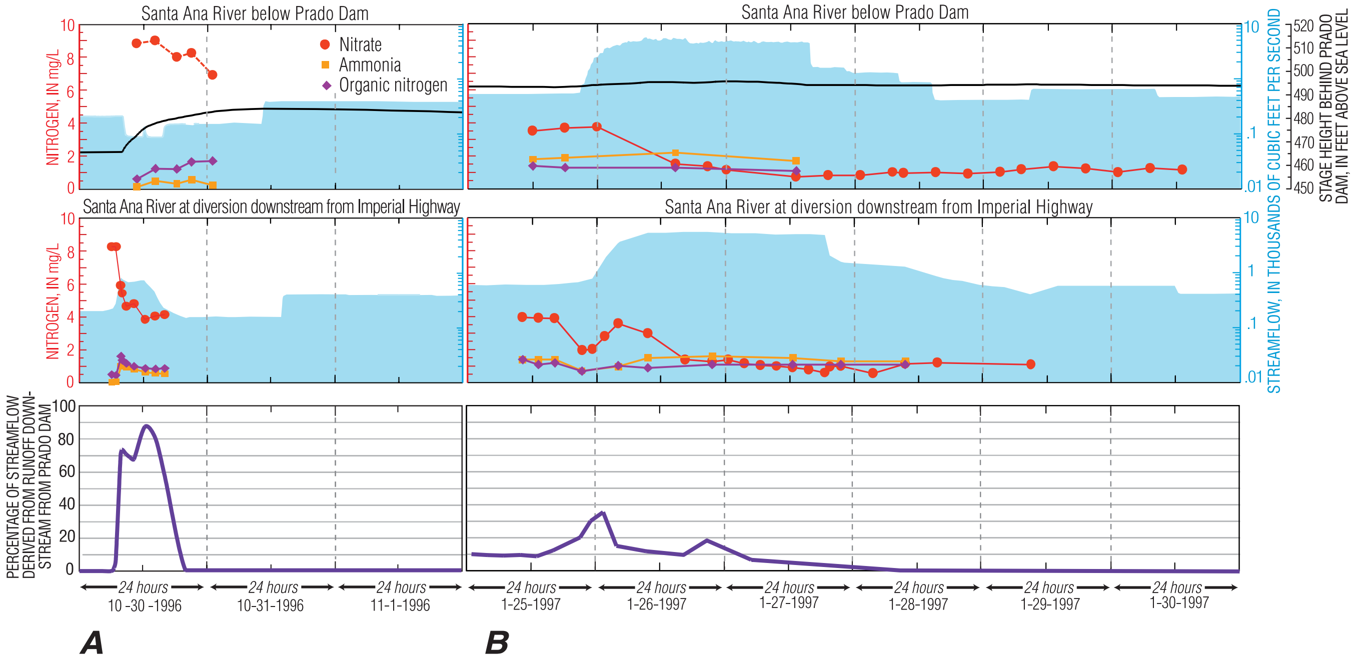


Figure 8. Dissolved nitrate, ammonia, and organic nitrogen concentrations during stormflow in the Santa Ana River below Prado Dam, and at the diversion downstream from Imperial Highway, southern California: ***(A)*** October30–November 1, 1996; ***(B)*** January 25–30, 1997; and ***(C)*** September 25–27, 1997. (mg/L, milligram per liter)

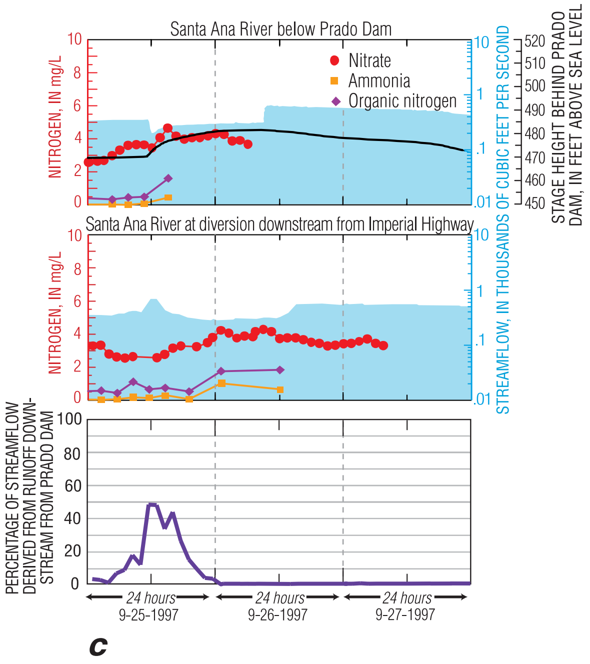


Figure 8. Continued.

water stored behind the dam was released. During this time, stage in the reservoir was held constant at 494 ft. This represents a total volume of 8,440 acre-ft. Given an outflow of 5,000 ft^3/s, about 20 hours would have been required to replace the volume of water stored behind the dam. After about 20 hours, approximately the length of time required for water in storage behind the dam to be replaced by stormflow from upstream areas, water released from Prado Dam was primarily stormflow from parts of the basin farther upstream and nitrate concentrations were less than 1 mg/L. Although simple piston flow of stormflow water through the reservoir behind Prado Dam may explain changes in nitrate concentrations observed during the January 25–30, 1997, stormflow, water movement through the reservoir during stormflows is probably very complex, possibly having preferred flow paths and mixing with water stored in the reservoir.

Reduced Forms of Nitrogen

Nitrogen in nitrite, ammonia, and organic nitrogen is more reduced (has a lower oxidation state) than is nitrogen in nitrate. Nitrite, ammonia, and organic nitrogen can be oxidized to nitrate under aerobic conditions and thus contribute to nitrate contamination. For this reason, it is often important to consider total nitrogen concentration, the sum of nitrogen in all its different chemical forms, when assessing the suitability of water for use as a source of ground-water recharge in aquifers pumped for public supply.

Median concentrations of dissolved nitrite, dissolved ammonia, and dissolved organic nitrogen in base flow (sampled prior to stormflows) in the Santa Ana River below Prado Dam and at Imperial Highway were 0.06, 0.16, and 0.49 mg/L as nitrogen, respectively. Maximum concentrations were 0.79, 0.56, and 1.1 mg/L as nitrogen, respectively (fig. 7). The USEPA MCL for nitrite is 1 mg/L as nitrogen. There are no MCL's for the other reduced forms of nitrogen. However, ammonia is toxic to fish at concentrations as low as 0.4 mg/L (U.S. Environmental Protection Agency, 1976, 1986). The toxicity of ammonia is greater for the un-ionized form of ammonia; as a result, toxicity increases with pH.

Concentrations of nitrite, ammonia, and organic nitrogen in base flow are low, in part because of the advanced wastewater-treatment technologies used throughout the basin that convert reduced forms of nitrogen to nitrate prior to discharge. Possibly as a result of this treatment, ammonia concentrations in the Santa Ana River below Prado Dam have decreased at a rate of 0.04 mg/L as nitrogen per year over the last 25 years (Burton and others, 1998). No statistically significant trends in nitrite or organic nitrogen concentrations were observed during that period (Burton and others, 1998).

In general, reduced forms of nitrogen increase as a result of stormflow (fig. 7). Median concentrations of nitrite, ammonia, and organic nitrogen during early season stormflows were 0.06, 0.17, and 0.81 mg/L as nitrogen, and median concentrations during late season stormflows were 0.12, 0.35, and 0.69 mg/L as nitrogen, respectively. However, only the median organic nitrogen concentration in early season stormflows and median nitrite concentrations in late season stormflows were statistically different from the corresponding concentrations in base flow.

The highest concentrations of ammonia and organic nitrogen occurred during late season stormflows (fig. 7). Increases also occurred during early season stormflows, especially during the recessional flows of early season stormflows (figs. 8A,C), but those concentrations were lower than concentration in late season stormflows. Ammonia concentrations exceeded 2 mg/L in the Santa Ana River below Prado Dam during the January 25–30, 1997, stormflow (fig. 8B). Although other factors, such as dissolved-oxygen concentrations, are important, high ammonia concentrations could have contributed to fish kills observed during this study. Toxicity associated with increased ammonia may be partly offset by decreases in pH during stormflow (as measured during this study) that reduce un-ionized ammonia concentrations.

Because storm and sanitary sewers are separate in the Santa Ana River basin, combined sewer overflows are not a source of ammonia or organic nitrogen; however, water flushed from storm sewers could contain high concentrations of reduced nitrogen.

Many late season stormflows contain water that was held in storage behind Prado Dam. It is possible that oxygen-poor conditions and biochemical reactions in the flooded wetlands behind the dam may result in the conversion of nitrate to more reduced forms of nitrogen. Contamination from nonpoint sources such as fertilizer applications or animal-confinement facilities (Muller and others, 1995) also may explain increases in reduced-nitrogen concentrations during the recessional flow. Increases in reduced nitrogen also could be associated with disturbance of the streambed materials of the Santa Ana River or tributaries by increased flow velocities.

Phosphate

Median dissolved phosphate and dissolved orthophosphate concentrations in base flow (sampled prior to stormflows during 1995–98) in the Santa Ana River below Prado Dam and at Imperial Highway were 0.93 and 0.91 mg/L as P, respectively (fig. 7). These concentrations are high in comparison with concentrations in most large rivers in the United States but comparable to concentrations in smaller streams draining urban areas (Muller and others, 1995). Although phosphorous compounds have been largely removed from laundry detergent in recent years, there was no trend in phosphate concentrations in the Santa Ana River below Prado Dam (Burton and others, 1998). However, orthophosphate concentrations increased at a rate of 0.03 mg/L as P per year over the last 25 years (Burton and others, 1998). This is contrary to the decreasing trend in phosphate and orthophosphate concentrations in the Nation's rivers and streams observed by Muller and Helsel (1996).

The median dissolved phosphate and dissolved orthophosphate concentrations in both early season and late season stormflows below Prado Dam and at Imperial Highway are statistically different from concentrations in base flow (fig. 7). Decreases in phosphate and orthophosphate concentrations during stormflow are consistent with dilution. However, the highest phosphate and orthophosphate concentrations occurred during the largest late season stormflows, when phosphate absorbed on sediment can be mobilized during stormflows. This pattern is similar to changes in phosphate and orthophosphate concentrations observed during a nationwide study of stormflow in streams and rivers (Muller and others, 1995).

Changes in Concentration and Composition of Dissolved Organic Carbon During Stormflow

Because of health concerns it is desirable to minimize the amount of dissolved organic carbon (DOC) of wastewater origin in drinking water derived from ground water recharged from the Santa Ana River (Orange County Water District, 1996b). In addition, there is concern about the potential for trihalomethane formation when the water having high DOC concentrations is chlorinated. Trihalomethane formation is a function of both the concentration and composition of DOC (California Department of Water Resources, 1994; Orange County Water District, 1996b).

Dissolved Organic Carbon Concentrations

The median DOC concentration in base flow (sampled prior to the beginning of stormflows during 1995–98) in the Santa Ana River below Prado Dam and at Imperial Highway was 4.6 mg/L. Concentrations of 3 to 5 mg/L are typical for surface water in arid regions (Thurman, 1985). However, because base flow in the Santa Ana River is primarily treated municipal wastewater, the DOC concentration is largely controlled by the concentration in the wastewater discharges. About half the base flow of the Santa Ana River is treated in artificial wetlands upstream from Prado Dam to remove nitrate. Gray and others (1996) showed that treatment within the wetlands increased the concentration and changed the composition of DOC in the Santa Ana River.

During this study, DOC concentrations generally increased during stormflow (fig. 7). Median DOC concentrations during early season and late season stormflows were 8.8 and 6.8 mg/L, respectively. These values are significantly different from DOC concentrations in base flow. Maximum DOC concentrations in early season stormflows were as high as 23 mg/L. Data are given in Appendix D.

The highest DOC concentrations in stormflow were measured at Imperial Highway during the first storm of the 1996–97 rainy season (fig. 9A). At that time, most of the water at Imperial Highway was runoff from urban areas downstream from Prado Dam. Similar increases in DOC from urban areas downstream from Prado Dam also were observed during other early season stormflows. Increases in DOC concentrations from 3.6 to 8.1 mg/L measured during the first storm of the 1997–98 rainy season (not shown in figure 9) are noteworthy because the amount of precipitation was small (0.25 in. at Riverside and less than 0.03 in. at Prado Dam) and produced only a small increase in streamflow (table 1). For such large changes to occur during such a small storm, DOC in the basin must be highly mobile. Elevated DOC concentrations from urban areas downstream from Prado Dam were not present after the first stormflow of the 1996–97 rainy season, or after the first three storms of the 1997–98 rainy season. Apparently the source of this DOC was removed by the early season stormflows. However, elevated DOC concentrations occurred during late season stormflows when water stored behind Prado Dam was released. For example, DOC concentrations during the January 25–30, 1997, stormflow initially decreased as a result of runoff from areas downstream from Prado Dam and subsequently increased as water stored behind the dam was released (fig. 9B).

Possible sources of readily soluble, highly mobile organic carbon include anthropogenic sources such as partly burned hydrocarbons washed from streets and parking lots, and natural sources such as soil or partly decayed plant material. Partly decayed soil and plant material that accumulated in storm drains during the dry season may be especially mobile. Some organic carbon also could be mobilized from the bed of the Santa Ana River if the streambed was disturbed by increased flow velocities.

Increased DOC concentrations were measured in the Santa Ana River below Prado Dam during both the October 30–November 1, 1996 (fig. 9A), and the September 25–27, 1997, stormflows (fig. 9C). Sample collection at Imperial Highway continued over a longer period during the September 25–27 stormflow, and DOC from the upstream sample site was eventually observed at the downstream site. Increases in DOC observed during the later part of this stormflow

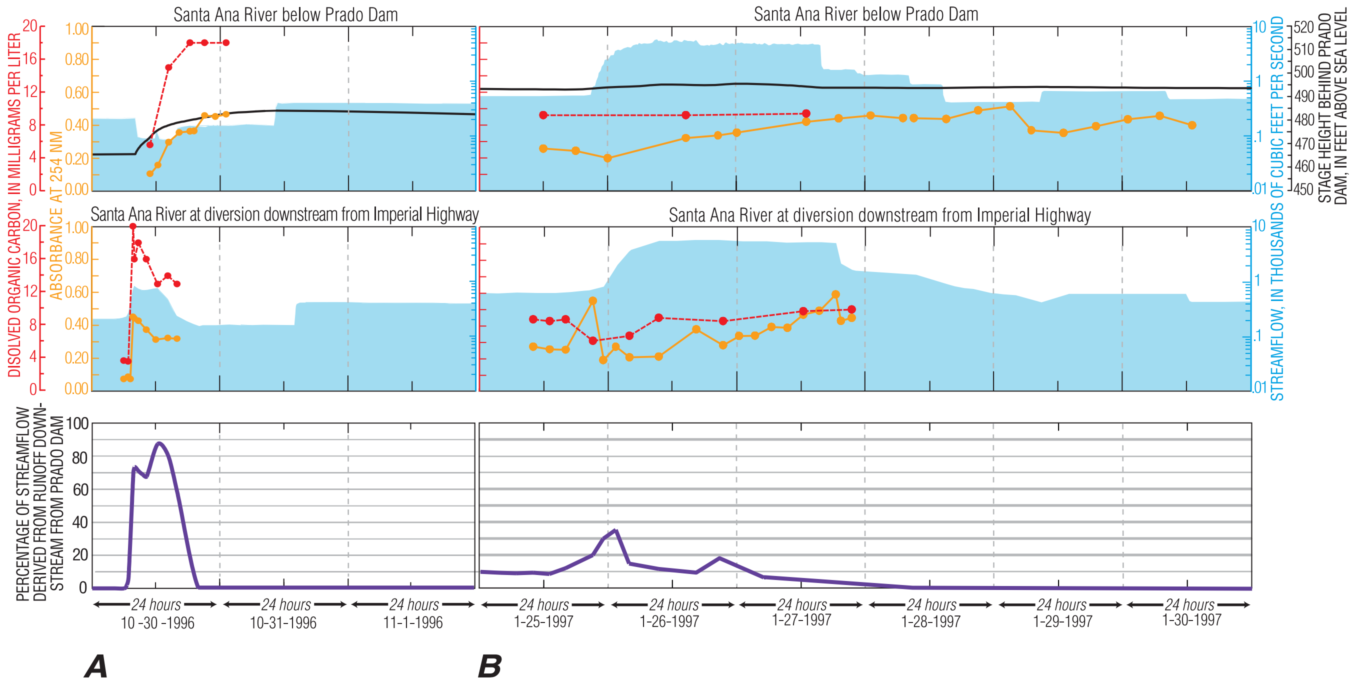


Figure 9. Dissolved organic carbon concentrations and UV_{254} absorbance during selected stormflows in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California: ***(A)*** October 30–November 1, 1996; ***(B)*** January 25–30, 1997; and ***(C)*** September 25–27, 1997.

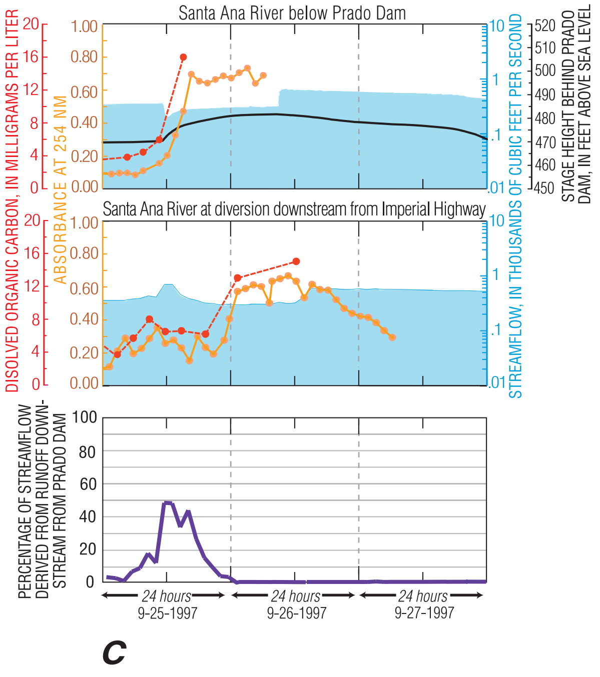


Figure 9. Continued.

coincided with increases in nitrate and reduced nitrogen species (fig. 8C). As previously discussed, this water may be associated with the arrival of runoff from Cucamonga and Chino Creeks.

Dissolved Organic Carbon Composition

Characterization of the composition of DOC during stormflow may help identify its origin and allow predictions about its fate in the environment and about its response to chlorination. Thorough characterization of DOC is a complex task requiring a hierarchical analytical approach that may determine, among other things, (1) operationally defined organic fractions, (2) functional-group characteristics, (3) molecular weight, and (4) ultimately, the concentration of specific organic compounds (Leenheer and Huffman, 1976; Barber, 1992). This hierarchical analytical approach is time consuming, labor intensive, and expensive. Given the number of samples collected, the rapid changes in DOC concentrations, and the number of potentially different sources contributing runoff and DOC during stormflows, such a rigorous approach was not within the scope of this study. Instead, a simplified approach that measures differences in UV absorbance and changes in nitrogen-to-carbon ratios was used to characterize DOC contributed from different sources during stormflow. Therefore, interpretations about the origin, fate, and response of DOC are limited. Data presented in this report are best used to identify changes in DOC composition during different stormflows and to determine if these differences require further characterization.

Ultraviolet Absorbance

Absorbance of light at different wavelengths is related to the presence of specific functional groups within complex carbon molecules. When electrons in organic molecules are exposed to light they become "excited"; the less firmly bound the electrons, the easier they are to excite. Excitation causes changes at the atomic level such as the transition of electrons to higher energy levels, rotation or vibrational changes within bonds, or changes in the spin of atomic nuclei (Hart and Schuetz, 1972), and results in the absorbance of energy. These changes are complex and even a simple molecule such as methane (CH_4) has several absorption bands. Despite the complexity of natural DOC, absorbance within the UV, visible, or infrared range can be useful in identifying similarities or differences between DOC from different sources. When this approach is used, DOC concentrations (or some other measure of organic material) are commonly compared with absorbance at selected wavelengths corresponding to the maximum absorbance for different functional groups (Black and Christman, 1963; Mrkva, 1983; Thurman, 1985; Krazner and others, 1996).

DOC absorbance within the UV range [220–800 nanometers (nm)] is usually associated with unsaturated molecules such as those containing carbon-carbon double bonds, carbon-oxygen double bonds, or carbon-carbon double bonds in complex aromatic (benzene-like) ring structures (Gutsche and Pasto, 1975). Carbon-carbon double bonds within aromatic rings generally absorb near 254 nm and carbon-oxygen double bonds generally absorb near 285 nm (Gutsche and Pasto, 1975). However, the exact wavelength absorbed increases with the length and complexity of the associated carbon chain and other structures. Ultraviolet absorbance spectra do not show pronounced peaks at wavelengths corresponding to specific functional groups but instead are smooth curves usually showing a maximum absorbance near 254 nm. Maximum absorbance near 254 nm results because aromatic rings are the basic building blocks of many complex, naturally occurring organic compounds. These aromatic rings also are the basic building blocks of many anthropogenic compounds, such as lubricants, polycyclic aromatic hydrocarbons (PAH) produced by the partial combustion of fossil fuel, and many pesticides. Although UV absorbance spectra can be used to quantify the concentrations of individual compounds in simple mixtures, these data are not quantitative for solutions containing complex mixtures of natural and anthropogenic organic molecules.

Ultraviolet absorbance data have been used in previous studies as a surrogate for DOC concentrations (California Department of Water Resources, 1994). In natural waters there commonly is large variability between DOC and UV absorbance and correlations may be poor. This variability results from differences in the composition of DOC and from interference with other compounds in water that also may absorb UV light (California Department of Water Resources, 1994; Krazner and others, 1996).

In this study, comparison of DOC concentrations and UV absorbance at 254 nm (UV_{254}) was used to determine qualitative differences in the composition of DOC in early season and late season stormflows. On the basis of an analysis of covariance (Neter and Wasserman, 1974), DOC in early season stormflows is different from DOC present in late season stormflows (fig. 10). The analysis of covariance has an R^2 of 0.63, but it is highly significant with a p value of 0.001. The slopes of the lines shown in the upper part of figure 10 have units of DOC in mg/L per absorbance at 254 nm; the inverse of these slopes is conceptually similar to specific UV absorbance (SUVA) discussed in many studies (Krazner and others, 1996). Because DOC in late season stormflows has a higher UV_{254} absorbance per unit of carbon, it may contain more carbon-carbon double bonds than DOC in early season stormflows. If this interpretation is correct, then DOC in late season stormflows may have a greater tendency (per unit of carbon) to form trihalomethanes as a result of chlorination (California Department of Water Resources, 1994; Krazner and others, 1996). Additional characterization of DOC would be required to verify differences in carbon composition and the potential for trihalomethane formation.

Nitrate and iron also absorb within the UV range, although the wavelengths of their maximum absorbance are different from 254 nm. When included in the analysis of covariance shown in figure 10, coefficients for nitrate and iron are small in magnitude but statistically significant. This result suggests that these constituents may interfere with UV_{254}

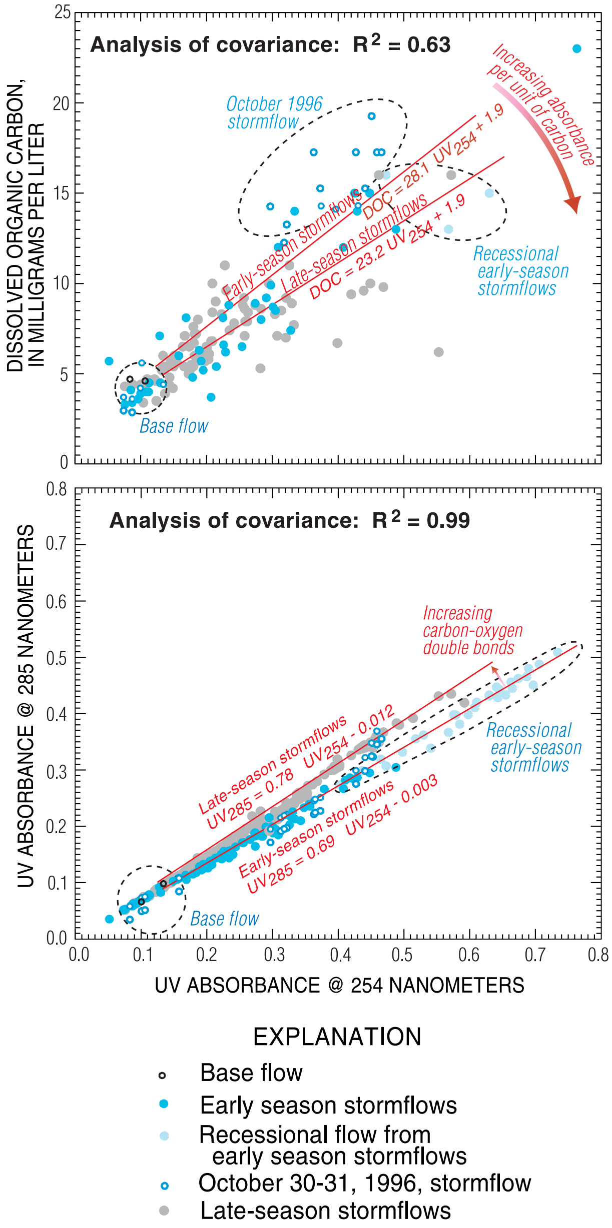


Figure 10. Dissolved organic carbon as a function of UV_{254}, and UV_{285} as a function of UV_{254}, in stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1995–98.

measurements by increasing UV_{254} absorbance. After accounting for interference, the difference between early season and late season stormflow remained statistically significant and the R^2 of the analysis of covariance increased to 0.82. Interference from nitrate may be more important during base flow then during stormflow because, in general, dissolved nitrate concentrations decrease during stormflow (figs. 7 and 8). In contrast, interference from iron may be important during stormflow because dissolved iron concentrations increase during stormflow (figs. 18 and 19, later in this report).

Carbon-oxygen double bonds in DOC have a maximum absorbance near 285 nm. Carbon-oxygen double bonds are a component of functional groups such as carboxylic acids and esters (Gutsche and Pasto, 1975). Comparison of UV_{254} and UV_{285} was used to determine qualitative differences between DOC in early season and late season stormflows. On the basis of analysis of covariance (Neter and Wasserman, 1974) with a p value of 0.001, the relation between UV_{254} and UV_{285} in early season stormflows is different from the relation in late season stormflows (fig. 10). Dissolved nitrate and dissolved iron concentrations did not interfere with this relation. On the basis of these data, DOC from late season stormflows have more UV_{285} absorbance per unit of UV_{254} absorbance than DOC from early season stormflows, and DOC from late season stormflows may be compositionally more complex than DOC from early season stormflows. Additional characterization of DOC would be required to verify differences in carbon composition.

Differences in DOC composition suggested by UV absorbance data (fig. 10) are consistent with differences in the sources of DOC between early season and late season storms. DOC in early season storms is highly mobile and readily washed from the basin after the early season storms. This DOC may originate as partly decayed plant material that accumulated in storm drains and in stream channels. DOC from such a source would be expected to contain simpler organic compounds and have lower UV_{254} and UV_{285} absorbances than DOC that originated from the flooded wetlands behind Prado Dam during the late season storms. Increased UV_{254} absorbance during the recessionals of early season stormflows (fig. 10) could be explained by interference from increased dissolved nitrate concentrations present during these recessional flows.

Nitrogen-to-Carbon Ratios

Nitrogen-to-carbon ratios vary greatly in organic material and can change rapidly in response to chemical and biochemical processes. However, these data may be used to indicate the source of DOC in stormflow because, in this study, residence times in streams are short and water temperatures are cool. Short residence times and cool temperatures may minimize alteration of DOC in stormflow by chemical and biochemical processes.

During early season stormflows, nitrogen-to-carbon ratios are significantly lower than ratios in base flow (fig. 7). The lowest ratios are associated with high DOC concentrations that occur as a result of runoff from urban areas downstream from Prado Dam. Lower values of this ratio may reflect inputs of DOC from the decay of plant material that has accumulated in storm drains and the stream channel during the dry season, as discussed previously. This material typically has low nitrogen-to-carbon ratios (Thurman, 1985). The nitrogen-to-carbon ratio of late season stormflows is not significantly different from that of base flow. However, the range in nitrogen-to-carbon ratios in late season stormflows is greater than in base flow or early season stormflows (fig. 7). This may be because different sources of carbon are contributing to the DOC. During late season stormflows, samples with lower nitrogen-to-carbon ratios were associated with runoff from urban areas downstream from Prado Dam, whereas samples with higher nitrogen-to-carbon ratios were associated with water that had been in storage behind Prado Dam. In water stored behind Prado Dam, the DOC may have been altered by the dissolution of humic or fulvic acids present in the wetlands or by microbial activity, such as algal growth, and by the inclusion of cellular debris and exudates. These organic materials typically have high nitrogen-to-carbon ratios (Thurman, 1985; Paul and Clark, 1996).

Comparison with Dissolved Organic Carbon Concentrations and UV Absorbance in Water from Other Sources

Comparison of stormflow samples from the Santa Ana River with water from the California Aqueduct and agricultural drains within the San Joaquin Delta is useful because (1) water from these sources has been extensively characterized using UV absorbance and other techniques, (2) water from the California Aqueduct is used in addition to water from the Santa Ana River to recharge aquifers underlying Orange County, and (3) the San Joaquin Delta is the source of much of the DOC in water from the California Aqueduct (California Department of Water Resources, 1994).

In general, DOC concentrations in stormflow in the Santa Ana River are higher than average concentrations in water from the California Aqueduct. DOC concentrations in aqueduct water range from 2 to 6 mg/L (California Department of Water Resources, 1994). At times, DOC concentration in stormflow from the Santa Ana River was within the range of water from some agricultural drains in the San Joaquin Delta, but maximum concentrations were not as high as the maximum concentration from agricultural drains. DOC concentrations in water from these drains can exceed 100 mg/L (California Department of Water Resources, 1994; Fujii and others, 1998).

Trihalomethane formation potential is a function of the concentration and composition of DOC, as well as the pH, bromide concentration, and various other factors (California Department of Water Resources, 1994; Krazner and others, 1996). The trihalomethane formation potential of DOC in water from many different sources sampled by Krazner and others (1996) ranged from 0.4 to 1 micromole per milligram of DOC. Typical trihalomethane formation potentials of water from the California Aqueduct (California Department of Water Resources, 1994) and agricultural drains in the San Joaquin Delta (Fujii and others, 1998) are near the high end of this range, about 0.8 micromole per milligram of DOC. On the basis of UV absorbance data (after correction for nitrate and iron interference), the composition of DOC in stormflow has relatively high absorbance per milligram of DOC; typical values are 0.04 and 0.06 absorbance units per milligram for early season and late season storms, respectively. These values are within the range of humic acids (Krazner and others, 1996) and similar to values measured in the California Aqueduct (California Department of Water Resources, 1994) and to water collected during the winter months from agricultural drains in the San Joaquin Valley (Fujii and others, 1998). On the basis of these data, DOC in stormflow also may have high trihalomethane formation potential. The trihalomethane formation potential of water recharged from the Santa Ana River is being studied as part of the SARWQHS by Orange County Water District (1996b). Some trihalomethanes were detected in stormflow water as part of this study (discussed later in this report).

Changes in Selected Organic Compound Concentrations During Stormflow

Pesticides and volatile organic compounds in stormflow from the Santa Ana River were analyzed as part of this study. These compounds have urban, agricultural, and industrial uses within the basin, and many of these compounds are found in surface water and ground water across the United States (Barbash and Resek, 1996; U.S. Geological Survey, 1996, 1997). The volatile organic compounds analyzed as part of this study included compounds associated with urban runoff such as methyl tert-butyl ether (MTBE), a gasoline oxygenate, and chlorination byproducts such as chloroform. Other organic compounds such as polycyclic aromatic hydrocarbons (PAH's) commonly associated with urban runoff were not analyzed as part of this study.

Pesticides

Pesticides in low concentrations are widespread in surface waters across the United States and the concentrations follow strong seasonal patterns that result from streamflow conditions and the timing of pesticide applications (U.S. Geological Survey, 1997). The potential effects on human or aquatic systems are difficult to evaluate because of (1) incomplete information on the distribution of pesticides in the environment, (2) the effects of low-concentration mixtures of pesticides and their transformation products, and (3) the effects of long-term exposure to these compounds. In recent years, with the development of increasingly sensitive analytical methods, the distribution of pesticides in the environment has become easier to evaluate.

This study addressed the distribution of pesticides in the Santa Ana River during 1996–98 stormflows with an emphasis on the association of pesticides in runoff from different parts of the basin and the possibility that "first-flush" effects may result in increased pesticide concentrations during the early part of the rainy season. An evaluation of the distribution of pesticide concentrations in the Santa Ana River resulting from seasonal-application patterns is beyond the scope of this report.

Occurrence of Pesticides During Stormflow

During the first year of the study (1995–96), 49 pesticides and selected organic compounds were analyzed by the Orange County Water District using USEPA drinking-water method 507, determination of nitrogen- and phosphorous-containing pesticides by gas-chromatography with a nitrogen phosphorus detector (U.S. Environmental Protection Agency, 1995), and method 525, determination of organic compounds in drinking water (U.S. Environmental Protection Agency, 1995). Almost all concentrations were below the detection limits obtainable using these methods, and all measured concentrations were low for the analyzed compounds.

During the second (1996–97) and third (1997–98) years of this study, 87 pesticides were analyzed using USGS solid-phase extraction methodology (Zaugg and others, 1995; Werner and others, 1996). These methods have detection limits several orders of magnitude lower than those of standard drinking-water methods (Appendix B). Using these methods, 25 pesticides were detected below Prado Dam and at Imperial Highway during six storms (table 2). All 25 compounds were detected at concentrations less than their respective MCL's, and only carbaryl, simazine, and diuron exceeded 1 µg/L. Using these methods, 62 pesticides included in the analyses were not detected. Results are given in Appendix E.

Concentrations of the 10 most commonly detected pesticides are shown as box plots in figure 11. The box plots show base flow, stormflow dominated by urban runoff originating downstream from Prado Dam, and all other stormflows determined on the basis of hydrograph seperation. This comparison is different from the comparison among base flow, early season, and late season stormflows presented elsewhere in this report and helps determine pesticides that are associated with runoff from urban areas downstream from Prado Dam for comparison with pesticides associated with runoff from areas upstream from the dam.

On the basis of the median test (Neter and Wasserman, 1974), concentrations of 8 of the 10 most commonly detected compounds increased during stormflow (fig. 11). For many of these compounds, statistically significant increases in concentrations occurred regardless of the source of runoff. However, increases in concentrations of the insecticides diazinon, malathion, and chlorpyrifos were larger in runoff from urban areas downstream from Prado Dam. In contrast, increases in concentrations of the herbicides DCPA, simazine, and diuron were larger in runoff from areas upstream from Prado Dam. No statistically significant changes in metolachlor concentrations were observed during stormflow. Statistically significant decreases in atrazine concentrations were observed in runoff from urban areas downstream from Prado Dam. Concentrations of metolachlor and atrazine were low

Table 2. Summary of detected pesticide data for the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98

[Pesticides listed by frequency of detection. Number of analyses is 73. Active ingredient data from the California Department of Pesticide Regulation. µg/L, microgram per liter; kg, kilogram; <, less than; —, no data or not reported]

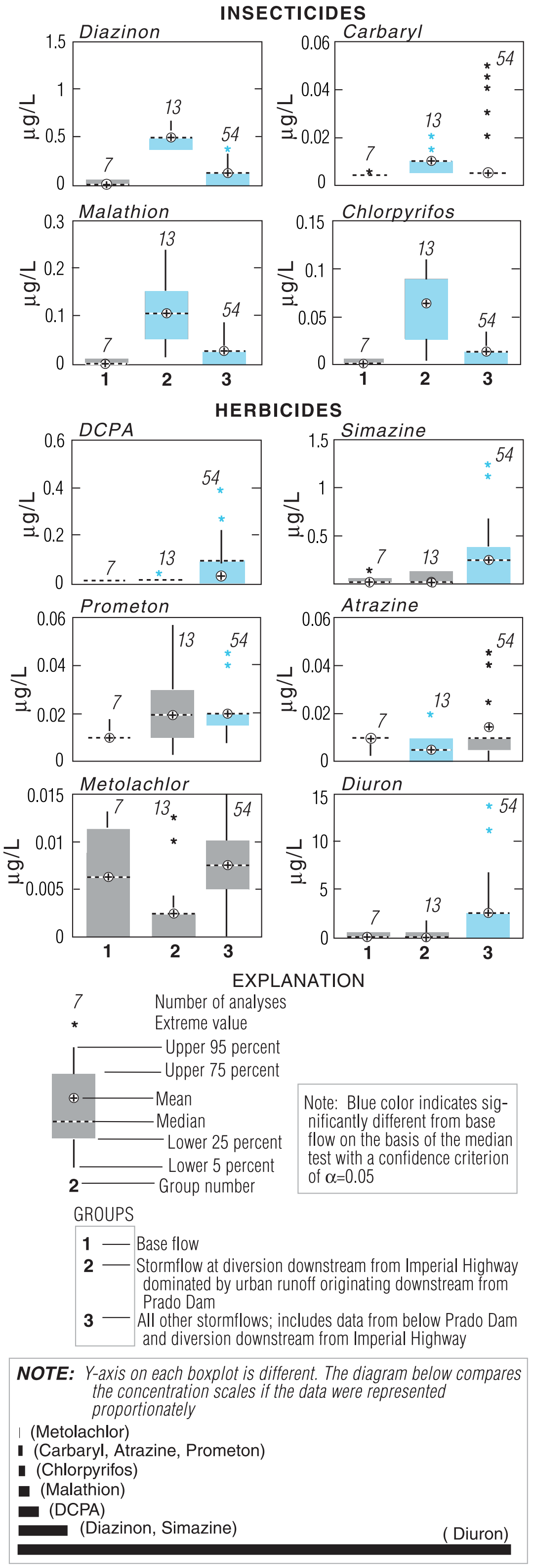
Pesticide	Trade name[1]	Number of detections	Minimum reporting level (µg/L)	Median concentration (µg/L)	Maximum concentration (µg/L)	Maximum contaminant level[2] (µg/L)	Active ingredient applied in 1995[3] (kg)	Use in Orange, Riverside, and San Bernardino Counties[3]
Insecticides and their metabolites								
Diazinon	Several	72	0.002	0.10	0.64	[4]14.	30,000	Structural pest control
Carbaryl	Sevin	69	.008	.062	1.2	[4]60.	17,400	Citrus, animal husbandry
Malathion	several	51	.005	.022	.22	[4]160.	40,200	Alfalfa, dates, citrus
Chlorpyfos	Genpest	48	.004	.01	.10	—	74,200	Structural pest control, alfalfa
Lindane	—	12	.004	<.004	.11	.2	60	Landscape maint., vegetables
Propoxur	Baygon	3	.035	<.035	.11	—	411	Structural pest control
DDE	(metabolite of DDT)	1	.006	<.006	.004	—	—	
Herbicides and their metabolites								
DCPA	Dacthal	73	0.001	0.004	0.36	—	26,900	Vegetables
Simazine	Aquazine	73	.005	.078	1.2	4.0	18,500	Citrus, right-of way maint.
Prometon	Ptamitol	70	.018	.018	.054	—	5	Landscape maint.
Atrazine	AAtrex	64	.001	.008	.057	3.0	57	Landscape maint.
Metolachlor	Dual	54	.002	.007	.015	—	83,100	Citrus
Diuron	Karmex	48	.02	.34	13	—	34,200	Right-of-way maint., citrus
Deethyl atrazine	(metabolite of atrazine)	15	.002	<.002	.013	—	—	
Tebuthiuron	Spike	13	.01	<.01	.025	—	912	Right-of-way maint., landscape maint.
Cyanazine	Bladex	10	.004	<.004	.03	—	440	Cotton
Bromacil	Hyvar X	10	.035	<.035	.50	—	9,880	Citrus, right-of-way maint.
Triclopyr	Garlon	10	.05	<.05	.93	—	4500	Landscape maint.
Norflurazon	Evital	8	.02	<.02	.39	—	1760	Landscape maint., citrus
Trifluralin	Treflan	8	.002	<.002	.005	—	37,900	Alfalfa, landscapes, cotton
Napropamide	Devrinol	7	.003	<.003	.085	—	260	Landscape maint., grapes
Benfluralin	Balan	5	.002	<.002	.007	—	2,150	Landscape maint., right-of-way maint.
Pendimethalin	Prowl	4	.004	<.004	.018	—	8,860	Landscape maint., cotton
2,4-D	several	3	.035	<.035	.41	70	2,140	Landscape maint., forage
Pronamide	Kerb	2	.004	<.004	.02	—	—	(pre-emergent herbicide)

[1] From Ware, 1982; Wagner and others, 1995; or Williamson and others, 1998.

[2] From California Department of Water Resources, 1997.

[3] Active ingredient applied and use figures for San Bernardino, Riverside, and Orange Counties. From California Department of Pesticide Regulation, 1995. Does not include home and garden use.

[4] California Department of Health Services Action Level. From California Department of Water Resources, 1997.



Note: Blue color indicates significantly different from base flow on the basis of the median test with a confidence criterion of α=0.05

NOTE: *Y-axis on each boxplot is different. The diagram below compares the concentration scales if the data were represented proportionately*

Figure 11. Concentrations of the 10 most commonly detected pesticides in base flow, stormflow dominated by runoff from urban areas downstream from Prado Dam, and all other stormflows in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98.

and near the minimum reporting level for these compounds.

The largest increases in the concentrations of the insecticides diazinon, malathion, and chlorpyrifos were during early season stormflows, and changes in concentration were rapid (figs. 12A, C). However, increases in diazinon concentrations also occurred later in the rainy season at Imperial Highway (fig. 12B). These data suggest that diazinon, unlike DOC, either is not readily washed from the basin during early season storms, or that diazinon may be applied throughout the rainy season and available to runoff during late season stormflows. In contrast, concentrations of the herbicides simazine, diuron, and carbaryl increased during stormflow that originated primarily from areas upstream from Prado Dam (fig. 13A). Concentrations of diuron and simazine decreased temporarily when streamflow was dominated by runoff from urban areas downstream from Prado Dam (fig. 13B), suggesting that there may be little use of these pesticides in that area during the rainy season.

Comparison with Reported-Use Data

Pesticide detections and concentrations are compared with 1995 reported application data collected by the California Department of Pesticide Regulation (1995) in table 2. Reported application data include agricultural, commercial, industrial, institutional, and government pesticide use. They do not include home and garden use. Reported use in San Bernardino, Riverside, and Orange Counties was used to approximate use in the Santa Ana River basin. Because the combined area of these three counties is larger than the Santa Ana River basin, the amount of active ingredient applied (table 2) probably overestimates pesticide use in the basin. However, the data are assumed to correctly identify pesticides commonly used in the basin, the relative usage of different compounds, and the purpose for which these compounds are used.

In general, pesticides such as chlorpyrifos, malathion, diuron, diazinon, DCPA, simazine, and carbaryl that have high reported use have high frequencies of detection (fig. 14). Chlorpyrifos and diazinon are insecticides commonly used in urban areas for structural pest control (table 2), and malathion has been widely used in urban areas throughout southern California to control medfly infestations. In addition, these insecticides are common home and garden chemicals. In the study area, diuron and simazine are

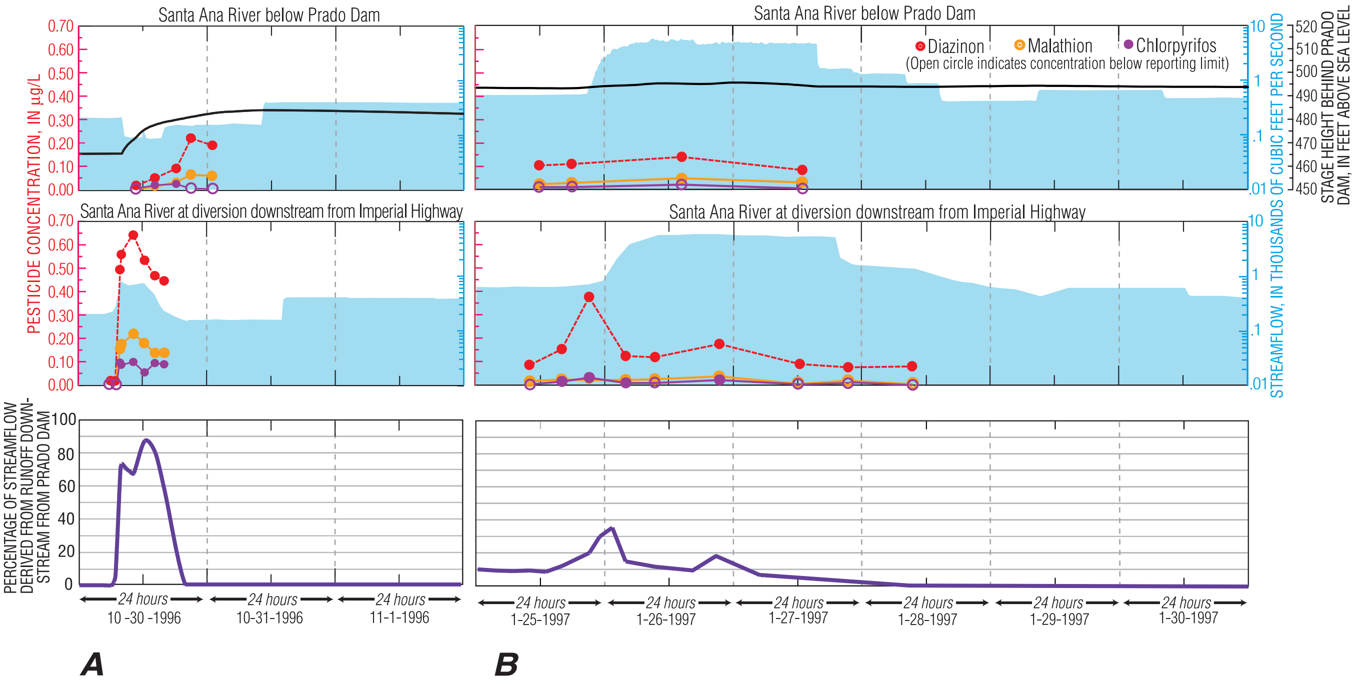


Figure 12. Diazinon, malathion, and chlorpyrifos concentrations during stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California: ***(A)*** October 30–November 1, 1996; ***(B)*** January 25–30, 1997; and ***(C)*** September 25–27, 1997. (µg/L, microgram per liter)

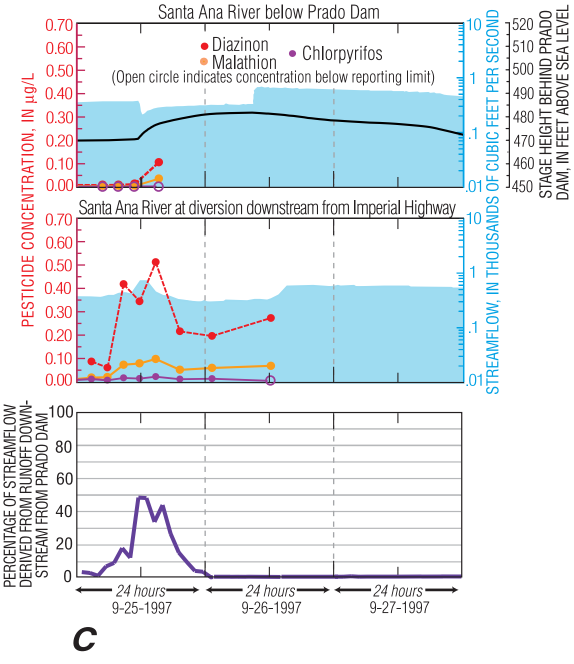


Figure 12. Continued.

used for citrus and for right-of-way maintenance (California Department of Pesticide Regulation, 1995). Diuron had the highest concentrations of any pesticide detected in this study. Panshin and others (1998) found that diuron used for right-of-way maintenance in the San Joaquin Valley was especially mobile. In the Santa Ana study area, carbaryl is used for citrus and animal husbandry (California Department of Pesticide Regulation, 1995) and may be associated with animal-confinement facilities in areas drained by Cucamonga and Chino Creeks. Carbaryl also is a common home and garden chemical used to kill snails.

In contrast, the herbicides prometon and atrazine have very low reported use but were present in 96 and 88 percent of the samples, respectively. These herbicides may have a large amount of unreported use, although atrazine cannot be legally sold for home and garden use. Both prometon and atrazine are triazine herbicides. This group of herbicides has been shown to be highly mobile and to have a high frequency of detections in surface water in relation to application rates (Panshin and others, 1998). Another triazine herbicide that has a high rate of detection in relation to its reported application rates is cyanazine.

Metolachlor has the highest reported use of any pesticide in the Santa Ana study area and was commonly detected, but only at low concentrations. The low concentrations may result from factors such as where the pesticide is used in the basin. For example, metolachlor is primarily used on citrus, and most of the remaining citrus is grown in the San Jacinto River basin, which rarely contributes flow to the Santa Ana

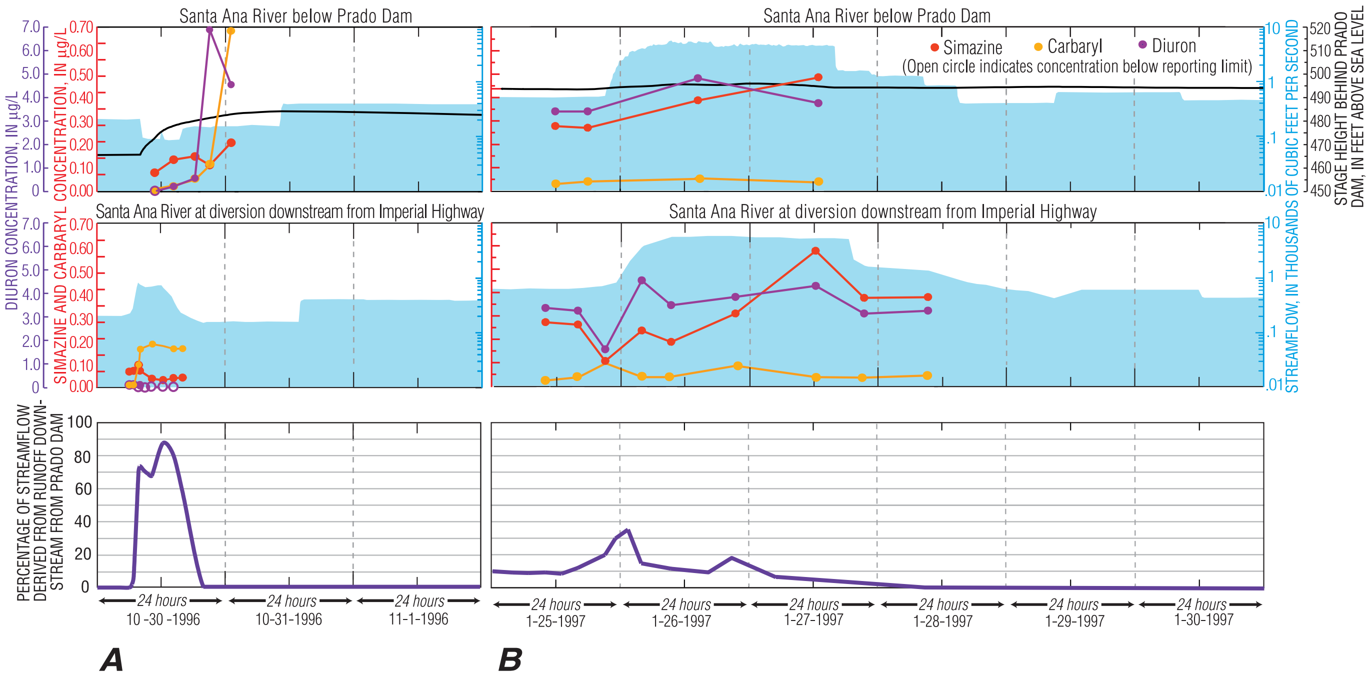


Figure 13. Simazine, carbaryl, and diuron, concentrations during stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California: ***(A)*** October 30–November 1, 1996; ***(B)*** January 25–30, 1997; and ***(C)*** September 25–27, 1997. (μg/L, microgram per liter)

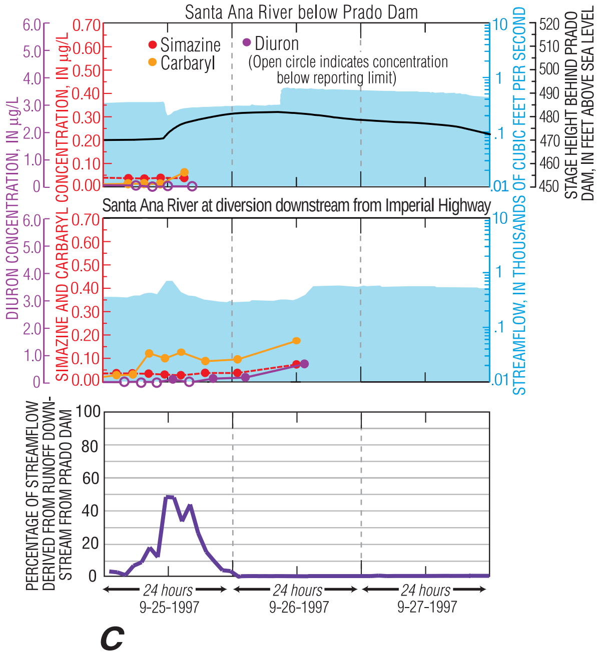


Figure 13. Continued.

River. Other factors such as seasonal application of the pesticide, its tendency to degrade, or its tendency to sorb to soils and particulate material also may be important.

In contrast to the more commonly detected pesticides, trifluralin has high reported use but was detected infrequently. Trifluralin is more commonly detected in runoff from urban areas downstream from Prado Dam than from upstream areas. Although used primarily on alfalfa, trifluralin's presence in stormflow derived from urban runoff may reflect use for landscape maintenance or unreported home and garden use.

Comparison of the frequency of detection for different pesticides in runoff derived from urban areas downstream from Prado Dam with runoff from urban and agricultural areas upstream from the dam shows differences in pesticide distribution in runoff from different parts of the basin (fig. 14). In general, insecticides are detected more frequently in runoff from urban areas downstream from Prado Dam (fig. 14). This result is consistent with reported-use data that suggests that some of these compounds, such as diazinon and chlorpyrifos, have high reported use for structural pest control (table 2). This also is consistent with the potentially large amount of unreported home and garden use of these chemicals. A number of herbicides, such as tebuthiuron, bromacil, triclopyr, and napropamide, also are detected more frequently in runoff from urban areas downstream from Prado Dam. These herbicides have a high reported use for landscape

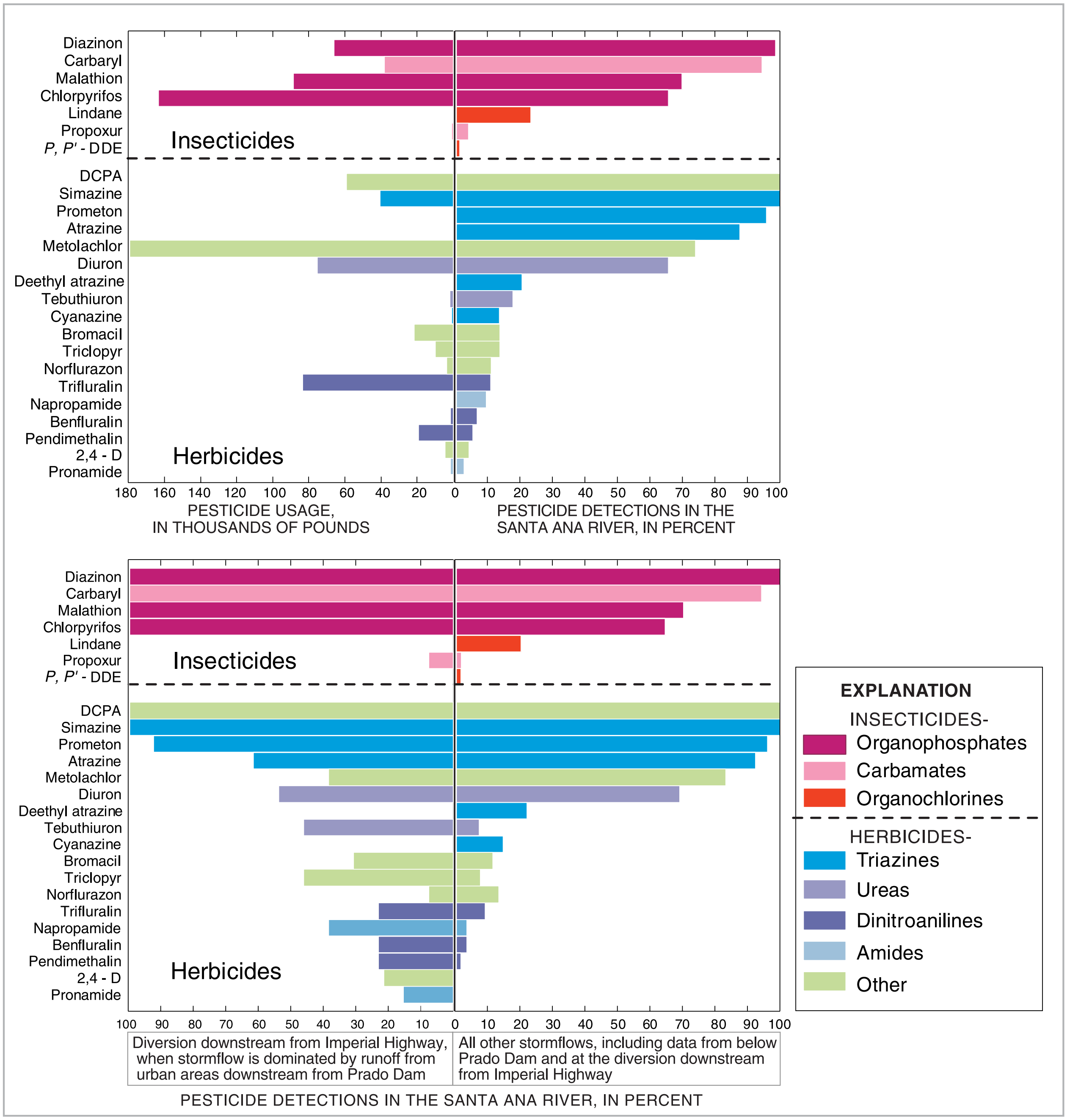


Figure 14. Pesticide use in Orange, Riverside, and San Bernardino Counties and frequency of detection in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98.

maintenance and also may have unreported home and garden use. Herbicides such as atrazine, metolachlor, lindane, cyanazine, and diuron may originate mainly from the upper basin (fig. 14).The herbicides are detected frequently at Imperial Highway, even when stormflow originated primarily as runoff from urban areas downstream from Prado Dam, because stormflow at Imperial Highway almost always contains some fraction of water that originated upstream from Prado Dam.

Recent studies (U.S. Geological Survey, 1999) show that pesticides usually occur in mixtures of several compounds rather than individually. A review of U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program data shows that more than 50 percent of all stream samples contained five or

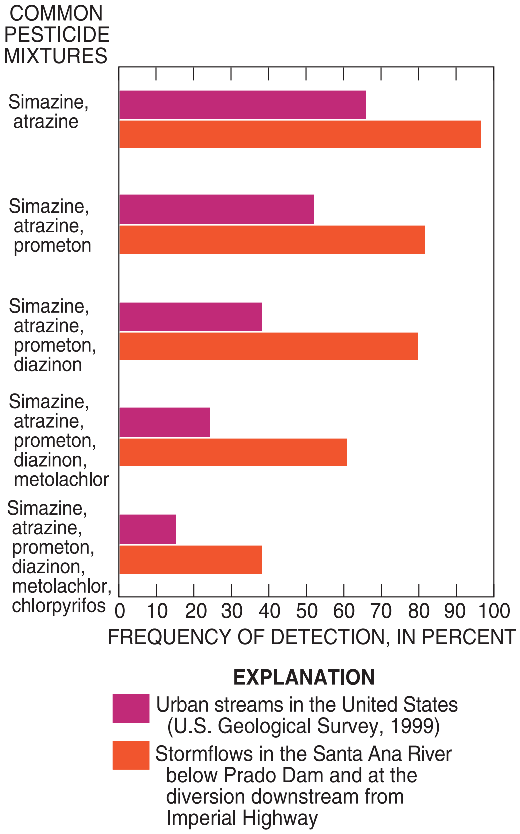


Figure 15. Common pesticide mixtures and frequency of detection in urban streams in the United States and in stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98.

more pesticides (U.S. Geological Survey, 1999). The most common pesticide mixtures in streams draining urban land in the United States are shown in figure 15. The frequency of occurrence of these mixtures in stormflows in the Santa Ana River also is shown in figure 15. These data show that common pesticide mixtures occur more frequently in stormflows in the Santa Ana River basin than in streams draining urban areas elsewhere in the United States.

The pesticide mixtures that occur in the Santa Ana River stormflows are different from the most common pesticide mixtures that occur in streams draining urban land in the United States. For example, during this study, 100 percent of the stormflow samples collected at Imperial Highway when flow was dominated by runoff from urban areas downstream from Prado Dam contained the insecticides diazinon, carbaryl, malathion, and chlorpyrifos, and the herbicides DCPA, and simazine (fig. 14). However, it is unclear if the frequency of pesticide detections during stormflow in the Santa Ana River is typical of the frequency of pesticide detections in stormflows from other streams in the United States (compiled data are not available to compare stormflow samples from the Santa Ana River with stormflow samples from urban streams in the United States).

Principal-Component Analysis

The occurrence of pesticides in stormflow is difficult to evaluate in a systematic manner because of the large number of compounds detected at wide concentration ranges. In addition, pesticides have different physical and chemical properties, different uses, different application rates, and different modes of transport and degradation in the environment. An analysis of the distribution and occurrence of each pesticide is beyond the scope of this report. To simplify interpretation of the data, principal-component analysis was used as a tool to identify pesticides that behave similarly in stormflow and formed the basis for much of the previous discussion.

Principal-component analysis is a multivariate statistical technique that transforms a set of intercorrelated variables, in this case the concentrations of the pesticides, into a new coordinate system (Kshirsagar, 1972; Morrison, 1976; Gnanadesikan, 1977). The transformed variables are known as principal components. Principal components are uncorrelated linear combinations of the original variables. They have a mean of zero and the same variance as the original data set. The values of the principal components are known as scores, and the scores are calculated on the basis of the contribution of each variable to the principal component (Preisendorfer and others, 1981). The magnitude and direction (plus or minus) of the contribution of each variable to the principal-component score is described by an eigenvector.

The eigenvectors composing the first and second principal components are listed in table 3. Of the 10 most commonly detected pesticides, the first principal component contains large positive eigenvectors for the insecticides diazinon, chlorpyrifos, and malathion. The second principal component contains large positive eigenvectors for the herbicides diuron and simazine and the insecticide carbaryl. On the basis of the data presented earlier (fig. 12), concentrations of diazinon, chlorpyrifos, and malathion change in a similar manner in stormflow. Concentrations of diuron, simazine, and

Table 3. Eigenvectors composing the first and second principal components of pesticides in stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98

[Pesticides listed in order of frequency of detection]

Pesticide	First principal component	Second principal component
Most commonly detected pesticides		
Simazine	0.02	0.42
DCPA	–.13	.13
Diazinon	.41	–.15
Prometon	.16	.16
Carbaryl	.27	.35
Atrazine	–.14	.08
Matolachlor	–.21	.13
Malathion	.35	–.18
Diuron	.11	.46
Chlorpyrifos	.36	–.20
Other pesticides detected		
Deethyl atrazine	–0.13	0.02
Tebuthiuron	.12	–.22
Lindane	–.06	–.03
Cyanazine	–.11	–.03
Bromacil	–.11	.07
Triclopyr	.06	–.12
Norflurazon	–.05	.06
Trifluralin	.13	.08
Napropamide	.18	–.18
Benfluralin	.26	.04
Pendimethalin	.20	.00
2,4-D	.20	–.01
Propoxur	–.11	–.04
Pronamide	.20	.00
DDE	.10	.30

carbaryl also change in a similar manner during stormflow (fig. 13), but these changes are different from changes in the concentrations of diazinon, chlorpyrifos, and malathion. With the exception of carbaryl, these similarities and differences also are reflected in the results of the median tests and box plots shown in figure 11. This suggests that grouping of pesticides on the basis of principal-component analysis is a reasonable approach to evaluating pesticide distribution in stormflow.

Comparison of the first and second principal-component scores (fig. 16) shows that there are differences between the pesticide concentrations in early season stormflows and late season stormflows. At first glance, these data suggest a "first-flush" response with respect to insecticides. However, these differences actually result from negative second principal-component scores during early season stormflows. These negative scores are consistent with lower concentrations of diuron and simazine observed in early season stormflows in comparison with late season stormflows. This may occur because of increased use of these herbicides during the rainy season. The largest second principal-component scores were calculated for samples collected during the recessional flow of the February 3–5, 1998, stormflow (fig. 16). This was one of the largest storms sampled and was the first of a series of El Niño-driven storms during one of the wettest Februarys on record. The data in figure 16 also show that the first principal-components score increase with increasing magnitude of the stormflows. This

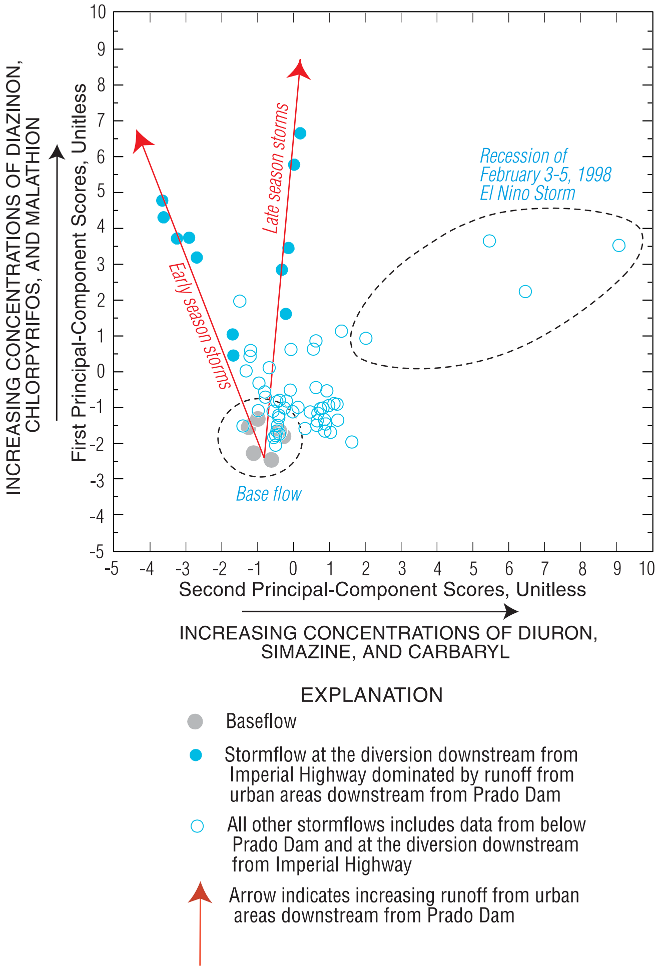


Figure 16. Principal-component scores calculated from pesticide concentrations in base flow and stormflow below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1996–98.

result is consistent with higher concentrations of the insecticides diazinon, chlorpyrifos, and malathion during larger stormflows derived as runoff from urban areas downstream from Prado Dam. A similar trend was not apparent for the second-principal-component scores.

Volatile Organic Compounds

Volatile organic compounds (VOC) occur in numerous commercial and industrial products including fuels, solvents, paints, adhesives, deodorants, and refrigerants (Smith and others, 1988). In addition, VOCs also occur in combustion-engine exhaust and can be produced as a byproduct of chlorinating water containing high concentrations of DOC (Hoekman, 1992; Lopes and Bender, 1998; Lopes and Dionne, 1998). Volatile organic compounds have been detected in surface water throughout the United States (Lopes and Bender, 1998; Lopes and Dionne, 1998; Reiser and O'Brien, 1998) and have been identified as potential contaminants in 38 percent of the community water systems in the United States (U.S. Environmental Protection Agency, 1997). There is increased concern about these compounds in urban areas because infiltration of stormwater containing VOCs associated with combustion-engine exhaust has been shown to contaminate ground water (Pritt and others, 1996; Maine Geological Survey, 1998). The potential effects of low concentrations of VOCs in drinking water are difficult to evaluate because of inadequate information on the effects of low-concentration mixtures, transformation products, and long-term exposure.

Volatile organic compounds were collected during the 1997–98 rainy season. Because these compounds have a high vapor pressure, they could not be collected with the automated samplers used in this study. Instead, grab samples for VOCs were collected during the September 14–16, 1997, November 10–12, 1997, and February 3–5, 1998, stormflows. Because manual collection was required, the number of VOC samples collected during most stormflows was fewer than the number of samples collected for other constituents. The most complete data set was obtained for the February 3, 1998, stormflow: during this stormflow, samples also were collected from a storm drain that discharges to the Santa Ana River at Imperial Highway (fig. 17).

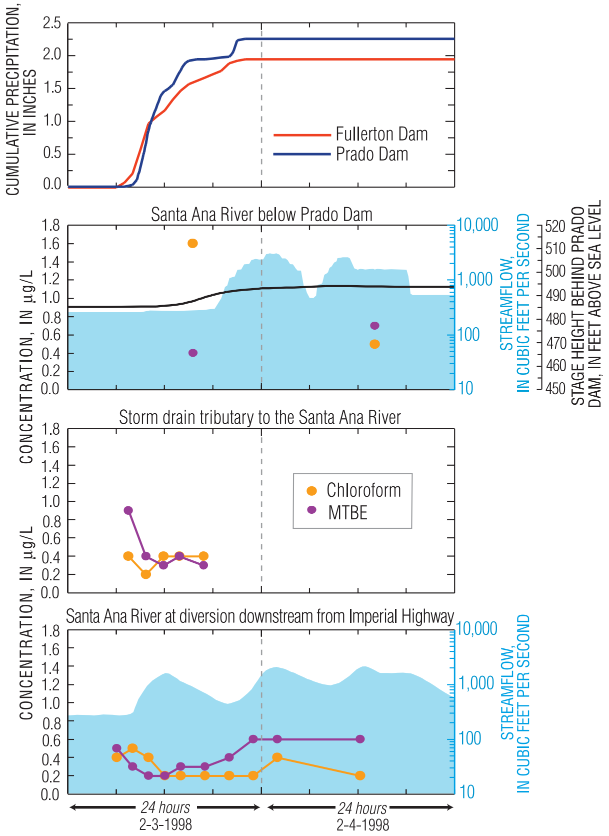


Figure 17. MTBE and chloroform concentrations in the Santa Ana River below Prado Dam, at the diversion downstream from Imperial Highway, and in a storm drain tributary to the Santa Ana River near Imperial Highway, southern California. (µg/L, microgram per liter)

Of the 29 VOCs analyzed, 5 were detected at low concentrations in stormflow from the Santa Ana River below Prado Dam and at Imperial Highway (Appendix F). These compounds included three chlorinated compounds, chloroform, dichloromethane, and bromodichloro-methane, and two compounds associated with combustion-engine exhaust, toluene and methyl tert-butyl ether (MTBE).

Maximum concentrations of chloroform, dichloromethane, and bromodichloro-methane were as high as 3.4, 1.3, and 0.6 µg/L, respectively. As a group these compounds are known as trihalomethanes and they are formed by the chlorination of water that has high DOC concentrations, but they also may be present from other sources. The USEPA MCL for total trihalomethanes is 100 µg/L (California Department of Water Resources, 1997). Chloroform, dichloromethane, and bromodichloro-methane were detected in 69, 16, and 28 percent, respectively, of all samples from the Santa Ana River. This frequency of detection is higher than the frequency reported for

Table 4. Volatile organic carbon compounds detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, and at other urban sites across the United States, 1997–98

[Percent detection in urban stormwater from Lopes and Bender (1998). IUPAC, International Union of Pure and Applied Chemistry; —, no data]

Compound (IUPAC nomenclature)	Common name	Percent detection in United States urban stormwater	[1]Percent detection in Santa Ana River stormflow
Chlorinated Compounds			
Trichloromethane	chloroform	13	69
Tetrachloroethene	perchloroethylene (PCE)	8.0	0
Dichloromethane	methylene chloride	5.9	16
Bromodichloro-methane	—	5.8	28
Trichloroethene	trichloroethylene (TCE)	4.7	0
cis-1,2-Dichloroethene	—	4.6	0
1,1,1-Trichloroethane	1,1,-TCA	4.2	0
Dibromochloro-methane	—	3.4	—
Gasoline-Related Compounds			
Methylbenzene	toluene	23	8
Dimethylbenzene	xylene	18	0
1,2,4,-Trimethyl-benzene	—	12	0
Napthalene	—	7.4	—
Methyl tert-butyl ether	MTBE	6.9	88
Ethylbenzene	—	5.0	0
Benzene	—	3.9	0

[1] Statistics calculated on the basis of 24 analyses collected during three stormflows: September 14–16, 1997; November 10–12, 1997; and February 3–5, 1998. Data given in Appendix F.

stormwater from urban areas in the United States by Lopes and Bender (1998) (table 4). This result is not unexpected given the large quantity of treated municipal wastewater discharged to the Santa Ana River.

Maximum concentrations of toluene and MTBE in stormflow were as high as 3.9 µg/L and an estimated 0.7 µg/L, respectively, and MTBE concentrations in the storm drain were as high as an estimated 0.9 µg/L. The USEPA MCL for toluene is 1,000 µg/L, and the California Department of Health Services Action Level for MTBE is 35 µg/L (California Department of Water Resources, 1997). Toluene and MTBE were detected in 8 and 88 percent, respectively, of stormflow samples from the Santa Ana River. The frequency of detection for toluene is less than detection nationally in urban stormwater reported by Lopes and Bender (1998). The frequency of detection for MTBE is much higher than that reported by Lopes and Bender (1998), possibly because of the high use of MTBE in gasoline as an oxygenate during the winter months in California.

Concentrations of MTBE are within the range expected for surface water in equilibrium with urban air (Lopes and Bender, 1998). In contrast, maximum toluene concentrations are much higher than expected for surface water in equilibrium with urban air, suggesting that spills or other sources also may contribute toluene to urban stormwater in the Santa Ana River basin. Because toluene was not frequently detected, it is probable that these sources are small and that toluene is readily washed from the basin.

Changes in chloroform and MTBE concentrations during the February 3–4, 1998, stormflow for the Santa Ana River below Prado Dam and at Imperial Highway, and for the storm drain tributary to the Santa Ana River, are shown in figure 17. In general, concentrations of chloroform decreased during stormflow, which is consistent with dilution by treated municipal wastewater that is the principal source of base flow in the Santa Ana River. Similar patterns have been observed for chloroform and other trihalomethanes in stormflow in other parts of the country (Lopes and Bender, 1998; Reiser and O'Brien, 1998).

Concentrations of MTBE initially decreased and later increased during stormflow. The decreases in MTBE concentrations were not expected and have not been reported in stormwater from urban areas in other parts of the country (Lopes and Bender, 1998; Reiser and O'Brien, 1998); in general, MTBE concentrations increase during stormflow. One possible explanation for the decrease is that water in the Santa Ana River initially was in equilibrium with MTBE concentrations in the urban air, but the large amount and intensity of the precipitation removed available MTBE from the atmosphere faster than it could be replaced. Later in the storm, MTBE concentrations increased when water stored behind Prado Dam, which was in equilibrium with MTBE in the atmosphere, was released. Toluene was not detected in the Santa Ana River, or the storm drain, during the February 3–4, 1998, stormflow.

Changes in Selected Trace-Element Concentrations During Stormflow

Trace elements sampled as part of this study were dissolved iron, manganese, and zinc. Iron and manganese are redox-active elements, and high concentrations of these dissolved metals are usually attributed to low dissolved oxygen conditions. Zinc is commonly used to protect other metals from corrosion. Motor vehicles, and especially motor oils, are believed to be a major source of zinc in the urban environment (Wigington and others, 1983). In this study zinc was evaluated for use as an indicator of contamination from highways. Zinc may be suitable for this purpose because it is commonly present in urban runoff (Harter, 1983; Schroeder, 1995), has been frequently detected in the Santa Ana River below Prado Dam (Burton and others, 1998), and is more soluble than other trace elements associated with street, highway, and other urban sources of contamination (Harter, 1983).

The median dissolved iron and dissolved manganese concentrations in base flow were 9.5 and 23 μg/L, respectively; maximum concentrations were 14 and 40 μg/L (fig. 18). The USEPA Secondary Maximum Contaminant Levels (SMCL) for iron and manganese are 300 and 50 μg/L, respectively (California Department of Water Resources, 1997). During this study, dissolved iron and dissolved manganese concentrations in the Santa Ana River typically increased during stormflows. The median dissolved iron concentrations in both early season and late season stormflows below Prado Dam and at Imperial Highway are statistically different from concentrations in base flow. Median dissolved manganese concentrations in early season and late season stormflows were not statistically different from concentrations in base flow. However, about 35 percent of the concentrations in early season stormflows and 10 percent of the concentrations in late season stormflows exceeded the USEPA SMCL for manganese.

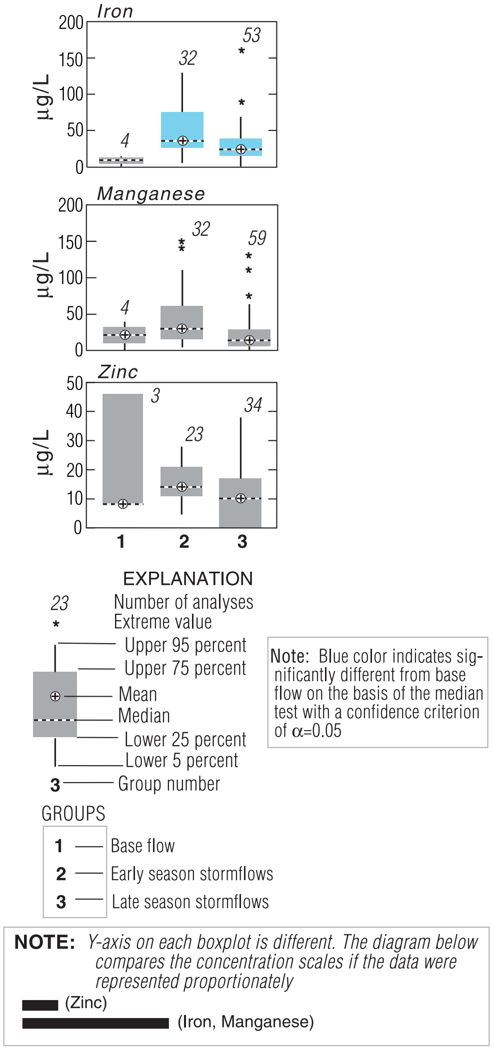


Figure 18. Dissolved iron, manganese, and zinc concentrations in base flow, and in early season and late season stormflows in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California, 1995–98. (μg/L, microgram per liter)

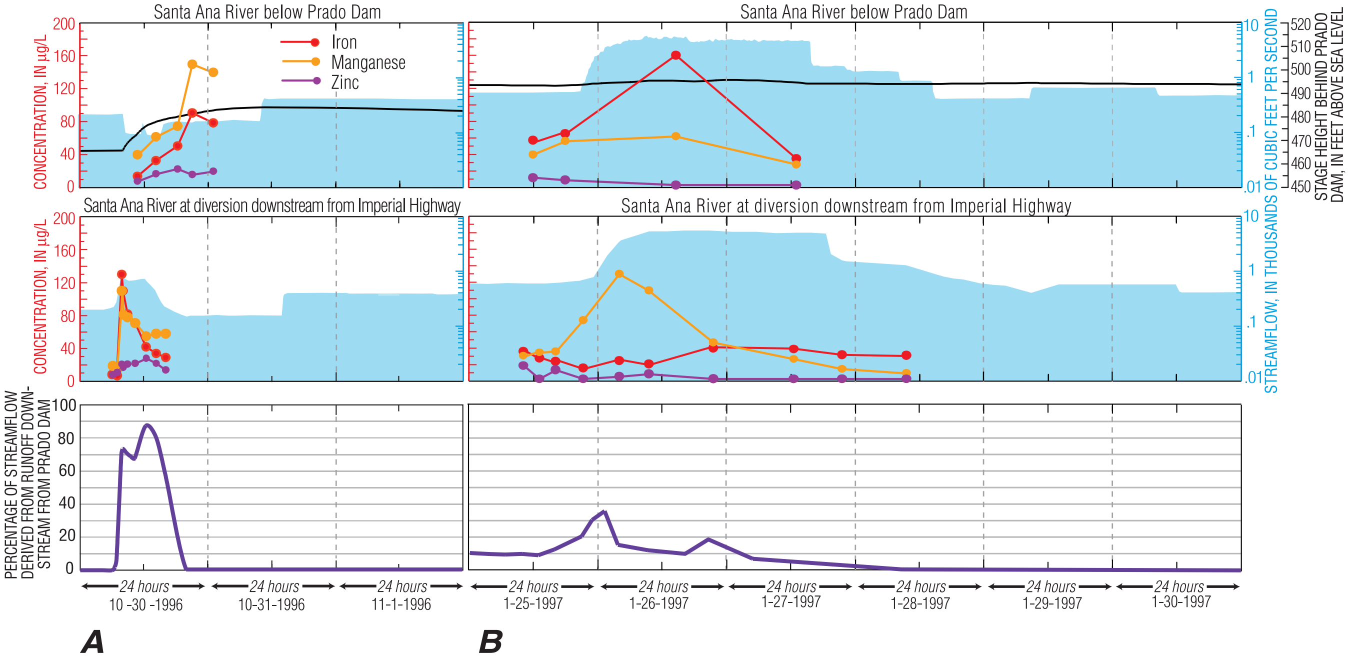


Figure 19. Dissolved iron, manganese, and zinc concentrations during stormflow in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California: (A) October 30–November 1, 1996, (B) January 25–30, 1997, and (C) September 25–27, 1997. (µg/L, microgram per liter)

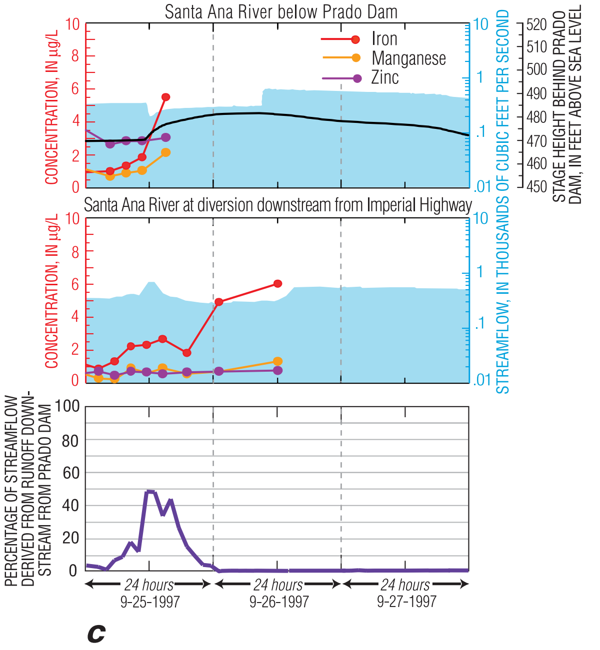


Figure 19. Continued.

High dissolved iron and dissolved manganese concentrations in early season stormflows are associated with runoff from urban areas downstream from Prado Dam and with the recession of early season stormflows; they also are associated with increases in the concentrations of reduced forms of nitrogen and high concentrations of DOC. In late season stormflows high iron and manganese concentrations are associated with release of water held in storage behind Prado Dam, such as during the January 25–30, 1997, stormflow (fig. 19), and can be attributed to low dissolved oxygen conditions that may develop in the flooded wetlands behind the dam.

During the 1997–98 rainy season, zinc concentrations in the Santa Ana River below Prado Dam were as high as 680 µg/L (December 5, 1997). High concentrations were not observed during other years and may have been related to nearby bridge construction. Equipment blanks and field blanks done during the 1997–98 rainy season showed no evidence of trace element contamination. Excluding these high concentrations, zinc in base flow (three samples) ranged from 8 to 46 µg/L. The USEPA SMCL for zinc is 5,000 µg/L. Median zinc concentrations were not significantly different during early season and late season stormflow, and concentrations do not increase consistently with increases in runoff from urban areas below Prado Dam. On the basis of these results, zinc in filtered water may be a poor indicator of runoff from urban areas.

DIVERSION OF STORMFLOWS AND THE EFFECTS ON THE QUALITY OF RECHARGE WATER

Base flow in the Santa Ana River is maintained almost entirely by discharge of treated municipal wastewater. At present (2000), as mentioned previously in this report, the management assumption guiding ground-water recharge operations is that stormflow in the Santa Ana River is “high-quality” water that is suitable for diversion to aquifers that are pumped for public supply (Orange County Water District, 1996b). Large quantities of water recharged during stormflows are believed to improve the overall quality of water recharged from the Santa Ana River (Orange County Water District, 1996b). In the past, there have been few data to support or refute this assumption. Results of this study show that stormflows are not of uniform chemistry and that there are large differences in the concentrations of selected constituents within individual stormflows and between stormflows during different parts of the rainy season.

At present, stormflow-management practices for ground-water recharge operations result in a reduction in the overall concentration of nitrate in water recharged from the Santa Ana River. High nitrate concentrations in base flow result from the discharge of treated municipal wastewater to the river (Burton and others, 1998). This study shows that nitrate concentrations decrease because of dilution during stormflow and, although concentrations of reduced forms of nitrogen (such as organic nitrogen) increase during stormflow, these increases do not result in an increase in total nitrogen.

Existing management strategies are less effective in minimizing DOC concentrations in water diverted for ground-water recharge. DOC concentrations increase during stormflows. DOC concentrations and ultraviolet absorbance data suggest that DOC may be a concern for trihalomethane formation when water is chlorinated for use as a drinking-water supply. Increases in DOC are greatest during early season stormflows, especially when stormflow is primarily runoff from urban areas downstream from Prado Dam. High DOC concentrations also are present during the recessional flow of some early season stormflows. This may be a special concern because streamflow data, and other chemical data, suggest that DOC may be associated with runoff from the Cucamonga and Chino Creek drainage basins. Large numbers of animal-confinement facilities are located in these basins. However, land use in these basins is mixed and includes large urban areas. Early season stormflows represent only a small part of the annual flow in the Santa Ana River, and it may be possible to time diversions to minimize the quantity of this water that is recharged. High DOC concentrations also are present during stormflows that occur later in the rainy season—especially if water has been held in the flooded wetlands behind Prado Dam for some time. Water is stored behind Prado Dam to reduce peak flows and allow for increased diversion of stormflow to recharge aquifers underlying Orange County. As a result, it may be difficult to manage stormflow to reduce DOC concentrations from late season stormflows. However, stormflow is not used directly as a source of public supply, and DOC may degrade after recharge. The potential for DOC to be degraded or removed within aquifers prior to withdrawal is being addressed as part of the SARWQH study.

All pesticide concentrations were below their respective USEPA MCLs, and most pesticide concentrations were less than the reporting limit obtainable using standard drinking-water analyses. Therefore, at this time, pesticide concentrations are not an important concern in stormflow diverted for recharging aquifers pumped for water supply. However, the long-term health effects of low levels of pesticides are poorly understood, and it may be necessary to reduce pesticide concentrations in water diverted for recharge in the future. On the basis of data collected as part of this study, stormflow contains higher concentrations of pesticides than does base flow. Management of stormflow to reduce pesticide concentrations would require (1) deciding which pesticides need to be controlled, (2) improving understanding of pesticide use within the basin, and (3) then developing stormwater-management plans to exclude runoff from different areas in the basin. For example, runoff from urban areas downstream from Prado Dam contains the highest concentrations of diazinon, malathion, and chlorpyrifos, and runoff from areas upstream from Prado Dam contains the highest concentrations of DCPA, simazine, and diuron. As a result, stormwater-management strategies intended to reduce diazinon concentrations may be different from management strategies intended to reduce diuron concentrations.

SUMMARY

The Santa Ana River, located in an extensively urbanized basin, drains about 2,670 square miles near Los Angeles, California. Almost all the flow in the river, more than 200,000 acre-feet annually, is diverted into ponds where it infiltrates and recharges underlying aquifers. About 2 million people are dependent on these aquifers for water supply. Stormflow in the Santa Ana River is believed to be a source of “high-quality” water suitable for use as a source of water supply. To test this assumption, stormflow samples were collected at two locations, below Prado Dam and at the diversion point downstream from Imperial Highway, for 12 winter storms between 1995 and 1998.

The quality of stormflow diverted for ground-water recharge at Imperial Highway is a result of the magnitude, timing, and distribution of runoff in the basin. The influence of urban areas downstream from Prado Dam on water quality is increased when runoff from upstream areas is held behind the dam to control peak flows. Stormflow quality also is altered for short periods when water stored behind the dam is released. Water stored behind Prado Dam is a mixture of base flow and water from previous storms. In addition, chemical and biochemical reactions or dissolution of soluble material from soil and plants in flooded wetlands behind the dam may alter the chemistry of this water. Changes in water chemistry also may occur if the channel of the Santa Ana River or its tributaries is disturbed by increased flow velocities that occur during stormflow. This may occur in the natural channels and in concrete-lined channels and storm drains as they are flushed clean during stormflow.

The median nitrate concentrations in base flow was 7.3 mg/L as nitrogen, and maximum base-flow concentrations were as high as 9.1 mg/L as nitrogen. These values are near the MCL for nitrate of 10 mg/L as nitrogen. In general, stormflow is low in nitrogen and lowers the average concentration of nitrate in water recharged from the Santa Ana River. Reduced forms of nitrogen are the predominant forms of nitrogen during stormflow. In some stormflows, ammonia concentrations can exceed 2 mg/L as nitrogen. Ammonia can be toxic to fish at concentrations as low as 0.4 mg/L as nitrogen.

It is desirable to minimize the DOC in water recharged from the Santa Ana River because of health concerns about carbon of wastewater origin and because of concerns about trihalomethane formation. In the Santa Ana River, DOC concentrations increased during stormflow and were as high as 23 mg/L. DOC concentrations may be especially high during the first storm of the rainy season when highly mobile organic carbon that accumulates in urban areas downstream from Prado Dam during the dry season washes into the river. On the basis of DOC concentrations and UV absorbance data, DOC in stormflow may have a trihalomethane formation potential similar to that of imported water from northern California. On the basis of UV absorbance data, the composition of DOC from early season stormflows is different from the composition of DOC in water that has been stored in the flooded wetlands behind Prado Dam.

Twenty-five pesticides were detected out of 87 compounds analyzed. All pesticide concentrations were below their respective USEPA MCLs, and most pesticide concentrations were less than the reporting limit obtainable using standard drinking-water analytical methods. Only carbaryl, simazine, and diuron had maximum concentrations greater than 1 μg/L. Although pesticide concentrations in Santa Ana River stormflow are not an important concern at this time, the long-term health effects of low concentrations of pesticides are poorly understood. On the basis of data collected as part of this study, stormflow contains higher concentrations of most pesticides than does base flow. Diazinon, malathion, and chlorpyrifos concentrations are higher in runoff from urban areas downstream from Prado Dam, and simazine, diuron, and carbaryl concentrations are higher in runoff from the upper basin. Pesticide concentrations in stormflow are related to the magnitude of the storm.

Five volatile organic carbon compounds were detected out of 29 compounds analyzed. All compounds were below their respective USEPA MCLs. Three chlorinated compounds (chloroform, dichloromethane, and bromodichloro-methane) associated with the chlorination of water containing high concentrations of DOC were detected. MTBE, a gasoline oxygenate widely used in California, was detected in 88 percent of stormflow samples. This is a much higher frequency of detection than recently reported frequencies of detection in United States urban stormwater.

In general, dissolved iron and dissolved manganese concentrations increased during stormflow and manganese concentrations occasionally exceeded the SMCLs of 300 and 50 μg/L, respectively. High iron and manganese concentrations are probably related to low dissolved oxygen conditions that develop in the flooded wetlands when stormflow water is stored behind Prado Dam. Zinc concentrations were generally low and zinc was not a good indicator of urban runoff.

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APPENDIX A

Quality-Assurance Procedures

APPENDIX A—QUALITY-ASSURANCE PROCEDURES

Quality assurance is defined as the procedures used to control the unmeasurable components of the sample collection, handling, and analysis procedures. Quality-assurance elements include standard operating procedures, instrument maintenance logs, and personnel training records. Quality-assurance procedures for this study had two components: field quality assurance implemented by study personnel and the laboratories' internal quality assurance.

Field Quality-Assurance Procedures

Field quality-assurance procedures included the collection and processing of samples using the following standard operating procedures and data tracking from the field to the lab. Environmental samples were collected using an automatic sampler or by grab sampling (VOC's). The intake line for the automatic samplers were made from Teflon tubing encased in a steel pipe. The line was replaced between storm seasons. The bottom 4 feet of the intake line was encased with stainless steel to minimize contamination from metals. The automatic sampler was programed to rinse the intake line twice before collecting each sample. Samples were processed and equipment was cleaned using methods adopted from USGS protocols developed for analysis of trace constituents at the part-per-billion level as described by Shelton (1994). All samples, except pesticides, were filtered in the field. Protocols for filtration and extraction of pesticides are complex and require specialized equipment. Pesticide samples were shipped to the USGS National Water Quality Laboratory (NWQL) for filtration and extraction prior to analysis.

Water-quality field forms were started and bottles were labeled on site. Samples were tracked by logging them into the USGS National Water Information System (NWIS), giving each sample a unique record number. Instrument-maintenance logs are kept for all equipment used to measure field parameters. All employees that collect and process water-quality samples are required to participate in a yearly National Field-Quality Assurance Program. Samples were reviewed for completeness and accuracy by the NWQL and by field personnel prior to release to public data bases.

Contamination and variability were assessed through field quality assurance. Contamination was assessed with field blanks and variability was assessed with replicate samples. Field blanks were done on the collection and processing equipment. Replicates were done on all schedules used to analyze environmental samples.

Blank samples are collected and analyzed to ensure that environmental samples have not been contaminated by any part of the collection, handling, or processing procedures. Many types of blank samples are possible; each is designed to isolate a different part of the overall data-collection process. Field blanks subjected to all aspects of sample collection, field processing, preservation, transportation, and laboratory handling to which an environmental sample is subjected were done during each storm season. If field blanks show no evidence of contamination there is no need to process other types of sample blanks. Blank solutions, free of the analyses of interest, were used to prepare field blanks. Three types of water were used for field blanks for this study: pesticide-free water, volatile-free water, and inorganic-free deionized water.

Results from field blanks were less than their respected detection limit for all constituents analyzed as part of this study except dissolved-organic carbon (DOC). DOC concentrations less than 0.3 mg/L were present in two field blanks. These concentrations are more than an order of magnitude less than concentrations of environmental samples collected as part of this study. The results for all pesticides in field blanks were less than their detection limits and show no contamination. This is important because in a study on field blanks by Martin and others (1999), data provided by the National Water-Quality Assessment Program, showed contamination in surface water for *cis*-permethrin, pronamide, *p*'-DDE, pebulate, propargite, ethalfluralin, and triallate. Although not present in any field blanks, pronamide and *p,p*'DDE were occasionally detected at low concentrations as part of this study.

Replicates were used to determine the variability associated with sample collection, handling, and analytical measurement of environmental samples. Replicate samples are a set of environmental samples collected in a manner such that the samples are thought to be virtually identical in composition. There are several types of replicate samples possible, and each may yield slightly different results in a dynamic hydrologic setting, such as a flowing stream. The type of replicate sampling done for this project is a split sample. A split sample is a sample that is split into subsamples contemporaneous in time and space. The variability between replicate samples is represented as the percent difference, which is the absolute difference between replicates divided by the average of the sum of the replicates times 100. The replicates on environmental samples analyzed at the NWQL are summarized in table A1, and replicates on samples analyzed at the USGS San Diego Laboratory are summarized in table A2. The median percent difference between an environmental sample and its replicate provides information on the typical variability of the data. In general, percent differences were greater when constituents were present at low concentrations.

Only one replicate was done on pesticide samples because it was not possible to collect an extra 2 liters of water with the automatic sampler. The pesticide replicate was collected using equal-width increments at a flume 100 ft downstream. The median percent difference for the 12 pesticides detected was 18.7 percent. However, like the other constituents, the variability associated with pesticides is small in relation to the changes in concentration during stormflow.

Laboratory Quality-Assurance Procedures

Laboratory quality-assurance procedures included the determination of surrogate compound recoveries in each sample, laboratory reagent-water blanks, laboratory reagent-water spikes, and an assessment of the instrument system. The NWQL in Denver, Colorado, analyzed most samples. The USGS San Diego Laboratory analyzed samples for nitrate, nitrite, chloride, and sulfate.

U.S. Geological Survey National Water Quality Laboratory

The NWQL, the primary analytical facility of the USGS, analyzes environmental samples from across the United States and from around the world. The NWQL has formal quality-assurance procedures to assess contamination, bias, and variability. Samples of water, sediment, aquatic biological materials, and air are analyzed at the laboratory using state-of-the-art instruments and methods.

Table A1. Replicate analyses by the USGS National Water Quality Laboratory.

[Constituents in milligrams per liter—except iron, manganese, and zinc, which are in micrograms per liter. All constituents dissolved—except suspended organic carbon]

	Number of duplicates	Range	Median percent difference
Trace elements			
Iron	3	<10–110	17
Manganese	3	25–81	1.6
Zinc	3	17–400	10
Nutrients			
Nitrite as nitrogen	6	.05–.11	3.7
Nitrate plus nitrite as nitrogen	6	3.4–7.4	2.8
Ammonia as nitrogen	6	.10–.95	1.6
Ammonia plus organic nitrogen as nitrogen	6	.60–2.3	5.3
Phosphorus	6	.5–.94	1.6
Orthophosphorus as phosphorus	6	.48–.97	1.6
Organic Carbon			
Dissolved organic carbon	5	4.0–16	14
Suspended organic carbon	4	2.8–16	8.2

Table A2. Replicate analyses by the USGS San Diego Laboratory

[mg/L, milligrams per liter]

	Number of duplicates	Range (mg/L)	Median percent differences
Major ions			
Sulfate	12	0.05–3.6	2.4
Chloride	12	1.3–15	1.1
Nutrients			
Nitrite	14	.02–.24	2.9
Nitrate	14	.92–.4.6	1.6

The NWQL uses a three-tiered approach to quality control divided into inorganic and organic analyses. The three-tiered approach is explained in more detail in a USGS Fact Sheet (Pirkey and Glodt, 1998).

The first tier is "Method Performance." At this level, a chemist uses quality-control sample data to evaluate the analytical process for each batch of environmental samples. If prescribed acceptable criteria are not met, the analysis is discontinued until corrected. The second tier is the "Data Review and

Blind Sample Programs." Chemists use data from these programs to monitor method performance throughout the laboratory and over long periods of time. The USGS laboratories and all laboratories working cooperatively with the USGS are required to participate in a Standard Reference Water Sample (SRWS) program. The blind-sample program began in 1962, and since 1966 it has used filtered natural surface water as the base from which to prepare reference materials. The third tier is NWQL's participation in "Performance-Evaluation Studies." Local, State, or Federal agencies external to the NWQL manage these studies. Data from these studies are used to compare laboratories. These studies are explained in more detail in the USGS Fact Sheet (Glodt and Pirkey, 1998). Summary reports from many of these studies are available on the NWQL web site home page at <http://wwwnwql.cr.usgs.gov/USGS/perf_eval.html> and on the Branch of Quality Systems web site home page at <http://btdqs.usgs.gov>.

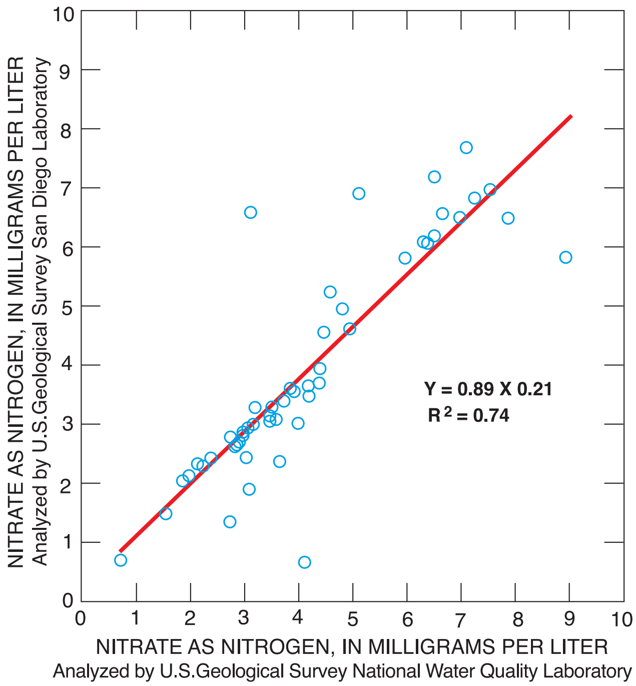

Figure A1. Comparison of nitrate analyses from different U.S. Geological Survey laboratories.

U.S. Geological Survey San Diego Laboratory

The USGS laboratory at the San Diego Project Office analyzed samples for nitrate, nitrite, chloride, and sulfate. These analyses are done by ion chromatography (American Public Health Association, 1992) and were intended to supplement analyses done by the NWQL. Twice a year, the San Diego laboratory is a participant in the NWQL blind-sample program. To calibrate the instrument, standard-reference samples (calibration standards) are used. Calibration samples used were purchased from a vendor and checked with samples from the SRWS program. Blanks were done on water used to clean equipment and check for contamination. Nitrate and nitrite were not present above their detection limits in blank water samples, 0.01 and 0.02 mg/L, respectively.

As part of this study an interlaboratory comparison was done for more than 50 nitrate samples analyzed by the NWQL and the San Diego laboratory (fig. A1). Comparison of the data between the two laboratories is generally good with an R^2 of 0.74. On the basis of results of the t-test with a confidence criterion of α=0.05, the slope of the line shown on figure A1 is not significantly different from 1, indicating a lack of bias to higher or lower values from either laboratory.

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APPENDIX B

Sample Collection, Preservation, and Analytical Methods

APPENDIX B—SAMPLE COLLECTION, PRESERVATION, AND ANALYTICAL METHODS

Samples from the two storms obtained during the winter of 1995–96 were collected using depth-integrated samplers and equal-width-increment methodology (Wilde and others, 1999) following the protocols in Horowitz and others (1994). Bottles provided by Orange County Water District (OCWD) were filled and sent to OCWD for processing and analysis.

Samples from 10 storms sampled during the winters of 1996–97 and 1997–98 were collected using automated samplers. Field parameters (pH, specific conductance, and alkalinity) were measured for each sample. Selected samples were processed in the field and sent to the U.S. Geological Survey's National Water Quality Laboratory (NWQL) for analysis.

Table B1. Analytical methods and reporting limits

[std, standard; ASF, automated segmented flow; USGS, U.S. Geological Survey; UV, ultraviolet; GC/MS, gas chromatography/mass spectrometry; HPLC, high performance liquid chromatography. µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; deg. C, degrees Celsius; nm, nanometers; µg/L, micrograms per liter]

Constituent	Methodology	Reporting limit	Reference
Field parameters			
pH	pH electrode	0.1 std. units	Fishman and Friedman, 1989
Specific conductance	Wheatstone bridge	1.0 µS/cm	Fishman and Friedman, 1989
Alkalinity	Titrimetry with sulfuric acid	1.0 mg/L	Fishman and Friedman, 1989
Major ions			
Sulfate, dissolved	Ion chromatography	.31 mg/L	Fishman and Friedman, 1989
Chloride, dissolved	Ion chromatography	.1 mg/L	Fishman and Friedman, 1989
Dissolved solids	Gravimetric, residue on evaporation at 180 deg. C	10 mg/L	Fishman and Friedman, 1989
Nutrients			
Nitrite, dissolved	Colorimetry, ASF	.01 mg/L	Fishman, M.J., 1993
Nitrite + nitrate, dissolved	Colorimetry, ASF, cadmium reduction-diazotization	.05 mg/L	Fishman, M.J., 1993
Ammonia, dissolved	Colorimetry, ASF, salicylate-hypochlorite	.02 mg/L	Fishman, M.J., 1993
Ammonia + organic nitrogen, total	Colorimetry, ASF, microkjeldahl digestion	.10 mg/L	C.J. Patton, USGS, written commun., 1999
Ammonia + organic nitrogen, dissolved	Colorimetry, ASF, microkjeldahl digestion	.10 mg/L	Patton and Truitt, 1992
Phosphorus, total	Colorimetry, ASF, microkjeldahl digestion	.05 mg/L	Patton and Truitt, 1992
Phosphorus, dissolved	Colorimetry, ASF, microkjeldahl digestion	.05 mg/L	Patton and Truit, 1992
Orthophosphate, dissolved	Colorimetry, ASF	.01 mg/L	Fishman, M.J., 1993
Organic carbon			
Dissolved organic carbon	UV-promoted persulfate oxidation	.100 mg/L	Brenton and Arnett, 1993
Suspended organic carbon	Wet-chemical oxidation	.2 mg/L	Burkhardt and others, 1997
UV absorbance at 254 nm	UV-visible spectrophotometry	.02 nm	American Public Health Association, 1992
Selected organic compounds			
Pesticides - USGS Schedule 2001	C-18 solid-phase extraction, GC/MS	see Table B2	Zaugg and others, 1995
Pesticides - USGS Schedule 2050	Carbopak-B solid-phase extraction, HPLC	see Table B3	Werner and others, 1996
Volatile organic compounds	GC/MS	see Table B4	Connor and others, 1997
Trace elements			
Iron, dissolved	Inductively coupled plasma	10.0 µg/L	Fishman, 1993
Manganese, dissolved	Inductively coupled plasma	3.0 µg/L	Fishman, 1993
Zinc, dissolved	Inductively coupled plasma	20.0 µg/L	Fishman, 1993

Table B2. Pesticides determined by C-18 solid-phase extraction and gas chromatography/mass spectrometry

[Reporting limits in micrograms per liter]

Pesticide	Reporting limit
2,6-Diethylaniline	0.003
Acetochlor	.002
Alachlor	.002
Atrazine	.001
Azinphos-methyl	.001
Benfluralin	.002
Butylate	.002
Carbaryl	.003
Carbofuran	.003
Chlorpyrifos	.004
Cyanazine	.004
DCPA (Dacthal)	.002
Deethyl atrazine	.002
Diazinon	.002
Dieldrin	.001
Disulfoton	.017
EPTC	.002
Ethalfluralin	.004
Ethoprophos	.003
Fonofos	.003
Lindane	.004
Linuron	.002
Malathion	.005
Metolchlor	.002
Metribuzin	0.004
Molinate	.004
Napropamide	.003
Parathion	.004
Parathion-methyl	.006
Pebulate	.004
Pendimethalin	.004
Phorate	.002
Prometon	.018
Pronamide (Propyzamide)	.003
Propachlor	.007
Propanil	.004
Propargite	.013
Simazine	.005
Tebuthiuron	.010
Terbacil	.007
Terbufos	.013
Thiobencarb	.002
Triallate	.001
Trifluralin	.002
alpha-HCH	.002
cis-Permethrin	.005
p,p'-DDE	.006

Table B3. Pesticides determined by Carbopak-B solid-phase extraction and high performance liquid chromatography

[Reporting limits in micrograms per liter]

Pesticide	Reporting limit
2,4,5-T	0.040
2,4-D	.11
2,4-DB	.10
2-(2,4,5-Trichlorophenoxy)propionic acid	.06
3-Hydroxycarbofuran	.11
4,6-Dinitro-2-methylphenol	.42
Acifluorfen	.09
Aldicarb	.21
Aldicarb sulfone	.10
Aldicarb sulfoxide	.021
Bentazon	.035
Bromacil	.06
Bromoxynil	.04
Chloramben	.14
Chlorothalonil	.48
Clopyralid	.23
Dacthal monoacid	.039
Dicamba	.043
Dichlobenil	0.07
Dichlorprop	.032
Dinoseb	.06
Diuron	.06
Fenuron	.07
Fluometuron	.06
MCPA, ((4-chloro-2-methly)phenoxyaceyic acid)	.17
MCPB, (4-(4-chloro-2-methlyphenoxy)butoanoic acid)	.13
Methiocarb	.026
Methomyl	.017
Neburon	.07
Norflurazon	.042
Oryzalin	.31
Oxamyl	.018
Picloram	.05
Propham	.035
Propoxur	.08
Triclopyr	.25

Table B4. Volatile organic compounds and reporting limits

[Compound names in International Union of Pure and Applied Chemitry nomenclature, common names given in parentheses. Reporting limits in micrograms per liter]

Compound	Reporting limit
1,1,1,2,2,2-Hexachloroethane	0.19
1,1,1,2-Tetrachloroethane	.03
1,1,1-Trichloroethane	.032
1,1,2,3,4,4-Hexachloro-1,3-butadiene	.14
1,1,2,2-Tetrachloroethane	.09
1,1,2-Trichloroethane	.06
1,1,2-Trichloro-1,2,2-trifluoroethane	.06
1,1,2-Trichloroethene (Trichloroethylene)	.038
1,1-Dichloroethane	.066
1,1-Dichloroethene (1,1-Dichloro-ethylene)	.04
1,1-Dichloropropene	.026
(1,1-Dimethylethyl)benzene (tert-Butylbenzene)	.06
1,1'-Oxybisethane (Diethyl ether)	.17
1,2,3,4-Tetramethylbenzene	.23
1,2,3,5-Tetramethylbenzene	.20
1,2,3-Trichlorobenzene	.27
1,2,3-Trichloropropane	.16
1,2,3-Trimethylbenzene	.12
1,2,4-Trichlorobenzene	.19
1,2,4-Trimethylbenzene	.056
1,2-Dibromo-3-chloropropane	.21
1,2-Dibromoethane	.036
1,2-Dichlorobenzene	.048
1,2-Dichloroethane	.13
cis-1,2-Dichloroethene	.038
trans-1,2-Dichloroethene	.032
1,2-Dichloropropane	.068
1,2-Dimethylbenzene (o-Xylene)	.038
1,3,5-Trimethylbenzene	.044
1,3-Dichlorobenzene	.054
1,3-Dichloropropane	.12
cis-1,3-Dichloropropene	.09
trans-1,3-Dichloropropene	.09
1,3- and 1,4-dimethylbenzene (m- and p-Xylene)	.06
1,4-Dichlorobenzene	.050
trans-1,4-Dichloro-2-butene	.7
1,4-Epoxybutane (Tetrahydrofuran)	2.2
1-Chloro-2-methylbenzene (o-Chlorotoluene, 2-Chlorotoluene)	.042
1-Chloro-4-methylbenzene (p-Chlorotoluene, 4-Chlorotoluene)	.06
1-Ethyl-2-methylbenzene (o-Ethyl toluene)	.06
1-Isopropyl-4-methylbenzene	.07
(1-Methylethyl)benzene (Isopropylbenzene)	.032
(1-Methylpropyl)benzene (sec-Butylbenzene)	.032
2,2-Dichloropropane	0.05
2,2'-Oxybis[propane] (Diisopropyl ether)	.10
2-Butanone	1.6
2-Ethoxy-2-methylpropane (Ethyl tert-butyl ether, ETBE)	.054
2-Hexanone	.7
2-Methoxy-2-methyl butane (tert-Pentyl methyl ether)	.11
2-Methoxy-2-methylpropane (Methyl tert-butyl ether, MTBE)	.17
2-Methyl-2-propenenitrile (Methyl acrylonitrile)	.6
2-Propanone (Acetone)	7
2-Propenenitrile (Acrylonitrile)	1.2
3-Chloro-1-propene	.20
4-Methyl-2-pentanone	.37
Benzene	.035
Bromobenzene	.036
Bromochloromethane	.044
Bromodichloromethane	.048
Bromoethene (Vinyl bromide)	.10
Bromomethane	.26
n-Butylbenzene	.19
Chlorobenzene	.028
Chloroethane	.12
Chloroethene (Vinyl chloride)	.11
Chloromethane	.5
Dibromochloromethane	.18
Dibromomethane	.050
Dichlorodifluoromethane	.27
Dichloromethane (methylene chloride)	.38
Dithiocarbonic anhydride (Carbon disulfide)	.07
Ethenylbenzene (Styrene)	.042
Ethylbenzene	.030
Ethyl 2-methyl-2-propanoate (Ethyl methacrylate)	.18
Iodomethane (Methyl iodide)	.12
Methylbenzene (Toluene)	.05
Methyl 2-methyl-2-propenoate (Methyl methacrylate)	.35
Methyl-2-propenoate (Methyl acrylate)	1.4
Naphthalene	.25
n-Propylbenzene	.042
Tetrachloroethene	.10
Tetrachloromethane	.06
Tribromomethane (Bromoform)	.06
Trichlorofluoromethane	.09
Trichloromethane (Chloroform)	.052

Samples for inorganic analysis were filtered in the field using a capsule filter having a pore size of 0.45-µm (Shelton, 1994). Nutrients were preserved by chilling at 4°C and were analyzed within 7 days. Trace elements were preserved by acidification to pH < 2.0. Dissolved and suspended organic carbon samples were filtered with a stainless steel filtration unit that holds a silver filter with a 0.45 µm pore size (Shelton, 1994). Pesticide samples were shipped to the NWQL for filtering through a glass fiber filter and solid-phase extraction (Shelton, 1994; Werner and others, 1996; Zaugg and others, 1995). Grab samples for volatile organic compound samples were collected in septum bottles and preserved by acidifying with 1:1 hydrochloric acid. Analytical methods and associated reporting limits are listed in tables B1–4.

Selected samples were analyzed in the San Diego Projects Office laboratory for anions (chloride, sulfate, nitrate) utilizing ion chromatography (U.S. Environmental Protection Agency, 1998). UV absorbance scans from 200 to 800 nm were done for selected samples. UV absorbance samples collected during the 1995–96 and 1996–97 rainy seasons were filtered through a 0.8-mm membrane filter and analyzed by Scripps Institute of Oceanography by ultraviolet-visible spectrophotometry (American Public Health Association, 1995). UV samples collected during the 1997–98 rainy season were filtered in the field through 0.45-µm pore size silver filters, in the same manner as dissolved organic carbon samples, and analyzed by Scripps Institute of Oceanography.

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APPENDIX C

Data for Field Parameters, Major Ions, Nutrients, and Selected Trace Elements

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California

[Alkalinity measured as filtered incremental titrations. 11074000, Santa Ana River below Prado Dam; 11075620, Santa Ana River at the diversion downstream from Imperial Highway. ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligram per liter; μg/L, microgram per liter; <, less than; —, no data]

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (μS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11074000	10/30/96	1045	90	966	8.1	200	110	100	598	8.9	0.05	8.9
11074000	10/30/96	1215	106	996	7.6	—	—	—	—	—	—	—
11074000	10/30/96	1415	89	898	7.8	174	100	99	556	9.0	.08	9.1
11074000	10/30/96	1615	148	890	7.6	—	—	—	—	—	—	—
11074000	10/30/96	1815	153	842	7.4	172	96	86	526	8.0	.08	8.1
11074000	10/30/96	1900	155	835	7.7	—	—	—	—	—	—	—
11074000	10/30/96	2100	155	721	7.5	162	97	87	520	8.3	.13	8.4
11074000	10/30/96	2300	159	767	7.6	—	—	—	—	—	—	—
11074000	10/31/96	0100	159	714	7.3	141	83	76	452	7.0	.15	7.1
11074000	11/21/96	0730	217	908	7.9	183	98	92	—	8.9	.06	9.0
11074000	11/21/96	0830	226	918	8.0	—	110	93	—	8.0	.08	—
11074000	11/21/96	0930	157	909	8.0	—	100	91	—	5.5	.06	—
11074000	11/21/96	1030	110	804	8.0	167	97	80	—	7.2	.07	7.3
11074000	11/21/96	1638	100	860	8.0	—	110	88	—	5.9	.15	—
11074000	11/21/96	1838	102	764	8.0	—	110	74	—	3.5	.15	—
11074000	11/21/96	2038	105	721	8.0	—	87	66	—	4.9	<.01	—
11074000	11/21/96	2238	111	690	7.8	—	67	61	—	4.0	<.01	—
11074000	11/22/96	0038	114	623	7.8	—	62	55	—	3.3	.05	—
11074000	11/22/96	0238	113	610	7.8	—	73	57	—	3.4	.17	—
11074000	11/22/96	0438	116	628	7.7	96	83	61	—	4.2	.15	4.3
11074000	11/22/96	0715	118	623	7.4	91	89	66	—	3.5	.17	3.7
11074000	11/24/96	0011	505	514	7.6	—	55	47	—	2.6	.16	—
11074000	11/24/96	0341	506	510	7.6	—	54	48	—	2.8	.19	—
11074000	11/24/96	0711	505	510	7.6	109	56	44	—	2.9	.20	3.1
11074000	11/24/96	1041	505	507	7.5	—	55	45	—	2.7	.20	—
11074000	11/24/96	1411	505	534	7.5	—	56	46	—	2.7	.19	—
11074000	11/24/96	1741	504	557	7.6	—	57	47	—	2.7	.18	—
11074000	11/24/96	2111	504	579	7.6	—	58	49	—	2.6	.18	—
11074000	11/25/96	0041	505	559	7.6	—	57	47	—	2.4	.22	—
11074000	11/25/96	0411	505	545	7.5	—	58	47	—	2.6	.23	—
11074000	11/25/96	0741	504	544	7.6	—	59	48	—	2.6	.25	—
11074000	11/25/96	1111	495	551	7.6	—	59	48	—	2.5	.25	—
11074000	11/25/96	1441	500	585	7.6	—	62	52	—	2.6	.21	—
11074000	12/9/96	1244	243	970	8.1	208	110	93	—	5.1	.09	5.2
11074000	12/9/96	1444	243	990	8.1	—	100	89	—	6.9	.06	—
11074000	12/9/96	1644	424	949	8.1	—	100	99	—	6.5	.07	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11074000	10/30/96	1045	0.16	2.4	0.8	0.72	0.89	0.92	10	40	8
11074000	10/30/96	1215	—	—	—	—	—	—	—	—	—
11074000	10/30/96	1415	.53	2.5	1.8	1.2	.94	.95	30	62	20
11074000	10/30/96	1615	—	—	—	—	—	—	—	—	—
11074000	10/30/96	1815	.35	2.4	1.6	1.1	.88	.87	50	75	20
11074000	10/30/96	1900	—	—	—	—	—	—	—	—	—
11074000	10/30/96	2100	.61	3.2	2.3	1.1	.82	.82	90	150	20
11074000	10/30/96	2300	—	—	—	—	—	—	—	—	—
11074000	10/31/96	0100	.26	3.0	2.0	1.1	.80	.77	80	140	20
11074000	11/21/96	0730	.11	—	.6	—	.99	.40	—	—	—
11074000	11/21/96	0830	—	—	—	—	—	.70	—	—	—
11074000	11/21/96	0930	—	—	—	—	—	<.60	—	—	—
11074000	11/21/96	1030	.31	—	1.8	—	.82	.77	—	—	—
11074000	11/21/96	1638	—	—	—	—	—	<.60	—	—	—
11074000	11/21/96	1838	—	—	—	—	—	<.60	—	—	—
11074000	11/21/96	2038	—	—	—	—	—	.40	—	—	—
11074000	11/21/96	2238	—	—	—	—	—	.50	—	—	—
11074000	11/22/96	0038	—	—	—	—	—	.60	—	—	—
11074000	11/22/96	0238	—	—	—	—	—	.30	—	—	—
11074000	11/22/96	0438	.34	—	1.4	—	.79	.71	—	—	—
11074000	11/22/96	0715	.31	—	1.8	—	.78	.68	—	—	—
11074000	11/24/96	0011	—	—	—	—	—	—	—	—	—
11074000	11/24/96	0341	—	—	—	—	—	<.60	—	—	—
11074000	11/24/96	0711	.35	—	1.4	—	.59	.51	—	—	—
11074000	11/24/96	1041	—	—	—	—	—	.30	—	—	—
11074000	11/24/96	1411	—	—	—	—	—	.40	—	—	—
11074000	11/24/96	1741	—	—	—	—	—	.50	—	—	—
11074000	11/24/96	2111	—	—	—	—	—	—	—	—	—
11074000	11/25/96	0041	—	—	—	—	—	.50	—	—	—
11074000	11/25/96	0411	—	—	—	—	—	.40	—	—	—
11074000	11/25/96	0741	—	—	—	—	—	.60	—	—	—
11074000	11/25/96	1111	—	—	—	—	—	.50	—	—	—
11074000	11/25/96	1441	—	—	—	—	—	.50	—	—	—
11074000	12/9/96	1244	.53	—	1.0	—	.92	.96	—	—	—
11074000	12/9/96	1444	—	—	—	—	—	.60	—	—	—
11074000	12/9/96	1644	—	—	—	—	—	<.30	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11074000	12/9/96	1844	57	868	8.0	179	89	93	—	7.9	0.15	8.0
11074000	12/9/96	2044	204	579	8.0	—	79	55	—	4.4	.07	—
11074000	12/9/96	2244	217	650	8.0	—	76	65	—	4.5	.06	—
11074000	12/10/96	0044	168	631	8.0	132	66	59	—	4.4	.09	4.5
11074000	12/10/96	0244	172	538	8.0	—	73	48	—	3.4	.06	—
11074000	12/10/96	0734	184	542	7.8	114	62	49	—	3.5	.10	3.6
11074000	12/10/96	1134	368	473	7.8	—	49	41	—	2.9	.07	—
11074000	12/10/96	1534	356	472	7.9	104	53	42	—	3.0	.10	3.1
11074000	12/10/96	1934	370	459	8.0	—	51	41	—	2.9	.08	—
11074000	12/10/96	2334	372	445	7.8	99	47	38	—	3.0	.10	3.1
11074000	12/11/96	0334	379	458	7.8	—	50	40	—	3.0	.09	—
11074000	12/11/96	0734	379	467	7.9	106	52	41	—	3.2	.11	3.3
11074000	12/11/96	1134	268	511	7.9	—	55	44	—	3.2	.52	—
11074000	12/17/96	0421	517	665	7.8	189	66	62	—	2.9	.16	3.1
11074000	1/19/97	2304	461	578	7.9	—	55	54	—	2.8	.18	—
11074000	1/20/97	0204	461	600	7.9	—	59	53	—	2.8	.18	—
11074000	1/20/97	0504	461	610	7.9	—	57	52	—	3.1	.16	—
11074000	1/20/97	0804	460	620	7.7	142	60	58	374	3.5	.20	3.7
11074000	1/20/97	1119	394	640	7.7	—	59	54	—	3.3	.16	—
11074000	1/20/97	1419	394	638	7.6	150	62	59	391	3.6	.20	3.8
11074000	1/20/97	1719	394	656	7.6	—	61	55	—	3.1	.19	—
11074000	1/20/97	2019	394	630	7.6	—	58	53	—	3.0	.18	—
11074000	1/25/97	1157	520	708	7.9	145	67	67	416	4.2	.29	4.5
11074000	1/25/97	1757	526	698	7.7	130	68	66	424	4.2	.31	4.5
11074000	1/25/97	2357	2510	658	7.8	125	59	57	—	3.8	.18	—
11074000	1/26/97	1430	5490	524	7.5	104	45	46	306	1.6	.20	1.8
11074000	1/26/97	2030	4850	440	7.7	—	34	32	—	1.4	.14	—
11074000	1/26/97	2359	5030	386	8.1	—	28	27	—	1.2	.10	—
11074000	1/27/97	1300	4760	381	7.8	104	28	26	228	.8	.12	.89
11074000	1/27/97	1900	1600	388	7.7	—	25	24	—	.8	.07	—
11074000	1/28/97	0100	1320	390	7.6	—	26	25	—	.8	.10	—
11074000	1/28/97	0700	1300	397	7.7	—	27	—	—	1.0	.10	—
11074000	1/28/97	0904	861	406	7.9	—	27	26	—	.97	.11	—
11074000	1/28/97	1504	394	416	7.9	—	30	28	—	1.0	.10	—
11074000	1/28/97	2104	398	397	7.7	—	27	26	—	.92	.09	—
11074000	1/29/97	0304	397	411	7.7	—	29	28	—	1.0	.13	—
11074000	1/29/97	0700	394	417	7.8	—	31	28	—	1.2	.14	—
11074000	1/29/97	1300	610	420	8.0	—	31	28	—	1.4	.13	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11074000	12/9/96	1844	0.90	—	1.6	—	1.0	0.94	—	—	—
11074000	12/9/96	2044	—	—	—	—	—	<.30	—	—	—
11074000	12/9/96	2244	—	—	—	—	—	<.30	—	—	—
11074000	12/10/96	0044	.38	—	1.0	—	.54	.50	—	—	—
11074000	12/10/96	0244	—	—	—	—	—	.30	—	—	—
11074000	12/10/96	0734	.32	—	.9	—	.51	.49	—	—	—
11074000	12/10/96	1134	—	—	—	—	—	<.30	—	—	—
11074000	12/10/96	1534	.26	—	.7	—	.45	.44	—	—	—
11074000	12/10/96	1934	—	—	—	—	—	.40	—	—	—
11074000	12/10/96	2334	.35	—	.8	—	.47	.46	—	—	—
11074000	12/11/96	0334	—	—	—	—	—	.90	—	—	—
11074000	12/11/96	0734	.37	—	.8	—	.51	.49	—	—	—
11074000	12/11/96	1134	—	—	—	—	—	.30	—	—	—
11074000	12/17/96	0421	1.2	—	2.3	—	1.1	1.1	—	—	—
11074000	1/19/97	2304	—	—	—	—	—	—	—	—	—
11074000	1/20/97	0204	—	—	—	—	—	—	—	—	—
11074000	1/20/97	0504	—	—	—	—	—	—	—	—	—
11074000	1/20/97	0804	1.4	3.5	2.7	1.3	1.1	.99	70	18	20
11074000	1/20/97	1119	—	—	—	—	—	—	—	—	—
11074000	1/20/97	1419	1.4	3.3	2.6	1.3	1.1	1. 0	40	17	20
11074000	1/20/97	1719	—	—	—	—	—	—	—	—	—
11074000	1/20/97	2019	—	—	—	—	—	—	—	—	—
11074000	1/25/97	1157	1.8	3.3	3.2	1.3	1.4	1.1	60	40	10
11074000	1/25/97	1757	1.9	4.1	3.2	1.6	1.3	1.1	60	56	9
11074000	1/25/97	2357	—	—	—	—	—	<.30	—	—	—
11074000	1/26/97	1430	2.2	4.8	3.5	2.0	1.4	1.2	160	62	<3
11074000	1/26/97	2030	—	—	—	—	—	1. 0	—	—	—
11074000	1/26/97	2359	—	—	—	—	—	.80	—	—	—
11074000	1/27/97	1300	1.7	5.2	2.8	2.2	1.2	1. 0	40	28	<3
11074000	1/27/97	1900	—	—	—	—	—	.80	—	—	—
11074000	1/28/97	0100	—	—	—	—	—	1.1	—	—	—
11074000	1/28/97	0700	—	—	—	—	—	1. 0	—	—	—
11074000	1/28/97	0904	—	—	—	—	—	1.3	—	—	—
11074000	1/28/97	1504	—	—	—	—	—	1.6	—	—	—
11074000	1/28/97	2104	—	—	—	—	—	1.3	—	—	—
11074000	1/29/97	0304	—	—	—	—	—	.90	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11074000	1/29/97	1900	618	433	7.9	—	32	30	—	1.2	0.14	—
11074000	1/30/97	0100	625	460	8.0	—	32	31	—	1.0	.15	—
11074000	1/30/97	0700	618	470	8.0	—	36	33	—	1.3	.13	—
11074000	1/30/97	1300	457	474	7.9	—	36	33	—	1.2	.14	—
11074000	9/14/97	2240	376	616	7.9	124	61	73	380	2.78	.02	2.8
11074000	9/15/97	0240	362	584	7.9	125	61	76	385	3.1	.03	3.2
11074000	9/15/97	0640	372	579	7.7	114	58	68	362	3.7	.05	3.8
11074000	9/15/97	1040	372	623	7.7	—	62	74	399	4.4	.07	4.5
11074000	9/15/97	1250	372	634	7.8	124	62	71	395	4.0	.08	4.1
11074000	9/15/97	1415	376	654	7.7	—	72	77	—	2.7	.10	—
11074000	9/15/97	1845	387	632	7.9	133	65	71	412	3.7	.08	3.8
11074000	9/15/97	2315	390	635	8.0	—	65	74	—	1.6	.04	—
11074000	9/16/97	0215	390	645	7.9	—	70	80	—	2.7	.06	—
11074000	9/16/97	0515	398	655	8.0	—	69	77	—	2.0	.06	—
11074000	9/16/97	0815	401	652	8.1	—	—	—	—	—	—	—
11074000	9/16/97	1115	352	674	8.1	—	69	77	—	2.1	.21	—
11074000	9/24/97	1937	355	632	7.9	—	20	68	370	2.9	.02	2.9
11074000	9/24/97	2107	355	621	8.0	—	16	68	—	2.5	.01	—
11074000	9/24/97	2237	355	622	8.0	—	58	68	—	2.5	.02	—
11074000	9/25/97	0007	355	620	8.2	—	56	67	—	2.6	.02	—
11074000	9/25/97	0137	359	622	8.2	—	56	67	—	2.7	.03	—
11074000	9/25/97	0307	359	623	8.1	—	55	67	—	2.7	.02	—
11074000	9/25/97	0437	362	623	8.0	—	41	68	380	3.1	.03	3.1
11074000	9/25/97	0607	362	626	8.0	—	56	69	—	3.3	.04	—
11074000	9/25/97	0737	367	632	8.0	—	49	69	370	3.9	.04	4.0
11074000	9/25/97	0907	369	634	7.9	—	58	70	—	3.7	.04	—
11074000	9/25/97	1037	222	640	7.8	—	58	69	390	3.9	.05	3.9
11074000	9/25/97	1207	209	620	7.9	—	55	66	—	3.5	.06	—
11074000	9/25/97	1337	258	638	7.9	—	57	67	—	4.1	.08	—
11074000	9/25/97	1507	275	664	7.7	—	62	69	440	5.0	.13	5.1
11074000	9/25/97	1637	284	569	7.6	—	53	54	—	4.2	.17	—
11074000	9/25/97	1807	290	538	7.6	—	53	50	—	4.0	.16	—
11074000	9/25/97	1937	294	554	7.4	—	58	53	—	4.1	.16	—
11074000	9/25/97	2107	300	572	7.4	—	61	54	—	4.1	.19	—
11074000	9/25/97	2237	305	556	7.4	—	59	53	—	4.2	.25	—
11074000	9/26/97	0007	312	574	7.4	—	62	53	—	4.3	.32	—
11074000	9/26/97	0137	312	639	7.3	—	77	63	—	4.3	.52	—
11074000	9/26/97	0307	313	691	7.3	—	92	67	—	3.9	.67	—
11074000	9/26/97	0437	313	700	7.4	—	88	71	—	3.9	.83	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11074000	1/29/97	0700	—	—	—	—	—	1.6	—	—	—
11074000	1/29/97	1300	—	—	—	—	—	.60	—	—	—
11074000	1/29/97	1900	—	—	—	—	—	.70	—	—	—
11074000	1/30/97	0100	—	—	—	—	—	.90	—	—	—
11074000	1/30/97	0700	—	—	—	—	—	.70	—	—	—
11074000	1/30/97	1300	—	—	—	—	—	1.0	—	—	—
11074000	9/14/97	2240	0.07	5.2	0.4	3.6	0.44	.46	10	100	180
11074000	9/15/97	0240	.06	1.8	.4	1.4	.54	.53	30	57	130
11074000	9/15/97	0640	.15	1.5	.9	1.0	.63	.61	20	41	160
11074000	9/15/97	1040	.19	1.6	1.1	1.0	.70	.71	30	30	40
11074000	9/15/97	1250	.18	2.3	1.2	1.2	.68	.66	30	36	90
11074000	9/15/97	1415	—	—	—	—	—	—	—	—	—
11074000	9/15/97	1845	.19	1.4	1.2	.67	.58	.58	30	29	60
11074000	9/15/97	2315	—	—	—	—	—	—	—	—	—
11074000	9/16/97	0215	—	—	—	—	—	—	—	—	—
11074000	9/16/97	0515	—	—	—	—	—	—	—	—	—
11074000	9/16/97	0815	—	—	—	—	—	—	—	—	—
11074000	9/16/97	1115	—	—	—	—	—	—	—	—	—
11074000	9/24/97	1937	<.01	3.3	.5	2.5	.46	.45	20	31	90
11074000	9/24/97	2107	—	—	—	—	—	—	—	—	—
11074000	9/24/97	2237	—	—	—	—	—	—	—	—	—
11074000	9/25/97	0007	—	—	—	—	—	—	—	—	—
11074000	9/25/97	0137	—	—	—	—	—	—	—	—	—
11074000	9/25/97	0307	—	—	—	—	—	—	—	—	—
11074000	9/25/97	0437	.05	2.3	.4	1.0	.61	.59	20	14	50
11074000	9/25/97	0607	—	—	—	—	—	—	—	—	—
11074000	9/25/97	0737	.03	.9	.5	.99	.70	.68	30	18	60
11074000	9/25/97	0907	—	—	—	—	—	—	—	—	—
11074000	9/25/97	1037	.10	1.7	.6	1.0	.67	.61	40	21	60
11074000	9/25/97	1207	—	—	—	—	—	—	—	—	—
11074000	9/25/97	1337	—	—	—	—	—	—	—	—	—
11074000	9/25/97	1507	.47	3.1	2.1	1.2	.87	.79	110	43	60
11074000	9/25/97	1637	—	—	—	—	—	—	—	—	—
11074000	9/25/97	1807	—	—	—	—	—	—	—	—	—
11074000	9/25/97	1937	—	—	—	—	—	—	—	—	—
11074000	9/25/97	2107	—	—	—	—	—	—	—	—	—
11074000	9/25/97	2237	—	—	—	—	—	—	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11074000	9/26/97	0607	315	720	7.4	—	84	68	—	3.7	0.86	—
11074000	11/10/97	0900	215	872	7.9	130	100	94	—	7.5	.04	7.6
11074000	11/10/97	1300	210	912	8.1	188	100	93	—	7.0	.04	7.0
11074000	11/10/97	1700	285	661	7.9	125	70	67	—	6.3	.09	6.4
11074000	11/10/97	2156	365	441	7.6	77	48	37	—	4.5	.09	4.6
11074000	11/11/97	0256	376	578	7.5	101	82	48	—	4.6	.19	4.8
11074000	11/11/97	0756	379	746	7.6	187	110	66	—	6.0	.21	6.2
11074000	11/11/97	1459	376	786	7.8	153	100	75	—	6.4	.37	6.8
11074000	11/11/97	1759	376	773	7.9	174	100	78	—	6.1	.12	—
11074000	11/11/97	2059	376	779	8.0	176	99	78	—	5.9	.12	—
11074000	11/11/97	2359	372	813	8.0	183	100	82	—	6.0	.13	—
11074000	11/12/97	0259	372	821	8.0	182	99	84	—	6.2	.11	—
11074000	11/12/97	0559	369	826	8.1	177	100	88	—	6.7	.11	—
11074000	11/12/97	0859	365	840	8.0	185	100	88	—	6.8	.11	—
11074000	12/5/97	1623	226	912	8.0	187	100	110	—	6.5	.13	6.6
11074000	12/5/97	1923	228	923	8.0	—	100	110	—	7.6	.11	—
11074000	12/5/97	2223	231	875	8.1	—	110	120	—	8.0	.24	—
11074000	12/6/97	0123	231	952	8.1	—	100	110	—	7.7	.10	—
11074000	12/6/97	0423	237	837	8.3	—	110	110	—	7.9	.08	—
11074000	12/6/97	0723	286	908	8.1	185	110	110	—	7.1	.08	7.2
11074000	12/6/97	1023	315	601	8.0	120	72	68	—	4.8	.05	4.9
11074000	12/6/97	1305	340	478	7.7	—	72	53	—	3.7	.07	—
11074000	12/6/97	1705	530	284	7.7	—	48	33	—	2.4	.10	—
11074000	12/6/97	2105	545	277	7.7	—	43	28	—	2.1	.08	—
11074000	12/7/97	0105	3060	288	7.7	—	37	28	—	2.0	.10	—
11074000	12/7/97	0505	3160	283	7.6	62	38	29	—	1.9	.04	2.0
11074000	12/7/97	0905	2530	310	7.6	—	39	31	—	2.0	.04	2.1
11074000	12/7/97	1305	1560	388	7.6	—	41	33	—	2.3	.06	—
11074000	12/7/97	1714	1540	342	7.8	71	41	34	—	2.2	.04	2.2
11074000	12/7/97	2114	1540	358	7.7	—	43	36	—	2.5	.08	—
11074000	12/8/97	0114	1540	358	7.7	—	44	38	—	2.7	.09	—
11074000	12/8/97	0514	1540	366	7.6	76	45	38	—	2.7	.08	—
11074000	12/8/97	0914	975	445	7.8	—	150	130	—	8.0	.20	—
11074000	12/8/97	1314	964	432	7.6	—	54	49	—	3.1	.13	—
11074000	12/8/97	1736	545	418	7.8	93	52	45	—	2.9	.12	—
11074000	12/8/97	2136	542	417	7.8	—	55	48	—	3.0	.14	—
11074000	12/9/97	0136	545	407	7.8	—	49	43	—	2.9	.13	—
11074000	12/9/97	0536	547	422	7.7	91	48	47	—	2.7	.10	2.8

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11074000	9/26/97	0007	—	—	—	—	—	—	—	—	—
11074000	9/26/97	0137	—	—	—	—	—	—	—	—	—
11074000	9/26/97	0307	—	—	—	—	—	—	—	—	—
11074000	9/26/97	0437	—	—	—	—	—	—	—	—	—
11074000	9/26/97	0607	—	—	—	—	—	—	—	—	—
11074000	11/10/97	0900	0.10	—	0.6	—	0.95	0.90	—	—	—
11074000	11/10/97	1300	.11	—	.6	—	.91	.94	—	—	—
11074000	11/10/97	1700	.86	—	2.1	—	.68	.65	—	—	—
11074000	11/10/97	2156	.77	—	2.4	—	.56	.52	—	—	—
11074000	11/11/97	0256	.81	—	2.0	—	.56	.55	—	—	—
11074000	11/11/97	0756	.69	—	2.1	—	.55	.53	—	—	—
11074000	11/11/97	1459	.35	—	1.2	—	.66	.61	—	—	—
11074000	11/11/97	1759	—	—	—	—	—	—	—	—	—
11074000	11/11/97	2059	—	—	—	—	—	—	—	—	—
11074000	11/11/97	2359	—	—	—	—	—	—	—	—	—
11074000	11/12/97	0259	—	—	—	—	—	—	—	—	—
11074000	11/12/97	0559	—	—	—	—	—	—	—	—	—
11074000	11/12/97	0859	—	—	—	—	—	—	—	—	—
11074000	12/5/97	1623	.39	—	1.0	—	.54	.50	<3	70	680
11074000	12/5/97	1923	—	—	—	—	—	—	—	—	—
11074000	12/5/97	2223	—	—	—	—	—	—	—	—	—
11074000	12/6/97	0123	—	—	—	—	—	—	—	—	—
11074000	12/6/97	0423	—	—	—	—	—	—	—	—	—
11074000	12/6/97	0723	.47	—	1.0	—	.79	.76	<10	62	400
11074000	12/6/97	1023	.35	—	.9	—	.56	.53	20	33	210
11074000	12/6/97	1305	—	—	—	—	—	—	—	—	—
11074000	12/6/97	1705	—	—	—	—	—	—	—	—	—
11074000	12/6/97	2105	—	—	—	—	—	—	—	—	—
11074000	12/7/97	0105	—	—	—	—	—	—	—	—	—
11074000	12/7/97	0505	.17	—	.8	—	.35	.31	90	22	130
11074000	12/7/97	0905	.15	—	.7	—	.36	.31	60	11	160
11074000	12/7/97	1305	—	—	—	—	—	—	—	—	—
11074000	12/7/97	1714	.16	—	.7	—	.38	.33	60	11	170
11074000	12/7/97	2114	—	—	—	—	—	—	—	—	—
11074000	12/8/97	0114	—	—	—	—	—	—	—	—	—
11074000	12/8/97	0514	—	—	—	—	—	—	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11074000	12/9/97	0936	517	426	7.8	—	53	47	—	3.1	0.11	—
11074000	12/9/97	1336	507	447	7.9	105	55	49	—	3.1	.08	—
11074000	12/9/97	1736	512	491	7.9	—	62	61	—	3.6	.12	—
11074000	12/9/97	2136	510	509	7.9	—	64	60	—	3.6	.11	—
11074000	2/3/98	0800	257	930	7.8	203	99	96	582	6.4	.22	6.7
11074000	2/3/98	1130	272	937	7.9	197	97	93	570	6.7	.19	6.8
11074000	2/3/98	1500	279	—	—	188	100	95	564	6.5	.18	6.7
11074000	2/3/98	1530	279	—	—	—	—	—	—	—	—	—
11074000	2/3/98	1900	416	598	7.8	105	57	46	305	3.2	.05	3.3
11074000	2/3/98	2300	2410	276	7.8	—	31	23	—	1.9	.03	—
11074000	2/4/98	0300	2470	342	7.9	79	34	31	210	2.3	.04	2.3
11074000	2/4/98	0700	831	320	7.9	—	34	26	—	2.0	.04	—
11074000	2/4/98	1005	2570	—	—	84	36	34	234	2.4	.05	2.5
11074000	2/4/98	1405	1570	—	—	—	38	33	—	2.5	.06	—
11074000	2/4/98	1805	1570	396	7.9	—	41	36	—	2.7	.05	—
11074000	2/4/98	2205	535	399	7.8	—	39	37	—	2.7	.05	—
11074000	2/5/98	0205	540	451	7.8	—	45	43	—	3.1	.08	—
11074000	2/5/98	0605	535	492	7.8	—	50	48	—	3.4	.08	—
11074000	2/5/98	1005	530	508	7.8	—	52	50	—	3.5	.08	—
11074000	2/5/98	1405	535	505	7.8	—	52	49	—	3.5	.07	—
11075620	10/30/96	0600	210	970	8.2	202	120	97	592	8.3	.04	8.3
11075620	10/30/96	0650	225	961	8.1	178	120	100	568	8.3	.05	8.3
11075620	10/30/96	0715	299	939	8.3	—	—	—	—	—	—	—
11075620	10/30/96	0745	712	712	8.0	130	100	70	458	5.9	.06	6.0
11075620	10/30/96	0800	799	646	8.1	110	96	59	386	5.4	.06	5.5
11075620	10/30/96	0845	731	617	8.0	96	97	58	380	4.6	.07	4.7
11075620	10/30/96	1015	663	624	8.0	103	97	59	384	4.8	.06	4.8
11075620	10/30/96	1200	559	554	8.0	93	—	—	—	—	—	—
11075620	10/30/96	1220	754	571	8.0	94	91	55	340	3.8	.07	3.9
11075620	10/30/96	1415	466	607	7.9	99	100	58	370	4.0	.07	4.1
11075620	10/30/96	1600	228	651	8.0	103	110	64	392	4.1	.07	4.2
11075620	11/21/96	0600	258	961	7.8	—	110	86	—	6.9	.10	7.0
11075620	11/21/96	0800	304	806	8.0	153	110	74	—	6.3	.10	6.4
11075620	11/21/96	1000	348	824	8.0	151	110	72	—	6.1	.07	6.2
11075620	11/21/96	1200	332	844	7.9	159	120	81	—	6.5	.10	6.6
11075620	11/21/96	1300	412	508	7.5	118	62	43	—	3.6	.06	3.7
11075620	11/21/96	1400	733	335	7.9	63	50	25	—	1.5	.06	1.6

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11074000	12/8/97	0914	—	—	—	—	—	—	—	—	—
11074000	12/8/97	1314	—	—	—	—	—	—	—	—	—
11074000	12/8/97	1736	—	—	—	—	—	—	—	—	—
11074000	12/8/97	2136	—	—	—	—	—	—	—	—	—
11074000	12/9/97	0136	—	—	—	—	—	—	—	—	—
11074000	12/9/97	0536	0.21	—	0.7	—	0.43	0.39	30	7	350
11074000	12/9/97	0936	—	—	—	—	—	—	—	—	—
11074000	12/9/97	1336	—	—	—	—	—	—	—	—	—
11074000	12/9/97	1736	—	—	—	—	—	—	—	—	—
11074000	12/9/97	2136	—	—	—	—	—	—	—	—	—
11074000	2/3/98	0800	1.1	2.8	2.1	1.3	1.2	0.02	20	19	200
11074000	2/3/98	1130	.94	2.7	1.8	1.3	1.1	1.0	10	14	320
11074000	2/3/98	1500	.79	2.6	1.5	1.4	.95	.99	50	12	110
11074000	2/3/98	1530	—	—	—	—	—	—	—	—	—
11074000	2/3/98	1900	.22	2.0	.7	.92	.43	.46	20	36	84
11074000	2/3/98	2300	—	—	—	—	—	—	—	—	—
11074000	2/4/98	0300	.20	2.0	.6	1.0	.36	.37	20	17	160
11074000	2/4/98	0700	—	—	—	—	—	—	—	—	—
11074000	2/4/98	1005	.31	2.2	.9	1.2	.42	.38	60	<4	99
11074000	2/4/98	1405	—	—	—	—	—	—	—	—	—
11074000	2/4/98	1805	—	—	—	—	—	—	—	—	—
11074000	2/4/98	2205	—	—	—	—	—	—	—	—	—
11074000	2/5/98	0205	—	—	—	—	—	—	—	—	—
11074000	2/5/98	0605	—	—	—	—	—	—	—	—	—
11074000	2/5/98	1005	—	—	—	—	—	—	—	—	—
11074000	2/5/98	1405	—	—	—	—	—	—	—	—	—
11075620	10/30/96	0600	.02	.6	.5	1.0	.93	.95	8	19	8
11075620	10/30/96	0650	.06	.6	.5	.97	.93	.93	7	15	10
11075620	10/30/96	0715	—	—	—	—	—	—	—	—	—
11075620	10/30/96	0745	.99	2.9	2.6	.88	.69	.66	130	110	20
11075620	10/30/96	0800	.95	2.8	2.3	.84	.60	.62	110	81	20
11075620	10/30/96	0845	.93	2.2	2.1	.64	.60	.56	80	78	20
11075620	10/30/96	1015	.82	—	1.8	—	.59	.56	70	71	20
11075620	10/30/96	1200	—	—	—	—	—	—	—	—	—
11075620	10/30/96	1220	.63	2.0	1.5	.79	.61	.57	40	55	30
11075620	10/30/96	1415	.57	1.7	1.4	.75	.60	.57	30	58	20
11075620	10/30/96	1600	.53	1.6	1.4	.68	.62	.58	30	58	10

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11075620	11/21/96	2000	—	576	7.5	73	110	45	—	2.5	0.07	2.6
11075620	11/21/96	2300	—	396	7.8	56	77	29	—	1.5	.05	1.5
11075620	11/22/96	0615	—	752	7.6	95	200	66	—	2.7	.06	2.8
11075620	11/22/96	1112	198	945	7.9	—	200	80	—	3.8	.08	—
11075620	11/22/96	1412	450	788	7.9	—	130	70	—	3.9	.07	—
11075620	11/22/96	2012	361	400	7.9	—	74	29	—	1.6	.06	—
11075620	11/22/96	2312	554	528	7.8	—	92	40	—	2.1	.09	—
11075620	11/23/96	0212	558	551	—	—	93	46	—	2.4	.10	—
11075620	11/23/96	0512	559	550	7.8	—	77	45	—	2.5	.10	—
11075620	11/23/96	0812	595	538	7.8	—	73	47	—	2.7	.11	—
11075620	11/23/96	1112	576	533	7.8	—	71	46	—	2.7	.11	—
11075620	11/23/96	1412	566	531	7.9	—	66	43	—	2.1	.11	—
11075620	11/23/96	1712	559	540	7.9	—	70	47	—	2.0	.18	—
11075620	11/23/96	2012	557	551	7.9	—	70	50	—	2.8	.12	—
11075620	11/23/96	2312	554	562	7.9	—	70	51	—	2.8	.12	—
11075620	11/24/96	0212	550	568	7.9	—	66	50	—	2.6	.10	—
11075620	11/24/96	0512	551	563	7.9	—	67	51	—	1.5	.17	—
11075620	11/24/96	0812	553	560	7.9	—	68	50	—	1.6	.05	—
11075620	11/24/96	1112	554	554	7.9	111	65	48	—	2.8	.17	3.0
11075620	11/24/96	1412	552	556	7.9	—	64	47	—	2.8	.15	—
11075620	11/24/96	1712	546	552	7.9	—	67	49	—	2.9	.17	—
11075620	11/24/96	2012	550	571	7.9	—	68	50	—	2.9	.17	—
11075620	11/24/96	2312	546	594	7.9	—	68	52	—	2.8	.15	—
11075620	11/25/96	0212	545	616	7.9	—	73	57	—	2.7	.19	—
11075620	11/25/96	0512	548	607	7.9	—	72	55	—	2.7	.18	—
11075620	11/25/96	0812	551	596	7.9	—	71	53	—	2.7	.19	—
11075620	11/25/96	1112	550	593	7.9	—	70	52	—	2.6	.19	—
11075620	11/25/96	1412	551	594	7.9	—	73	53	—	2.6	.19	—
11075620	12/9/96	1252	280	1020	8.3	212	130	93	—	7.8	.19	8.0
11075620	12/9/96	1430	416	901	8.3	184	110	77	—	6.7	.19	6.9
11075620	12/9/96	1630	529	710	8.2	70	84	58	—	4.9	.16	5.1
11075620	12/9/96	1830	978	417	8.1	74	65	33	—	2.4	.08	2.5
11075620	12/9/96	2030	897	558	8.2	—	92	46	—	3.1	.08	—
11075620	12/9/96	2230	666	664	8.2	121	110	58	—	3.8	.11	3.9
11075620	12/10/96	0030	341	702	8.2	—	120	58	—	3.5	.10	—
11075620	12/10/96	0230	339	830	8.2	147	120	74	—	4.8	.15	4.9
11075620	12/10/96	0430	306	823	8.2	—	120	—	—	4.5	.15	—
11075620	12/10/96	0630	265	758	8.1	—	130	63	—	4.1	.15	4.2
11075620	12/10/96	0830	262	814	8.2	—	130	70	—	3.8	.12	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11075620	11/21/96	0600	.29	—	1.4	—	0.81	0.73	—	—	—
11075620	11/21/96	0800	.51	—	1.5	—	.70	.67	—	—	—
11075620	11/21/96	1000	.32	—	1.2	—	.82	.65	—	—	—
11075620	11/21/96	1200	.25	—	.9	—	.74	.68	—	—	—
11075620	11/21/96	1300	.31	—	1.0	—	.70	.45	—	—	—
11075620	11/21/96	1400	.29	—	.8	—	.34	.28	—	—	—
11075620	11/21/96	2000	.23	—	.9	—	.44	.36	—	—	—
11075620	11/21/96	2300	.24	—	1.0	—	.38	.31	—	—	—
11075620	11/22/96	0615	.16	—	.8	—	.43	.36	—	—	—
11075620	11/22/96	1112	—	—	—	—	—	.40	—	—	—
11075620	11/22/96	1412	—	—	—	—	—	<.30	—	—	—
11075620	11/22/96	2012	—	—	—	—	—	.40	—	—	—
11075620	11/22/96	2312	—	—	—	—	—	—	—	—	—
11075620	11/23/96	0212	—	—	—	—	—	.10	—	—	—
11075620	11/23/96	0512	—	—	—	—	—	—	—	—	—
11075620	11/23/96	0812	—	—	—	—	—	.40	—	—	—
11075620	11/23/96	1112	—	—	—	—	—	<.30	—	—	—
11075620	11/23/96	1412	—	—	—	—	—	<.30	—	—	—
11075620	11/23/96	1712	—	—	—	—	—	<.30	—	—	—
11075620	11/23/96	2012	—	—	—	—	—	<.30	—	—	—
11075620	11/23/96	2312	—	—	—	—	—	<.30	—	—	—
11075620	11/24/96	0212	—	—	—	—	—	<.30	—	—	—
11075620	11/24/96	0512	—	—	—	—	—	<.30	—	—	—
11075620	11/24/96	0812	—	—	—	—	—	<.30	—	—	—
11075620	11/24/96	1112	.25	—	1.3	—	.58	.50	—	—	—
11075620	11/24/96	1412	—	—	—	—	—	<.30	—	—	—
11075620	11/24/96	1712	—	—	—	—	—	.40	—	—	—
11075620	11/24/96	2012	—	—	—	—	—	.70	—	—	—
11075620	11/24/96	2312	—	—	—	—	—	.40	—	—	—
11075620	11/25/96	0212	—	—	—	—	—	<.30	—	—	—
11075620	11/25/96	0512	—	—	—	—	—	<.30	—	—	—
11075620	11/25/96	0812	—	—	—	—	—	<.30	—	—	—
11075620	11/25/96	1112	—	—	—	—	—	<.30	—	—	—
11075620	11/25/96	1412	—	—	—	—	—	.20	—	—	—
11075620	12/9/96	1252	.56	—	1.1	—	.95	.92	—	—	—
11075620	12/9/96	1430	.58	—	1.2	—	.80	.81	—	—	—
11075620	12/9/96	1630	.54	—	1.0	—	.62	.61	—	—	—
11075620	12/9/96	1830	.45	—	.8	—	.40	.40	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11075620	1/19/97	2308	527	650	8.1	—	78	56	—	3.3	0.20	—
11075620	1/20/97	0208	528	647	8.1	—	77	58	—	3.4	.21	—
11075620	1/20/97	0508	528	664	8.1	—	76	53	—	3.0	.21	—
11075620	1/20/97	0808	531	643	8.1	128	76	56	403	3.2	.27	3.5
11075620	1/20/97	1155	565	683	8.1	144	79	61	409	3.5	.26	3.8
11075620	1/20/97	1455	542	665	8.1	143	85	61	414	3.6	.24	3.8
11075620	1/20/97	1755	493	705	7.9	151	89	64	436	3.9	.25	4.1
11075620	1/20/97	2055	460	702	8.0	—	88	59	—	3.4	.22	—
11075620	1/25/97	1008	614	748	8.1	—	88	66	466	4.0	.34	4.3
11075620	1/25/97	1308	612	700	8.0	137	90	68	458	4.1	.35	4.4
11075620	1/25/97	1608	633	758	8.2	128	94	68	462	4.0	.36	4.4
11075620	1/25/97	2114	700	478	7.9	73	67	38	282	2.1	.19	2.3
11075620	1/25/97	2310	800	534	7.9	85	82	38	—	2.0	.16	—
11075620	1/26/97	0130	1850	685	8.2	117	99	51	—	2.8	.23	—
11075620	1/26/97	0400	3600	661	8.1	119	75	57	398	4.4	.22	4.6
11075620	1/26/97	0930	5500	642	8.1	121	73	57	380	3.5	.30	3.8
11075620	1/26/97	1630	5800	538	7.9	111	72	48	—	1.4	.16	—
11075620	1/26/97	2130	5700	455	7.8	89	49	35	276	1.3	.18	1.5
11075620	1/27/97	0030	5500	472	7.8	94	47	36	—	1.4	.15	—
11075620	1/27/97	0330	5400	424	7.6	105	39	31	—	1.2	.11	—
11075620	1/27/97	0630	5320	400	7.8	83	36	28	—	1.0	.09	—
11075620	1/27/97	0930	5200	387	7.8	—	33	26	—	1.0	.08	—
11075620	1/27/97	1230	5170	400	7.9	105	34	28	242	.97	.13	1.1
11075620	1/27/97	1530	5150	399	7.8	—	43	28	—	.79	.11	—
11075620	1/27/97	1830	5100	402	8.3	—	32	26	—	.60	.13	—
11075620	1/27/97	1930	2140	420	8.2	118	39	28	—	.97	.10	—
11075620	1/27/97	2130	1640	438	7.9	108	46	30	258	1.1	.14	1.2
11075620	1/28/97	0330	400	458	7.7	—	46	31	—	.55	.14	—
11075620	1/28/97	0930	1300	462	7.8	111	50	33	282	1.2	.17	1.4
11075620	1/28/97	1530	860	507	—	—	61	34	—	1.2	.13	—
11075620	1/29/97	0900	421	591	8.0	—	81	40	—	1.1	.14	—
11075620	9/15/97	0010	385	660	8.0	142	76	76	421	3.1	.02	3.1
11075620	9/15/97	0310	379	702	8.0	140	80	78	430	3.2	.02	3.2
11075620	9/15/97	0610	383	670	8.0	135	76	75	412	2.9	.02	2.9
11075620	9/15/97	0910	398	663	8.0	130	77	74	417	3.1	.03	3.1
11075620	9/15/97	1115	388	632	8.2	132	75	73	414	3.2	.03	3.2
11075620	9/15/97	1550	380	616	8.2	—	72	79	—	2.1	.08	—
11075620	9/15/97	1850	377	631	8.1	—	66	79	—	3.0	.09	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophosphate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11075620	12/9/96	2030	—	—	—	—	—	<0.30	—	—	—
11075620	12/9/96	2230	0.36	—	0.9	—	.51	.50	—	—	—
11075620	12/10/96	0030	—	—	—	—	—	.30	—	—	—
11075620	12/10/96	0230	.37	—	1.0	—	.59	.59	—	—	—
11075620	12/10/96	0430	—	—	—	—	—	<.30	—	—	—
11075620	12/10/96	0630	.29	—	.7	—	.48	.49	—	—	—
11075620	12/10/96	0830	—	—	—	—	—	<.30	—	—	—
11075620	1/19/97	2308	—	—	—	—	—	—	—	—	—
11075620	1/20/97	0208	—	—	—	—	—	—	—	—	—
11075620	1/20/97	00508	—	—	—	—	—	—	—	—	—
11075620	1/20/97	0808	1.2	3.2	2.4	1.3	1.1	.98	30	7	10
11075620	1/20/97	1155	1.1	3.1	2.3	1.2	1.0	.94	30	10	20
11075620	1/20/97	1455	1.0	2.6	2.1	1.2	.99	.87	20	15	20
11075620	1/20/97	1755	.94	2.8	2.0	1.2	1.0	.90	20	14	20
11075620	1/20/97	2055	—	—	—	—	—	—	—	—	—
11075620	1/25/97	1008	1.4	2.8	2.8	1.2	1.2	1.1	40	31	20
11075620	1/25/97	1308	1.4	2.9	2.5	1.4	1.2	1.1	30	35	<3
11075620	1/25/97	1608	1.4	2.9	2.6	1.3	1.2	1.0	20	36	10
11075620	1/25/97	2114	.71	2.0	1.4	1.0	.65	.57	20	74	<3
11075620	1/25/97	2310	—	—	—	—	—	.80	—	—	—
11075620	1/26/97	0130	—	—	—	—	—	.90	—	—	—
11075620	1/26/97	0400	.97	1.8	2.0	.75	.76	.66	20	130	6
11075620	1/26/97	0930	1.5	4.4	2.4	2.2	.89	.82	20	110	9
11075620	1/26/97	1630	—	—	—	—	—	.70	—	—	—
11075620	1/26/97	2130	1.6	3.8	2.7	1.5	.98	.70	40	47	<3
11075620	1/27/97	0030	—	—	—	—	—	1.1	—	—	—
11075620	1/27/97	0330	—	—	—	—	—	1.6	—	—	—
11075620	1/27/97	0630	—	—	—	—	—	1.7	—	—	—
11075620	1/27/97	0930	—	—	—	—	—	1.0	—	—	—
11075620	1/27/97	1230	1.5	5.8	2.6	2.3	1.1	1.0	40	27	<3
11075620	1/27/97	1530	—	—	—	—	—	.90	—	—	—
11075620	1/27/97	1830	—	—	—	—	—	1.1	—	—	—
11075620	1/27/97	1930	—	—	—	—	—	—	—	—	—
11075620	1/27/97	2130	1.3	4.4	2.4	1.8	1.0	.98	30	15	<3
11075620	1/28/97	0330	—	—	—	—	—	.60	—	—	—
11075620	1/28/97	0930	1.3	3.5	2.4	1.4	1.1	1.0	30	10	<3

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11075620	9/15/97	2350	390	662	8.0	130	75	74	428	4.0	0.07	4.1
11075620	9/16/97	0350	393	692	8.1	—	94	92	—	2.2	.11	—
11075620	9/16/97	0650	398	692	8.3	—	83	82	—	1.7	.09	—
11075620	9/16/97	0950	405	667	8.2	—	82	79	—	2.0	.12	—
11075620	9/16/97	1250	406	692	8.3	—	83	79	—	2.0	.16	—
11075620	9/24/97	2030	366	667	8.1	—	72	72	410	2.9	.02	2.9
11075620	9/24/97	2200	366	632	8.0	—	80	74	—	3.1	.03	—
11075620	9/24/97	2330	365	678	7.9	—	71	72	—	2.9	.01	—
11075620	9/25/97	0100	368	672	8.0	—	71	71	—	3.3	.01	—
11075620	9/25/97	0230	366	663	8.1	—	77	72	400	3.0	.02	3.0
11075620	9/25/97	0400	363	677	8.0	—	76	70	—	2.8	.03	—
11075620	9/25/97	0530	385	629	8.2	—	74	76	440	2.6	.02	2.7
11075620	9/25/97	0700	394	599	7.9	—	75	65	—	2.5	.05	—
11075620	9/25/97	0830	437	642	8.1	—	80	66	390	2.6	.04	2.7
11075620	9/25/97	1000	414	642	8.0	—	77	67	—	3.6	.03	—
11075620	9/25/97	1130	717	601	8.1	—	69	60	370	2.6	.04	2.6
11075620	9/25/97	1300	715	487	7.8	—	62	39	—	2.6	.03	—
11075620	9/25/97	1430	459	579	7.8	—	76	55	360	2.8	.04	2.9
11075620	9/25/97	1600	396	642	7.7	—	77	64	—	3.1	.04	—
11075620	9/25/97	1730	363	679	7.8	—	80	67	—	3.3	.05	—
11075620	9/25/97	1900	329	654	7.8	—	84	67	380	3.3	.05	3.4
11075620	9/25/97	2030	315	714	7.8	—	87	69	—	3.2	.05	—
11075620	9/25/97	2230	—	693	7.8	—	84	—	—	—	—	—
11075620	9/25/97	2330	307	725	7.4	—	82	70	—	3.8	.06	—
11075620	9/26/97	0100	300	660	7.7	—	83	67	440	4.5	.12	4.6
11075620	9/26/97	0230	300	620	7.6	—	74	58	—	4.1	.12	—
11075620	9/26/97	0400	304	625	7.5	—	74	56	—	3.8	.12	—
11075620	9/26/97	0530	310	641	7.5	—	78	58	—	3.9	.13	—
11075620	9/26/97	0700	304	636	7.5	—	76	57	—	3.8	.16	—
11075620	9/26/97	0730	—	635	7.5	—	84	59	—	4.1	.22	—
11075620	9/26/97	0900	338	674	7.6	—	70	64	—	4.3	.37	—
11075620	9/26/97	1030	319	732	7.6	—	89	72	—	4.2	.54	—
11075620	9/26/97	1200	322	730	7.7	—	100	72	470	4.0	.69	4.7
11075620	9/26/97	1330	405	763	8.0	—	97	73	—	3.8	.78	—
11075620	9/26/97	1500	597	748	7.6	—	87	73	—	3.8	.92	—
11075620	9/26/97	1630	592	745	7.7	—	90	72	—	3.7	.91	—
11075620	9/26/97	1800	584	736	7.7	—	88	72	—	3.5	.93	—
11075620	9/26/97	1930	587	749	7.7	—	87	72	—	3.4	.85	—
11075620	9/26/97	2100	575	761	7.8	—	83	70	—	3.3	.70	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11075620	1/28/97	1530	—	—	—	—	—	1.0	—	—	—
11075620	1/29/97	0900	—	—	—	—	—	3.1	—	—	—
11075620	9/15/97	0010	<0.01	0.7	0.3	0.75	0.60	0.61	<3	5	9
11075620	9/15/97	0310	.06	1.0	.6	.72	.57	.61	20	10	10
11075620	9/15/97	0610	<.01	.6	.4	.68	.59	.57	5	4	10
11075620	9/15/97	0910	.02	.8	.4	.65	.55	.55	10	5	5
11075620	9/15/97	1115	<.01	.6	.3	.66	.58	.57	7	8	9
11075620	9/15/97	1550	—	—	—	—	—	—	—	—	—
11075620	9/15/97	1850	—	—	—	—	—	—	—	—	—
11075620	9/15/97	2350	.14	1.5	1.2	.73	.60	.63	30	7	10
11075620	9/16/97	0350	—	—	—	—	—	—	—	—	—
11075620	9/16/97	0650	—	—	—	—	—	—	—	—	—
11075620	9/16/97	0950	—	—	—	—	—	—	—	—	—
11075620	9/16/97	1250	—	—	—	—	—	—	—	—	—
11075620	9/24/97	2030	.10	1.1	.6	.61	.49	.45	30	17	9
11075620	9/24/97	2200	—	—	—	—	—	—	—	—	—
11075620	9/24/97	2330	—	—	—	—	—	—	—	—	—
11075620	9/25/97	0100	—	—	—	—	—	—	—	—	—
11075620	9/25/97	0230	<.01	.7	.6	.65	.55	.52	20	5	10
11075620	9/25/97	0400	—	—	—	—	—	—	—	—	—
11075620	9/25/97	0530	.06	1.1	.5	.68	.52	.50	30	4	9
11075620	9/25/97	0700	—	—	—	—	—	—	—	—	—
11075620	9/25/97	0830	.18	.9	1.3	.85	.54	.48	40	18	10
11075620	9/25/97	1000	—	—	—	—	—	—	—	—	—
11075620	9/25/97	1130	.13	1.4	.8	.69	.54	.50	50	12	10
11075620	9/25/97	1300	—	—	—	—	—	—	—	—	—
11075620	9/25/97	1430	.15	1.3	.9	.7	.54	.49	50	18	10
11075620	9/25/97	1600	—	—	—	—	—	—	—	—	—
11075620	9/25/97	1730	—	—	—	—	—	—	—	—	—
11075620	9/25/97	1900	.07	1.1	.6	.74	.60	.56	40	11	10
11075620	9/25/97	2030	—	—	—	—	—	—	—	—	—
11075620	9/25/97	2230	—	—	—	—	—	—	—	—	—
11075620	9/25/97	2330	—	—	—	—	—	—	—	—	—
11075620	9/26/97	0100	.83	3.0	2.6	.96	.80	.73	100	14	10
11075620	9/26/97	0230	—	—	—	—	—	—	—	—	—
11075620	9/26/97	0400	—	—	—	—	—	—	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11075620	9/26/97	2230	577	768	7.9	—	85	73	—	3.3	0.62	—
11075620	9/27/97	0001	582	777	7.8	—	86	—	—	—	—	—
11075620	9/27/97	0130	580	815	7.8	—	100	—	—	—	—	—
11075620	9/27/97	0300	589	840	7.8	—	98	—	—	—	—	—
11075620	9/27/97	0430	570	849	7.8	—	99	—	—	—	—	—
11075620	9/27/97	0600	577	814	7.7	—	91	82	—	3.4	.12	—
11075620	9/27/97	0730	570	773	7.8	—	87	78	—	3.3	.08	—
11075620	11/10/97	1000	219	945	8.2	199	120	96	—	6.4	.03	6.4
11075620	11/10/97	1230	395	886	8.2	175	120	85	—	6.3	.05	6.4
11075620	11/10/97	1500	337	783	8.2	145	110	72	—	4.7	.05	4.7
11075620	11/10/97	1951	256	824	7.9	173	120	83	—	5.9	.19	6.1
11075620	11/10/97	2351	298	920	8.3	195	120	93	—	6.3	.27	6.5
11075620	11/11/97	0351	341	453	7.8	85	53	39	—	4.3	.25	4.5
11075620	11/11/97	1451	369	719	8.0	139	120	66	—	5.9	.37	6.3
11075620	11/11/97	1721	364	819	8.1	160	120	75	—	6.0	.13	—
11075620	11/11/97	1951	362	806	8.2	168	110	77	—	6.1	.10	—
11075620	11/11/97	2221	366	818	8.3	165	110	79	—	6.1	.09	—
11075620	11/12/97	0051	363	822	8.3	174	110	80	—	6.0	.09	—
11075620	11/12/97	0321	366	821	8.4	156	110	81	—	5.9	.08	—
11075620	11/12/97	0551	363	828	8.4	179	110	83	—	5.9	.09	—
11075620	11/12/97	0821	368	860	8.2	182	110	85	—	5.9	.09	—
11075620	12/5/97	1523	237	—	—	198	140	120	—	7.2	.12	7.3
11075620	12/5/97	1723	235	992	8.1	—	150	140	—	9.1	.21	—
11075620	12/5/97	1923	241	—	—	—	140	120	—	7.8	.17	—
11075620	12/5/97	2123	238	993	8.3	—	170	120	—	8.3	.19	—
11075620	12/6/97	0123	288	936	8.2	202	140	120	—	6.9	.13	7.0
11075620	12/6/97	0323	484	706	8.1	145	97	—	—	4.5	.11	4.6
11075620	12/6/97	0523	—	249	7.9	50	43	23	—	1.5	.03	1.5
11075620	12/6/97	0723	—	298	8.0	27	—	28	—	1.1	.02	1.1
11075620	12/6/97	0923	3050	360	8.1	50	84	35	—	1.2	.02	1.2
11075620	12/6/97	1123	1820	531	7.8	—	140	50	—	2.2	.08	—
11075620	12/6/97	1323	1230	642	7.8	80	160	76	—	2.8	.05	2.8
11075620	12/6/97	2108	1500	449	7.9	55	110	42	—	1.7	.03	1.7
11075620	12/7/97	0508	3460	416	8.0	59	88	37	—	1.7	.04	1.7
11075620	12/7/97	1130	2520	346	7.8	71	47	36	—	1.9	.04	2.0
11075620	12/8/97	1208	2320	441	8.0	—	61	48	—	3.1	.11	—
11075620	12/8/97	1608	1750	512	8.0	—	67	52	—	2.8	.05	2.9
11075620	12/8/97	2008	1800	495	8.1	—	77	57	—	3.1	.11	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11075620	9/26/97	0530	—	—	—	—	—	—	—	—	—
11075620	9/26/97	0700	—	—	—	—	—	—	—	—	—
11075620	9/26/97	0730	—	—	—	—	—	—	—	—	—
11075620	9/26/97	0900	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1030	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1200	0.46	2.9	2.3	1.0	0.82	0.73	120	26	20
11075620	9/26/97	1330	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1500	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1630	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1800	—	—	—	—	—	—	—	—	—
11075620	9/26/97	1930	—	—	—	—	—	—	—	—	—
11075620	9/26/97	2100	—	—	—	—	—	—	—	—	—
11075620	9/26/97	2230	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0001	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0130	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0300	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0430	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0600	—	—	—	—	—	—	—	—	—
11075620	9/27/97	0730	—	—	—	—	—	—	—	—	—
11075620	11/10/97	1000	.06	—	.5	—	.88	.82	—	—	—
11075620	11/10/97	1230	.41	—	1.2	—	.78	.79	—	—	—
11075620	11/10/97	1500	.38	—	1.3	—	.66	.66	—	—	—
11075620	11/10/97	1951	.15	—	.7	—	.81	.77	—	—	—
11075620	11/10/97	2351	.04	—	.6	—	.95	.90	—	—	—
11075620	11/11/97	0351	.65	—	1.6	—	.55	.55	—	—	—
11075620	11/11/97	1451	.44	—	1.7	—	.59	.57	—	—	—
11075620	11/11/97	1721	—	—	—	—	—	—	—	—	—
11075620	11/11/97	1951	—	—	—	—	—	—	—	—	—
11075620	11/11/97	2221	—	—	—	—	—	—	—	—	—
11075620	11/12/97	0051	—	—	—	—	—	—	—	—	—
11075620	11/12/97	0321	—	—	—	—	—	—	—	—	—
11075620	11/12/97	0551	—	—	—	—	—	—	—	—	—
11075620	11/12/97	0821	—	—	—	—	—	—	—	—	—
11075620	12/5/97	1523	.28	—	1.0	—	.97	.94	10	24	50
11075620	12/5/97	1723	—	—	—	—	—	—	—	—	—
11075620	12/5/97	1923	—	—	—	—	—	—	—	—	—
11075620	12/5/97	2123	—	—	—	—	—	—	—	—	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Streamflow (f^3/s)	Specific conductance (µS/cm)	pH (standard units)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Dissolved solids (mg/L)	Nitrate, dissolved (mg/L as N)	Nitrite, dissolved (mg/L as N)	Nitrite + nitrate, dissolved (mg/L as N)
11075620	12/9/97	0008	1600	487	8.0	—	73	52	—	2.8	0.07	—
11075620	12/9/97	0408	1570	497	8.0	106	74	54	—	3.0	.09	—
11075620	12/9/97	0808	917	464	8.0	—	70	51	—	2.9	.13	—
11075620	12/9/97	1208	684	480	8.1	—	71	52	—	3.0	.10	—
11075620	12/9/97	1608	642	491	8.2	100	79	59	—	3.2	.13	—
11075620	2/3/98	0603	275	964	7.8	—	110	92	592	6.2	.47	6.6
11075620	2/3/98	0800	302	963	8.1	188	120	94	603	6.5	.46	7.0
11075620	2/3/98	1000	700	486	7.9	104	64	45	302	3.2	.19	3.4
11075620	2/3/98	1200	1580	486	7.9	104	44	21	175	1.3	.06	1.4
11075620	2/3/98	1400	1140	410	7.9	72	65	29	243	2.0	.08	2.1
11075620	2/3/98	1700	693	463	7.9	76	83	32	283	2.0	.09	2.1
11075620	2/3/98	2000	445	—	—	124	130	63	466	2.9	.14	3.1
11075620	2/3/98	2300	900	739	8.0	—	140	65	—	3.7	.13	—
11075620	2/4/98	0200	2050	376	7.8	66	50	30	238	1.7	.05	1.8
11075620	2/4/98	0820	970	377	7.8	85	50	33	—	2.2	.07	—
11075620	2/4/98	1218	2080	376	7.9	—	48	32	—	2.3	.07	—
11075620	2/4/98	1556	1600	420	7.9	—	50	37	—	2.7	.07	—
11075620	2/4/98	1956	1520	404	7.9	—	47	35	—	2.6	.07	—
11075620	2/4/98	2356	580	468	7.9	—	60	42	—	2.8	.07	—
11075620	2/5/98	0356	567	479	7.9	—	65	42	—	2.7	.07	—
11075620	2/5/98	0756	580	537	8.0	—	70	55	—	3.3	.11	—
11075620	2/5/98	1156	570	570	8.1	—	75	55	—	3.6	.12	—

Appendix C. Data for field parameters, major ions, nutrients, and selected trace elements in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station no.	Date	Time	Ammonia, dissolved (mg/L as N)	Ammonia + organic nitrogen (mg/L as N)	Ammonia + organic nitrogen, dissolved (mg/L as N)	Phosphorus, total (mg/L as P)	Phosphorus, dissolved (mg/L as P)	Orthophos-phate, dissolved (mg/L as P)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Zinc, dissolved (µg/L)
11075620	12/6/97	0923	0.22	—	0.7	—	0.19	0.20	20	<4	20
11075620	12/6/97	1123	—	—	—	—	—	—	—	—	—
11075620	12/6/97	1323	.21	—	1.1	—	.27	.24	20	4	20
11075620	12/6/97	2108	.14	—	.7	—	.25	.22	20	6	20
11075620	12/7/97	0508	.08	—	.6	—	.33	.31	50	<4	4
11075620	12/7/97	1130	.16	—	.8	—	.32	.30	70	10	10
11075620	12/8/97	1208	—	—	—	—	—	—	—	—	—
11075620	12/8/97	1608	.17	—	.7	—	.43	.40	30	<4	30
11075620	12/8/97	2008	—	—	—	—	—	—	—	—	—
11075620	12/9/97	0008	—	—	—	—	—	—	—	—	—
11075620	12/9/97	0408	—	—	—	—	—	—	—	—	—
11075620	12/9/97	0808	—	—	—	—	—	—	—	—	—
11075620	12/9/97	1208	—	—	—	—	—	—	—	—	—
11075620	12/9/97	1608	—	—	—	—	—	—	—	—	—
11075620	2/3/98	0603	.69	2.2	1.6	1.4	1.2	1.2	20	<4	<20
11075620	2/3/98	0800	.68	2.1	1.6	1.3	1.3	1.4	20	<4	<20
11075620	2/3/98	1000	.43	1.2	1.0	.66	.59	.60	<10	10	<20
11075620	2/3/98	1200	.19	2.6	.6	1.3	.35	.36	20	13	<20
11075620	2/3/98	1400	.20	6.6	.7	7.0	.38	.35	<10	7	<20
11075620	2/3/98	1700	.19	2.7	.8	1.8	.36	.38	<10	5	<20
11075620	2/3/98	2000	.18	5.8	.9	2.2	.50	.47	30	<4	40
11075620	2/3/98	2300	—	—	—	—	—	—	—	—	—
11075620	2/4/98	0200	.10	3.1	.6	2.2	.36	.35	20	7	<20
11075620	2/4/98	0820	—	—	—	—	—	—	—	—	—
11075620	2/4/98	1218	—	—	—	—	—	—	—	—	—
11075620	2/4/98	1556	—	—	—	—	—	—	—	—	—
11075620	2/4/98	1956	—	—	—	—	—	—	—	—	—
11075620	2/4/98	2356	—	—	—	—	—	—	—	—	—
11075620	2/5/98	0356	—	—	—	—	—	—	—	—	—
11075620	2/5/98	0756	—	—	—	—	—	—	—	—	—
11075620	2/5/98	1156	—	—	—	—	—	—	—	—	—

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APPENDIX D

Data for Organic Carbon and Ultraviolet Absorption

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California

[Streamflow data for the entire flow of the river. USGS, U.S. Geological Survey; DOC, dissolved organic carbon; SOC, suspended organic carbon; UV_{254}, ultraviolet absorbance at 254 nanometers; UV_{285}, ultraviolet absorbance at 285 nanometers; mg/L, milligrams per liter; cm-1, per centimeter; >, greater than; —, no data. Streamflow data are for the entire flow of the River.]

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV_{285} (cm-1)
Santa Ana River below Prado Dam	11074000	10/30/96	1045	5.6	3.8	0.101	0.073
	11074000	10/30/96	1215	—	—	.158	.108
	11074000	10/30/96	1415	15	1.3	.297	.195
	11074000	10/30/96	1615	—	—	.356	.239
	11074000	10/30/96	1815	18	1.3	.363	.245
	11074000	10/30/96	1900	—	—	.365	.248
	11074000	10/30/96	2100	18	3.4	.459	.369
	11074000	10/30/96	2300	—	—	.453	.347
	11074000	10/31/96	0100	18	1.9	.466	.379
	11074000	11/21/96	0730	4.7	—	.083	.058
	11074000	11/21/96	0930	—	—	.090	.064
	11074000	11/21/96	1030	7.6	—	—	—
	11074000	11/21/96	1638	—	—	.154	.107
	11074000	11/21/96	1838	—	—	.220	.153
	11074000	11/21/96	2038	—	—	.251	.175
	11074000	11/21/96	2238	—	—	.283	.198
	11074000	11/22/96	0038	—	—	.307	.215
	11074000	11/22/96	0238	—	—	.353	.251
	11074000	11/22/96	0438	16	—	.462	.349
	11074000	11/22/96	0715	16	—	.572	.435
	11074000	11/24/96	0011	—	—	.402	.306
	11074000	11/24/96	0341	—	—	.323	.234
	11074000	11/24/96	0711	.2	—	.397	.303
	11074000	11/24/96	1041	—	—	.353	.258
	11074000	11/24/96	1411	—	—	.334	.242
	11074000	11/24/96	1741	—	—	.317	.230
	11074000	11/24/96	2111	—	—	.340	.254
	11074000	11/25/96	0041	—	—	.320	.234
	11074000	11/25/96	0411	—	—	.332	.243
	11074000	11/25/96	0741	—	—	.337	.247
	11074000	11/25/96	1111	—	—	.319	.233
	11074000	11/25/96	1441	—	—	.314	.229
	11074000	12/9/96	1244	4.6	4.3	.106	.075
	11074000	12/9/96	1444	—	—	.103	.072
	11074000	12/9/96	1644	—	—	.104	.073
	11074000	12/9/96	1844	6	5.1	.134	.093
	11074000	12/9/96	2044	—	—	.158	.109
	11074000	12/9/96	2244	—	—	.160	.114
	11074000	12/10/96	0044	6	3	.182	.130
	11074000	12/10/96	0244	—	—	.189	.133
	11074000	12/10/96	0734	8.4	3.7	.209	.147

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV$_{254}$ (cm-1)	UV $_{285}$ (cm-1)
Santa Ana River below Prado Dam	11074000	12/10/96	1134	—	—	0.201	0.141
	11074000	12/10/96	1534	6.7	4.5	.399	.319
	11074000	12/10/96	1934	—	—	.229	.167
	11074000	12/10/96	2334	6.4	2.8	.201	.142
	11074000	12/11/96	0334	—	—	.207	.149
	11074000	12/11/96	0734	7.2	2.4	.182	.128
	11074000	12/11/96	1134	—	—	.222	.162
	11074000	12/12/96	1221	—	—	.264	.198
	11074000	12/13/96	2021	—	—	.285	.210
	11074000	12/14/96	1221	—	—	.157	.112
	11074000	12/15/96	0421	—	—	.226	.165
	11074000	12/15/96	2021	—	—	.225	.163
	11074000	12/16/96	1221	—	—	.260	.196
	11074000	12/17/96	0421	8.3	3.5	.304	.226
	11074000	1/19/97	2304	—	—	.271	.202
	11074000	1/20/97	0204	—	—	.269	.201
	11074000	1/20/97	0504	—	—	.269	.202
	11074000	1/20/97	0804	8.4	2.3	.263	.196
	11074000	1/20/97	1119	—	—	.247	.184
	11074000	1/20/97	1419	7.9	3.3	.259	.193
	11074000	1/20/97	1719	—	—	.263	.196
	11074000	1/20/97	2019	—	—	.268	.200
	11074000	1/25/97	1157	9.2	2.4	.257	.191
	11074000	1/25/97	1757	—	3.5	.243	.179
	11074000	1/25/97	2357	—	—	.199	.145
	11074000	1/26/97	1430	9.2	6.6	.321	.242
	11074000	1/26/97	2030	—	—	.337	.257
	11074000	1/26/97	2359	—	—	.354	.272
	11074000	1/27/97	1300	9.4	> 17	.420	.326
	11074000	1/27/97	1900	—	—	.440	.344
	11074000	1/28/97	0100	—	—	.458	.359
	11074000	1/28/97	0700	—	—	.442	.340
	11074000	1/28/97	0904	—	—	.442	.340
	11074000	1/28/97	1504	—	—	.437	.338
	11074000	1/28/97	2104	—	—	.489	.383
	11074000	1/29/97	0304	—	—	.514	.392
	11074000	1/29/97	0700	—	—	.368	.280
	11074000	1/29/97	1300	—	—	.352	.266
	11074000	1/29/97	1900	—	—	.393	.300
	11074000	1/30/97	0100	—	—	.435	.340
	11074000	1/30/97	0700	—	—	.456	.355
	11074000	1/30/97	1300	—	—	.399	.307
	11074000	9/14/97	2240	4.2	3.2	.100	.066

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV_{285} (cm-1)
Santa Ana River below Prado Dam	11074000	9/15/97	0240	4.4	2.5	0.134	0.099
	11074000	9/15/97	0640	8.8	2.4	.234	.144
	11074000	9/15/97	1040	—	—	.343	.210
	11074000	9/15/97	1250	12	2.1	.309	.185
	11074000	9/15/97	1415	—	—	.541	.339
	11074000	9/15/97	1845	8.9	2.9	.274	.164
	11074000	9/15/97	2315	—	—	.239	.150
	11074000	9/16/97	0215	—	—	.195	.125
	11074000	9/16/97	0515	—	—	.222	.150
	11074000	9/16/97	0815	—	—	.192	.126
	11074000	9/16/97	1115	—	—	.169	.109
	11074000	9/24/97	1937	3.4	> 8.4	.087	.058
	11074000	9/24/97	2107	—	—	.073	.051
	11074000	9/24/97	2237	—	—	.100	.069
	11074000	9/25/97	0007	—	—	.095	.064
	11074000	9/25/97	0137	—	—	.093	.063
	11074000	9/25/97	0307	—	—	.098	.068
	11074000	9/25/97	0437	3.9	3.3	.100	.069
	11074000	9/25/97	0607	—	—	.088	.063
	11074000	9/25/97	0737	4.5	4.1	.113	.078
	11074000	9/25/97	1037	6	2.9	.158	.108
	11074000	9/25/97	1207	—	—	.205	.138
	11074000	9/25/97	1337	—	—	.328	.217
	11074000	9/25/97	1507	16	2.7	.473	.307
	11074000	9/25/97	1637	—	—	.697	.451
	11074000	9/25/97	1807	—	—	.655	.433
	11074000	9/25/97	1937	—	—	.643	.428
	11074000	9/25/97	2107	—	—	.665	.445
	11074000	9/25/97	2237	—	—	.687	.466
	11074000	9/26/97	0007	—	—	.674	.462
	11074000	9/26/97	0137	—	—	.706	.488
	11074000	9/26/97	0307	—	—	.734	.509
	11074000	9/26/97	0437	—	—	.641	.447
	11074000	9/26/97	0607	—	—	.690	.480
	11074000	11/10/97	0900	3.3	3.9	.076	.053
	11074000	11/10/97	1300	4.1	2.8	.085	.059
	11074000	11/10/97	1700	14	10	.334	.213
	11074000	11/10/97	2156	14	6.7	.429	.287
	11074000	11/11/97	0256	15	4.4	.425	.283
	11074000	11/11/97	0756	15	3.3	.448	.295
	11074000	11/11/97	1459	9.2	4.6	.291	.192
	11074000	11/11/97	1759	—	—	.266	.177
	11074000	11/11/97	2059	—	—	.244	.163
	11074000	11/11/97	2359	—	—	.213	.144

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV_{285} (cm-1)
Santa Ana River below Prado Dam	11074000	11/12/97	0259	—	—	0.189	0.127
	11074000	11/12/97	0559	—	—	.168	.113
	11074000	11/12/97	0859	—	—	.156	.106
	11074000	12/5/97	1623	4.3	> 5.0	.076	.052
	11074000	12/5/97	1923	—	—	.093	.064
	11074000	12/5/97	2223	—	—	.095	.065
	11074000	12/6/97	0123	—	—	.090	.062
	11074000	12/6/97	0423	—	—	.094	.064
	11074000	12/6/97	0723	4.4	2.6	.088	.062
	11074000	12/6/97	1023	4.7	3.5	.121	.085
	11074000	12/6/97	1305	—	—	.088	.062
	11074000	12/6/97	1705	—	—	.230	.168
	11074000	12/6/97	2105	—	—	.234	.173
	11074000	12/7/97	0105	—	—	.231	.169
	11074000	12/7/97	0505	6.1	7.9	.204	.151
	11074000	12/7/97	0905	5.9	5.5	.188	.138
	11074000	12/7/97	1305	—	—	.227	.166
	11074000	12/7/97	1714	6.5	4.6	.200	.145
	11074000	12/7/97	2114	—	—	.226	.165
	11074000	12/8/97	0114	—	—	.226	.165
	11074000	12/8/97	0514	—	—	.213	.154
	11074000	12/8/97	0914	—	—	.210	.150
	11074000	12/8/97	1314	—	—	.218	.158
	11074000	12/8/97	1736	—	—	.216	.156
	11074000	12/8/97	2136	—	—	.207	.147
	11074000	12/9/97	0136	—	—	.212	.153
	11074000	12/9/97	0536	5.8	2.1	.196	.140
	11074000	12/9/97	0936	—	—	.200	.143
	11074000	12/9/97	1336	—	—	.202	.144
	11074000	12/9/97	1736	—	—	.209	.151
	11074000	12/9/97	2136	—	—	.209	.151
	11074000	2/3/98	0800	6.5	2.4	.164	.117
	11074000	2/3/98	1130	6	2	.151	.106
	11074000	2/3/98	1500	5.7	2.8	.146	.104
	11074000	2/3/98	1900	5.8	4.4	.203	.146
	11074000	2/3/98	2300	—	—	.169	.122
	11074000	2/4/98	0300	5.2	6.6	.175	.125
	11074000	2/4/98	0700	—	—	.242	.176
	11074000	2/4/98	1005	5	6.4	.173	.123
	11074000	2/4/98	1405	—	—	.155	.110
	11074000	2/4/98	1805	—	—	.225	.163
	11074000	2/4/98	2205	—	—	.194	.139
	11074000	2/5/98	0205	—	—	.223	.162
	11074000	2/5/98	0605	—	—	.161	.114

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV$_{254}$ (cm-1)	UV $_{285}$ (cm-1)
Santa Ana River below Prado Dam	11074000	2/5/98	1005	—	—	0.180	0.132
	11074000	2/5/98	1405	—	—	.189	.136
Santa Ana River at the diversion downstream from Imperial Highway	11075620	10/30/96	0600	3.7	1.7	.074	.052
	11075620	10/30/96	0650	3.6	—	.087	.060
	11075620	10/30/96	0715	—	—	.074	.052
	11075620	10/30/96	0745	20	> 5.0	.451	.348
	11075620	10/30/96	0800	16	2.9	.441	.322
	11075620	10/30/96	0845	18	> 5.0	.427	.299
	11075620	10/30/96	1015	16	> 5.0	.373	.251
	11075620	10/30/96	1200	—	—	.313	.215
	11075620	10/30/96	1220	13	2	—	—
	11075620	10/30/96	1415	14	> 5.0	.322	.221
	11075620	10/30/96	1600	13	3.3	.318	.219
	11075620	11/21/96	0600	8.3	—	.223	.153
	11075620	11/21/96	0800	10	—	.295	.192
	11075620	11/21/96	1000	6	—	.197	.136
	11075620	11/21/96	1200	7.6	—	.180	.126
	11075620	11/21/96	1300	6.8	—	.207	.145
	11075620	11/21/96	1400	8	—	.187	.134
	11075620	11/21/96	2000	11	—	.228	.159
	11075620	11/21/96	2300	10	—	.209	.150
	11075620	11/22/96	0615	9.6	—	.230	.161
	11075620	11/22/96	1112	—	—	.227	.157
	11075620	11/22/96	1412	—	—	.329	.233
	11075620	11/22/96	1712	—	—	.453	.339
	11075620	11/22/96	2012	—	—	.277	.207
	11075620	11/22/96	2312	—	—	.255	.182
	11075620	11/23/96	0212	—	—	.288	.206
	11075620	11/23/96	0512	—	—	.342	.249
	11075620	11/23/96	0812	—	—	.349	.256
	11075620	11/23/96	1112	—	—	.319	.231
	11075620	11/23/96	1412	—	—	.341	.250
	11075620	11/23/96	1712	—	—	.330	.239
	11075620	11/23/96	2012	—	—	.314	.227
	11075620	11/23/96	2312	—	—	.325	.237
	11075620	11/24/96	0212	—	—	.321	.236
	11075620	11/24/96	0512	—	—	.297	.214
	11075620	11/24/96	0812	—	—	.339	.249
	11075620	11/24/96	1112	11	—	.326	.236
	11075620	11/24/96	1412	—	—	.322	.232
	11075620	11/24/96	1712	—	—	.333	.242
	11075620	11/24/96	2012	—	—	.339	.247
	11075620	11/24/96	2312	—	—	.303	.221
	11075620	11/25/96	0212	—	—	.274	.197

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV $_{285}$ (cm-1)
Santa Ana River at the diversion downstream from Imperial Highway	11075620	11/25/96	0512	—	—	0.307	0.225
	11075620	11/25/96	0812	—	—	.309	.225
	11075620	11/25/96	1112	—	—	.291	.211
	11075620	11/25/96	1412	—	—	.317	.231
	11075620	12/9/96	1252	4.4	.5	.108	.075
	11075620	12/9/96	1430	4.8	.7	.144	.101
	11075620	12/9/96	1630	5.6	—	.146	.100
	11075620	12/9/96	1830	5.2	1.8	.132	.097
	11075620	12/9/96	2030	—	—	.134	.097
	11075620	12/9/96	2230	5.2	4.9	.135	.092
	11075620	12/10/96	0030	—	—	.269	.218
	11075620	12/10/96	0230	5.4	2.3	.133	.093
	11075620	12/10/96	0430	—	—	.156	.109
	11075620	12/10/96	0630	5.6	2.6	.155	.108
	11075620	12/10/96	0830	—	—	.151	.105
	11075620	1/19/97	2308	—	—	.230	.170
	11075620	1/20/97	0208	—	—	.283	.213
	11075620	1/20/97	0508	—	—	.249	.186
	11075620	1/20/97	0808	7.9	2.6	.262	.196
	11075620	1/20/97	1155	7.1	3	.258	.192
	11075620	1/20/97	1455	7.8	3.2	.242	.178
	11075620	1/20/97	1755	7.4	2.8	.235	.175
	11075620	1/20/97	2055	—	—	.237	.176
	11075620	1/25/97	1008	8.8	2.5	.274	.205
	11075620	1/25/97	1308	8.6	2.1	.258	.191
	11075620	1/25/97	1608	8.8	2.3	.255	.187
	11075620	1/25/97	2114	6.2	9.6	.553	.431
	11075620	1/25/97	2310	—	—	.193	.142
	11075620	1/26/97	0130	—	—	.274	.211
	11075620	1/26/97	0400	6.8	17	.209	.153
	11075620	1/26/97	0930	9	> 17	.214	.156
	11075620	1/26/97	1630	—	—	.379	.292
	11075620	1/26/97	2130	8.6	9.8	.283	.213
	11075620	1/27/97	0030	—	—	.339	.258
	11075620	1/27/97	0330	—	—	.341	.260
	11075620	1/27/97	0630	—	—	.394	.306
	11075620	1/27/97	0930	—	—	.389	.300
	11075620	1/27/97	1230	9.8	15	.469	.367
	11075620	1/27/97	1530	—	—	.493	.380
	11075620	1/27/97	1830	—	—	.592	.420
	11075620	1/27/97	1930	—	—	.431	.336
	11075620	1/27/97	2130	10	> 17	.449	.349
	11075620	1/28/97	0330	—	—	.438	.341
	11075620	1/28/97	0930	9.6	9.7	.439	.341

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV$_{254}$ (cm-1)	UV $_{285}$ (cm-1)
Santa Ana River at the diversion downstream from Imperial Highway	11075620	1/28/97	1530	—	—	0.402	0.309
	11075620	1/29/97	0900	—	—	.361	.274
	11075620	9/15/97	0010	3.6	> 5	.096	.066
	11075620	9/15/97	0310	8.1	2.3	.169	.105
	11075620	9/15/97	0610	4.8	1.9	.179	.115
	11075620	9/15/97	0910	5.4	1.6	.215	.144
	11075620	9/15/97	1115	4.5	1.2	.130	.083
	11075620	9/15/97	1550	—	—	.202	.126
	11075620	9/15/97	1850	—	—	.301	.188
	11075620	9/15/97	2350	13	1.1	.488	.305
	11075620	9/16/97	0350	—	—	.326	.203
	11075620	9/16/97	650	—	—	.240	.150
	11075620	9/16/97	0950	—	—	.208	.132
	11075620	9/16/97	1250	—	—	.184	.118
	11075620	9/24/97	2030	5.7	1.4	.052	.035
	11075620	9/24/97	2200	—	—	.128	.092
	11075620	9/24/97	2330	—	—	.102	.071
	11075620	9/25/97	0100	—	—	.112	.079
	11075620	9/25/97	0230	3.7	1.7	.207	.132
	11075620	9/25/97	0400	—	—	.285	.182
	11075620	9/25/97	0530	5.7	1.2	.192	.122
	11075620	9/25/97	0700	—	—	.223	.142
	11075620	9/25/97	0830	8	1.4	.283	.183
	11075620	9/25/97	1000	—	—	.348	.233
	11075620	9/25/97	1130	6.5	2.2	.254	.171
	11075620	9/25/97	1300	—	—	.274	.189
	11075620	9/25/97	1430	6.6	2.1	.226	.156
	11075620	9/25/97	1600	—	—	.149	.102
	11075620	9/25/97	1730	—	—	.295	.215
	11075620	9/25/97	1900	6.2	1.4	.229	.155
	11075620	9/25/97	2030	—	—	.189	.129
	11075620	9/25/97	2230	—	—	.273	.188
	11075620	9/25/97	2330	—	—	.402	.274
	11075620	9/26/97	0100	13	1.9	.568	.367
	11075620	9/26/97	0230	—	—	.585	.381
	11075620	9/26/97	0400	—	—	.608	.411
	11075620	9/26/97	0530	—	—	.598	.398
	11075620	9/26/97	0700	—	—	.498	.332
	11075620	9/26/97	0730	—	—	.630	.433
	11075620	9/26/97	0900	—	—	.645	.443
	11075620	9/26/97	1030	—	—	.663	.456
	11075620	9/26/97	1200	15	1.9	.630	.431
	11075620	9/26/97	1330	—	—	.530	.362
	11075620	9/26/97	1500	—	—	.611	.420

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV_{285} (cm-1)
Santa Ana River at the diversion downstream from Imperial Highway	11075620	9/26/97	1630	—	—	0.579	0.398
	11075620	9/26/97	1800	—	—	.576	.398
	11075620	9/26/97	1930	—	—	.518	.355
	11075620	9/26/97	2100	—	—	.465	.319
	11075620	9/26/97	2230	—	—	.436	.299
	11075620	9/27/97	0001	—	—	.418	.286
	11075620	9/27/97	0130	—	—	.411	.282
	11075620	9/27/97	0300	—	—	.379	.266
	11075620	9/27/97	0430	—	—	.331	.226
	11075620	9/27/97	0600	—	—	.290	.199
	11075620	9/27/97	0730	—	—	—	—
	11075620	11/10/97	1000	4	2.6	.108	.072
	11075620	11/10/97	1230	8.5	3.4	.305	.195
	11075620	11/10/97	1500	8.7	3.1	.301	.198
	11075620	11/10/97	1951	5.2	3.4	.195	.133
	11075620	11/10/97	2351	4	2.6	.112	.077
	11075620	11/11/97	0351	7.4	4.1	.328	.217
	11075620	11/11/97	1451	12	3.9	.408	.267
	11075620	11/11/97	1721	—	—	.357	.236
	11075620	11/11/97	1951	—	—	.299	.199
	11075620	11/11/97	2221	—	—	.274	.183
	11075620	11/12/97	0051	—	—	.256	.171
	11075620	11/12/97	0321	—	—	.235	.157
	11075620	11/12/97	0551	—	—	.222	.150
	11075620	11/12/97	0821	—	—	.197	.133
	11075620	12/5/97	1523	4.4	1.6	.100	.069
	11075620	12/5/97	1723	—	—	.100	.069
	11075620	12/5/97	1923	—	—	.100	.069
	11075620	12/5/97	2123	—	—	.113	.076
	11075620	12/6/97	0123	4.7	1.3	.110	.074
	11075620	12/6/97	0323	4.6	3.1	.123	.083
	11075620	12/6/97	0523	3.4	35	.104	.075
	11075620	12/6/97	0723	3.5	27	.124	.089
	11075620	12/6/97	0923	3.9	50	.137	.098
	11075620	12/6/97	1123	—	—	.139	.097
	11075620	12/6/97	1323	5.3	24	.282	.227
	11075620	12/6/97	2108	5.7	50	.186	.144
	11075620	12/7/97	0508	6.5	21	.174	.128
	11075620	12/7/97	1130	6.7	10	.181	.133
	11075620	12/8/97	1208	—	—	.210	.149
	11075620	12/8/97	1608	6.2	3.9	.192	.136
	11075620	12/8/97	2008	—	—	.208	.148
	11075620	12/9/97	0008	—	—	.209	.150
	11075620	12/9/97	0408	—	—	.206	.148

Appendix D. Data for organic carbon and ultraviolet absorption in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, sourthern California—Continued

Staion name	USGS station number	Date	Time	DOC (mg/L)	SOC (mg/L)	UV_{254} (cm-1)	UV $_{285}$ (cm-1)
Santa Ana River at the diversion downstream from Imperial Highway	11075620	12/9/97	0808	—	—	0.202	0.146
	11075620	12/9/97	1208	—	—	.204	.145
	11075620	12/9/97	1608	—	—	.199	.142
	11075620	2/3/98	0603	7.2	1.2	.184	.132
	11075620	2/3/98	0800	7.1	.3	.167	.120
	11075620	2/3/98	1000	5.4	1.6	.150	.106
	11075620	2/3/98	1200	4.2	9.3	.149	.108
	11075620	2/3/98	1400	4.4	38	.143	.102
	11075620	2/3/98	1700	5.4	14	.180	.131
	11075620	2/3/98	2000	5.5	49	.177	.127
	11075620	2/3/98	2300	—	—	.194	.139
	11075620	2/4/98	0200	5.7	> 17	.198	.144
	11075620	2/4/98	0820	—	—	.195	.142
	11075620	2/4/98	1218	—	—	.203	.149
	11075620	2/4/98	1556	—	—	.267	.197
	11075620	2/4/98	1956	—	—	.267	.197
	11075620	2/4/98	2356	—	—	.250	.183
	11075620	2/5/98	0356	—	—	.247	.181
	11075620	2/5/98	0756	—	—	.219	.159
	11075620	2/5/98	1156	—	—	.243	.183

APPENDIX E

Data for Pesticides

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California

[USGS, U.S. Geological Survey; µg/L, microgram per liter; <, less than; E, estimated (see note at end of table]; —, no data]

Station name	USGS station number	Data	Time	2,4-d (µg/L)	Atrazine (µg/L)	Benfluralin (µg/L)	Bromacil (µg/L)	Carbarl (µg/L)
Santa Ana River below Prado Dam	11074000	10/30/96	1045	<0.035	0.011	<0.002	<0.035	E0.009
	11074000	10/30/96	1415	<.035	.012	<.002	<.035	E.024
	11074000	10/30/96	1815	<.035	.011	<.002	<.035	E.049
	11074000	10/30/96	2100	<.035	.012	<.002	<.035	E.111
	11074000	10/31/96	0100	<.035	.012	<.002	<.035	E.693
	11074000	1/20/97	0804	<.035	.007	<.002	<.035	E.034
	11074000	1/20/97	1419	<.035	.007	<.002	<.035	E.032
	11074000	1/25/97	1157	<.035	.057	<.002	<.035	E.030
	11074000	1/25/97	1757	<.035	.054	<.002	<.035	E.041
	11074000	1/26/97	1430	<.035	.040	<.002	<.035	E.052
	11074000	1/27/97	1300	<.035	.014	<.002	<.035	E.040
	11074000	9/14/97	2240	<.035	.007	<.002	<.035	E.022
	11074000	9/15/97	0240	<.035	.007	<.002	<.035	E.062
	11074000	9/15/97	0640	<.035	.007	<.002	<.035	E.119
	11074000	9/15/97	1040	—	.007	<.002	—	E.111
	11074000	9/15/97	1250	<.035	.008	<.002	<.035	E.107
	11074000	9/15/97	1845	<.035	.007	<.002	<.035	E.138
	11074000	9/24/97	1937	—	.010	<.002	—	E.012
	11074000	9/24/97	2107	<.035	—	—	<.035	—
	11074000	9/25/97	0437	—	.008	<.002	—	E.014
	11074000	9/25/97	0607	<.035	—	—	<.035	—
	11074000	9/25/97	0737	—	.008	<.002	—	E.015
	11074000	9/25/97	0907	<.035	—	—	<.035	—
	11074000	9/25/97	1037	—	.009	<.002	—	E.014
	11074000	9/25/97	1207	<.035	—	—	<.035	—
	11074000	9/25/97	1507	—	.009	<.002	—	E.063
	11074000	9/25/97	1637	<.035	—	—	<.035	—
	11074000	2/3/98	0800	<.15	.007	<.002	<.035	E.076
	11074000	2/3/98	1130	<.15	.007	<.002	.370	E.054
	11074000	2/3/98	1500	—	.007	<.002	—	E.048
	11074000	2/3/98	1900	<.15	<.001	<.002	.340	E.449
	11074000	2/4/98	0300	<.15	.009	<.002	.500	E1.12
	11074000	2/4/98	1005	<.15	.010	<.002	.480	E1.04
Santa Ana River at the diversion downstream from Imperial Highway	11075620	10/30/96	0600	<.035	.010	<.002	<.035	<.010
	11075620	10/30/96	0650	<.035	.011	<.002	<.035	<.009
	11075620	10/30/96	0745	<.035	.009	<.002	<.035	E.109
	11075620	10/30/96	0800	<.035	.007	<.002	<.035	E.167
	11075620	10/30/96	0845	<.035	—	—	<.035	—
	11075620	10/30/96	1015	<.035	.007	<.002	<.035	E.187
	11075620	10/30/96	1220	<.035	.006	<.002	<.035	E.179
	11075620	10/30/96	1415	<.035	<.008	<.002	<.035	E.167
	11075620	10/30/96	1600	<.035	.007	<.002	—	E.168
	11075620	1/20/97	0808	<.035	.009	<.002	<.035	E.055
	11075620	1/20/97	1155	<.035	.007	<.002	<.035	E.034
	11075620	1/20/97	1455	<.035	.008	.005	<.035	E.048
	11075620	1/20/97	1755	<.035	.007	<.002	<.035	E.027
	11075620	1/25/97	1008	<.035	.055	<.002	<.035	E.025
	11075620	1/25/97	1608	<.035	.054	<.002	<.035	E.038
	11075620	1/25/97	2114	.200	.022	.005	<.035	E.098

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Chlorpyrifos (μg/L)	Cyanazine (μg/L)	DCPA (μg/L)	p,p'-DDE (μg/L)	Deethyl atrazine (μg/L)	Diazinon (μg/L)	Diuron (μg/L)
11074000	10/30/96	1045	<0.004	<0.004	E0.003	<0.006	E0.011	0.018	<0. 02
11074000	10/30/96	1415	.020	<.004	.006	<.006	<.002	.050	.19
11074000	10/30/96	1815	.025	<.004	.007	<.006	<.002	.091	.49
11074000	10/30/96	2100	<.004	<.004	.006	<.006	<.002	.221	E5.9
11074000	10/31/96	0100	<.004	<.004	.008	<.006	<.002	.190	E3.9
11074000	1/20/97	0804	.010	.008	.220	<.006	E.0053	.095	1.20
11074000	1/20/97	1419	.007	.006	.218	<.006	E.0067	.099	1.10
11074000	1/25/97	1157	<.01	<.004	.098	<.006	<.002	.103	E2.9
11074000	1/25/97	1757	<.01	<.004	.091	<.006	<.002	.109	E2.9
11074000	1/26/97	1430	.021	<.004	.155	<.006	<.002	.139	E4.1
11074000	1/27/97	1300	<.004	<.004	.263	<.006	<.002	.083	E3.2
11074000	9/14/97	2240	<.007	.010	E.002	<.006	<.007	.009	<.02
11074000	9/15/97	0240	<.009	.009	E.002	<.006	<.006	.007	<.02
11074000	9/15/97	0640	.004	<.004	E.002	<.006	<.005	.019	<.02
11074000	9/15/97	1040	E.007	<.004	E.002	<.006	<.002	.018	—
11074000	9/15/97	1250	.010	<.004	E.003	<.006	<.002	.065	<.02
11074000	9/15/97	1845	<.004	<.004	E.003	<.006	<.002	.099	<.02
11074000	9/24/97	1937	<.004	<.004	E.003	<.006	<.002	.010	—
11074000	9/24/97	2107	—	—	—	—	—	—	E.07
11074000	9/25/97	0437	<.004	<.004	E.003	<.006	<.002	.009	—
11074000	9/25/97	0607	—	—	—	—	—	—	E.06
11074000	9/25/97	0737	<.004	<.004	E.002	<.006	<.002	.009	—
11074000	9/25/97	0907	—	—	—	—	—	—	<.02
11074000	9/25/97	1037	<.004	<.004	E.002	<.006	<.002	.013	—
11074000	9/25/97	1207	—	—	—	—	—	—	<.02
11074000	9/25/97	1507	<.004	<.040	E.003	<.006	<.002	.106	—
11074000	9/25/97	1637	—	—	—	—	—	—	<.02
11074000	2/3/98	0800	<.004	<.004	E.003	<.006	E.004	.059	E1.4
11074000	2/3/98	1130	.008	<.004	E.003	<.006	E.005	.056	E1.4
11074000	2/3/98	1500	.007	<.004	E.003	<.006	E.005	.055	—
11074000	2/3/98	1900	.013	<.004	.006	<.006	E.005	.161	E5.5
11074000	2/4/98	0300	.020	<.004	.011	E.004	<.002	.184	E13
11074000	2/4/98	1005	.010	<.004	.012	<.006	<.002	.173	E12
11075620	10/30/96	0600	<.004	<.004	E.002	<.006	E.008	.019	.08
11075620	10/30/96	0650	<.004	<.004	E.002	<.006	E.009	.017	.09
11075620	10/30/96	0745	.096	<.004	.009	<.006	<.002	.494	<. 02
11075620	10/30/96	0800	.087	<.004	.008	<.006	<.002	.559	.08
11075620	10/30/96	0845	—	—	—	—	—	—	<. 02
11075620	10/30/96	1015	.099	<.004	.008	<.006	<.002	.642	<. 02
11075620	10/30/96	1220	.054	<.004	.006	<.006	<.002	.534	<. 02
11075620	10/30/96	1415	.094	<.004	.008	<.006	<.002	.468	<. 02
11075620	10/30/96	1600	.089	<.004	.008	<.006	<.002	.446	—
11075620	1/20/97	0808	.012	.013	.213	<.006	E.010	.117	1.20
11075620	1/20/97	1155	.008	.007	.192	<.006	E.006	.087	1.00
11075620	1/20/97	1455	.026	.009	.187	<.006	E.006	.165	1.00
11075620	1/20/97	1755	.010	.007	.188	<.006	E.006	.083	.71
11075620	1/25/97	1008	<.004	<.004	.104	<.006	E.005	.087	E2.9
11075620	1/25/97	1608	.016	<.004	.100	<.006	E.006	.154	E2.8
11075620	1/25/97	2114	.033	<.004	.039	<.006	<.002	.377	1.40

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Lindane (µg/L)	Malathion (µg/L)	Metolachlor (µg/L)	Napropamide (µg/L)	Norflurazon (µg/L)	Pendimethalin (µg/L)	Prometon (µg/L)
11074000	10/30/96	1045	0.011	<0.005	<0.002	<0.003	<0.024	<0.004	E0.012
11074000	10/30/96	1415	<.01	.013	<.002	<.003	<.024	<.004	E.029
11074000	10/30/96	1815	<.008	.034	<.002	<.003	<.024	<.004	E.043
11074000	10/30/96	2100	<.004	.064	<.002	<.003	<.024	<.004	E.048
11074000	10/31/96	0100	<.004	.060	<.002	<.003	<.024	<.004	E.051
11074000	1/20/97	0804	.007	.018	.007	<.003	<.024	<.004	.030
11074000	1/20/97	1419	.007	.018	.009	<.003	<.024	<.004	.021
11074000	1/25/97	1157	<.004	.023	.007	<.003	E.390	<.004	.018
11074000	1/25/97	1757	<.004	.028	.006	<.003	E.010	<.004	E.015
11074000	1/26/97	1430	<.004	.048	.009	<.003	E.240	<.004	.021
11074000	1/27/97	1300	<.004	.030	.008	<.003	<.024	<.004	E.016
11074000	9/14/97	2240	.007	<.005	.009	<.003	<.024	<.004	E.007
11074000	9/15/97	0240	.007	<.005	.009	<.003	<.024	<.004	E.007
11074000	9/15/97	0640	<.004	.011	.008	<.003	<.024	<.004	E.010
11074000	9/15/97	1040	<.004	<.005	.010	<.003	—	<.004	.020
11074000	9/15/97	1250	<.004	.022	.008	<.003	<.024	<.004	.024
11074000	9/15/97	1845	<.004	.017	.015	<.003	<.024	<.004	.040
11074000	9/24/97	1937	<.01	<.005	.012	<.003	—	<.004	E.009
11074000	9/24/97	2107	—	—	—	—	<.024	—	—
11074000	9/25/97	0437	<.01	<.005	.012	<.003	—	<.004	E.009
11074000	9/25/97	0607	—	—	—	—	<.024	—	—
11074000	9/25/97	0737	<.01	<.005	.010	<.003	—	<.004	E.007
11074000	9/25/97	0907	—	—	—	—	<.024	—	—
11074000	9/25/97	1037	<.004	<.005	.012	<.003	—	<.004	E.0081
11074000	9/25/97	1207	—	—	—	—	<.024	—	—
11074000	9/25/97	1507	<.004	.036	.011	<.025	—	<.004	.022
11074000	9/25/97	1637	—	—	—	—	<.024	—	—
11074000	2/3/98	0800	.011	<.005	.005	<.003	<.024	<.004	E.014
11074000	2/3/98	1130	.010	<.005	.006	<.003	<.024	<.004	.019
11074000	2/3/98	1500	.010	<.005	.006	<.003	—	<.004	.018
11074000	2/3/98	1900	<.004	.021	.005	<.003	<.024	<.004	.020
11074000	2/4/98	0300	<.004	.055	.011	<.003	<.024	<.004	.043
11074000	2/4/98	1005	<.004	.047	.011	<.003	<.024	<.004	.040
11075620	10/30/96	0600	.009	<.005	<.002	<.0030	<.024	<.004	E.012
11075620	10/30/96	0650	.009	<.005	<.002	<.003	<.024	<.004	E.012
11075620	10/30/96	0745	<.010	E.156	<.002	.023	<.024	<.004	.021
11075620	10/30/96	0800	<.008	E.176	<.002	.043	<.024	<.004	.022
11075620	10/30/96	0845	—	—	—	—	<.024	—	—
11075620	10/30/96	1015	<.004	.220	<.002	.034	<.024	<.004	E.020
11075620	10/30/96	1220	<.004	.180	<.002	.017	<.024	<.004	E.021
11075620	10/30/96	1415	<.007	.136	<.002	.013	<.024	<.020	.039
11075620	10/30/96	1600	<.005	.139	<.002	<.008	—	<.025	.043
11075620	1/20/97	0808	.013	.018	.011	<.003	<.024	<.004	.024
11075620	1/20/97	1155	<.004	.014	.005	<.003	<.024	<.004	.037
11075620	1/20/97	1455	<.004	.084	.007	<.003	<.024	<.004	.021
11075620	1/20/97	1755	<.004	.014	.005	<.003	<.024	<.004	E.005
11075620	1/25/97	1008	<.010	.018	<.002	<.003	E .35	E.008	.026
11075620	1/25/97	1608	<.008	.025	<.002	<.003	E .36	<.004	.029
11075620	1/25/97	2114	<.007	.023	<.002	<.003	E .29	<.004	<.018

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Pronamide (µg/L)	Propoxur (µg/L)	Simazine (µg/L)	Tebuthiuron (µg/L)	Triclopyr (µg/L)	Trifluralin µg/L)
11074000	10/30/96	1045	<0.003	<0.035	0.081	E0.012	<0.05	<0.002
11074000	10/30/96	1415	<.003	<.035	E.136	E.025	<.05	<.002
11074000	10/30/96	1815	<.003	<.035	E.151	E.025	<.05	<.002
11074000	10/30/96	2100	<.003	<.035	E.113	<.01	<.05	<.002
11074000	10/31/96	0100	<.003	<.035	E.209	<.01	<.05	<.002
11074000	1/20/97	0804	<.003	<.035	.527	<.01	<.05	.004
11074000	1/20/97	1419	<.003	<.035	.514	<.01	<.05	<.002
11074000	1/25/97	1157	<.003	<.035	.276	<.01	<.05	<.002
11074000	1/25/97	1757	<.003	<.035	.269	<.01	<.05	<.002
11074000	1/26/97	1430	<.003	<.035	.385	<.01	<.05	<.002
11074000	1/27/97	1300	<.003	<.035	.482	<.01	<.05	<.002
11074000	9/14/97	2240	<.003	<.035	.045	<.01	<.05	<.002
11074000	9/15/97	0240	<.003	<.035	.044	<.01	<.05	<.002
11074000	9/15/97	0640	<.003	<.035	.046	<.01	<.05	<.002
11074000	9/15/97	1040	<.003	—	.039	<.01	—	<.002
11074000	9/15/97	1250	<.003	<.035	.046	<.01	<.05	<.002
11074000	9/15/97	1845	<.003	<.035	.052	<.01	<.05	<.002
11074000	9/24/97	1937	<.003	—	.042	<.01	—	<.002
11074000	9/24/97	2107	—	E.11	—	—	<.05	—
11074000	9/25/97	0437	<.003	—	.037	<.01	—	<.002
11074000	9/25/97	0607	—	E.05	—	—	<.05	—
11074000	9/25/97	0737	<.003	—	.036	<.01	—	<.002
11074000	9/25/97	0907	—	<.035	—	—	<.05	—
11074000	9/25/97	1037	<.003	—	.038	<.01	—	<.002
11074000	9/25/97	1207	—	<.035	—	—	<.05	—
11074000	9/25/97	1507	<.003	—	.038	<.01	—	<.002
11074000	9/25/97	1637	—	<.035	—	—	<.05	—
11074000	2/3/98	0800	<.003	<.035	.110	<.01	<.25	E.002
11074000	2/3/98	1130	<.003	<.035	.112	<.01	<.25	<.002
11074000	2/3/98	1500	<.003	—	.114	<.01	—	<.002
11074000	2/3/98	1900	<.003	<.035	.243	<.01	<.25	<.002
11074000	2/4/98	0300	<.003	<.035	1.090	<.01	<.25	<.002
11074000	2/4/98	1005	<.003	<.035	1.220	<.01	<.25	<.002
11075620	10/30/96	0600	<.003	<.035	.068	E.013	<.05	<.002
11075620	10/30/96	0650	<.003	<.035	.072	E.012	<.05	<.002
11075620	10/30/96	0745	<.040	<.035	E.096	E.018	.130	<.002
11075620	10/30/96	0800	<.035	<.035	E.072	E.020	.130	<.002
11075620	10/30/96	0845	—	<.035	—	—	<.05	—
11075620	10/30/96	1015	<.003	<.035	E.039	.015	<.05	<.002
11075620	10/30/96	1220	<.003	<.035	E.032	.013	<.05	<.002
11075620	10/30/96	1415	<.003	<.035	E.041	E.022	.080	<.002
11075620	10/30/96	1600	<.003	—	E.043	E.018	<.05	<.002
11075620	1/20/97	0808	<.003	<.035	.587	E.023	<.05	<.002
11075620	1/20/97	1155	<.003	<.035	.488	<.01	<.05	<.002
11075620	1/20/97	1455	<.003	<.035	.471	<.01	<.05	.005
11075620	1/20/97	1755	<.003	<.035	.459	<.01	<.05	.005
11075620	1/25/97	1008	<.003	<.035	.278	<.01	<.05	<.002
11075620	1/25/97	1608	<.003	<.035	.268	<.01	<.05	<.002
11075620	1/25/97	2114	0.009	<.035	.114	<.01	<.05	.004

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

Station name	USGS station number	Data	Time	2,4-d (μg/L)	Atrazine (μg/L)	Benfluralin (μg/L)	Bromacil (μg/L)	Carbarl (μg/L)
Santa Ana River at the diversion downstream from Imperial Highway	11075620	1/26/97	0400	<0.035	0.045	<0.002	<0.035	E0.039
	11075620	1/26/97	0930	<.035	.039	<.002	<.035	E.039
	11075620	1/26/97	2130	<.035	.025	<.002	<.035	E.083
	11075620	1/27/97	1230	<.035	.014	<.002	<.035	E.042
	11075620	1/27/97	2130	<.035	.015	<.002	<.035	E.040
	11075620	1/28/97	0930	<.035	.015	<.002	<.035	E.043
	11075620	9/15/97	0010	<.035	.008	<.002	<.035	E.074
	11075620	9/15/97	0310	<.035	.008	<.002	<.035	E.116
	11075620	9/15/97	0610	<.035	.008	<.002	<.035	E.02
	11075620	9/15/97	0910	<.035	.007	<.002	<.035	E.073
	11075620	9/15/97	1115	<.035	.008	<.002	<.035	E.084
	11075620	9/15/97	2350	<.035	<.001	<.002	<.035	E.173
	11075620	9/24/97	2030	—	.009	<.002	—	E.013
	11075620	9/24/97	2200	<.035	—	—	<.035	—
	11075620	9/25/97	0230	—	.009	<.002	—	E.03
	11075620	9/25/97	0400	<.035	—	—	<.035	—
	11075620	9/25/97	0530	—	.009	<.002	—	E.032
	11075620	9/25/97	0700	<.035	—	—	<.035	—
	11075620	9/25/97	0830	—	.009	<.002	—	E.124
	11075620	9/25/97	1000	<.035	—	—	<.035	—
	11075620	9/25/97	1130	—	.009	<.002	—	E.102
	11075620	9/25/97	1300	<.035	—	—	<.035	—
	11075620	9/25/97	1430	—	.008	<.002	—	E.128
	11075620	9/25/97	1600	<.035	—	—	<.035	—
	11075620	9/25/97	1900	—	.009	<.002	—	E.09
	11075620	9/25/97	2030	<.035	—	—	<.035	—
	11075620	9/26/97	0100	—	.009	<.002	—	E.097
	11075620	9/26/97	0230	<.035	—	—	<.035	—
	11075620	9/26/97	1200	—	.009	<.002	—	E.177
	11075620	9/26/97	1330	<.035	—	—	<.035	—
	11075620	2/3/98	0603	<.15	<.001	<.002	<.035	E.054
	11075620	2/3/98	0800	<.15	.006	<.002	<.035	<.003
	11075620	2/3/98	1000	<.15	<.001	.007	.360	E.199
	11075620	2/3/98	1200	.390	<.001	.006	.180	E.523
	11075620	2/3/98	1400	<.30	<.001	<.002	.210	E.391
	11075620	2/3/98	1700	.410	<.001	<.002	.190	E.410
	11075620	2/3/98	2000	—	<.001	<.002	—	E.178
	11075620	2/3/98	2300	<.15	—	—	.160	—
	11075620	2/4/98	0200	<.15	<.001	E.002	.450	E1.2

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Chlorpyrifos (µg/L)	Cyanazine (µg/L)	DCPA (µg/L)	p,p'-DDE (µg/L)	Deethyl atrazine (µg/L)	Diazinon (µg/L)	Diuron (µg/L)
11075620	1/26/97	0400	0.010	<.004	0.070	<0.006	E0.003	0.125	E3.9
11075620	1/26/97	0930	<.01	<.004	.052	<.006	<.002	.120	E3.0
11075620	1/26/97	2130	.023	<.004	.153	<.006	<.002	.176	E3.3
11075620	1/27/97	1230	<.0040	<.004	.358	<.006	<.002	.091	E3.7
11075620	1/27/97	2130	<.01	<.004	.159	<.006	<.002	.077	E2.7
11075620	1/28/97	0930	<.0040	<.004	.151	<.006	<.002	.081	E2.8
11075620	9/15/97	0010	<.004	<.004	E.002	<.006	E.005	.025	<.02
11075620	9/15/97	0310	.011	<.004	E.002	<.006	<.002	.132	<.02
11075620	9/15/97	0610	.005	<.004	E.002	<.006	<.002	.041	<.02
11075620	9/15/97	0910	.016	<.004	E.002	<.006	<.002	.087	<.02
11075620	9/15/97	1115	.008	<.004	E.002	<.006	<.002	.049	<.02
11075620	9/15/97	2350	<.004	<.004	E.004	<.006	<.002	.125	.050
11075620	9/24/97	2030	<.004	<.004	E.002	<.006	<.002	.010	—
11075620	9/24/97	2200	—	—	—	—	—	—	<.02
11075620	9/25/97	0230	.012	<.004	E.003	<.006	<.002	.087	—
11075620	9/25/97	0400	—	—	—	—	—	—	<.02
11075620	9/25/97	0530	.007	<.004	E.003	<.006	<.002	.061	—
11075620	9/25/97	0700	—	—	—	—	—	—	<.02
11075620	9/25/97	0830	.017	<.004	.004	<.006	<.002	.418	—
11075620	9/25/97	1000	—	—	—	—	—	—	<.02
11075620	9/25/97	1130	.014	<.004	.005	<.006	<.002	.344	—
11075620	9/25/97	1300	—	—	—	—	—	—	E.12
11075620	9/25/97	1430	.022	<.004	.004	<.006	<.002	.512	—
11075620	9/25/97	1600	—	—	—	—	—	—	<.02
11075620	9/25/97	1900	.011	<.004	E.003	<.006	<.002	.216	—
11075620	9/25/97	2030	—	—	—	—	—	—	E.15
11075620	9/26/97	0100	.014	<.004	.004	<.006	<.002	.196	—
11075620	9/26/97	0230	—	—	—	—	—	—	.190
11075620	9/26/97	1200	<.004	<.004	.006	<.006	<.002	.273	—
11075620	9/26/97	1330	—	—	—	—	—	—	.680
11075620	2/3/98	0603	.005	<.004	E.003	<.006	<.002	.060	1.400
11075620	2/3/98	0800	E.002	<.004	E.003	<.006	<.002	.054	1.300
11075620	2/3/98	1000	.043	<.004	E.003	<.006	<.002	.431	1.000
11075620	2/3/98	1200	.042	<.004	E.003	<.006	<.002	.474	.580
11075620	2/3/98	1400	.031	<.004	E.003	<.006	<.002	.386	.630
11075620	2/3/98	1700	.029	<.004	E.003	<.006	<.002	.364	.510
11075620	2/3/98	2000	.020	<.004	E.003	<.006	<.002	.234	—
11075620	2/3/98	2300	—	—	—	—	—	—	.850
11075620	2/4/98	0200	.017	<.004	.006	<.006	<.002	.242	E13

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Lindane (μg/L)	Malathion (μg/L)	Metolachlor (μg/L)	Napropamide (μg/L)	Norflurazon (μg/L)	Pendimethalin (μg/L)	Prometon (μg/L)
11075620	1/26/97	0400	<0.004	0.023	0.006	<0.003	E0.33	<0.004	E0.018
11075620	1/26/97	0930	<.004	.026	.006	<.003	E.27	<.004	E.014
11075620	1/26/97	2130	<.004	.038	.007	<.003	<.024	<.004	.023
11075620	1/27/97	1230	<.004	<.005	.010	<.003	<.024	<.004	<.018
11075620	1/27/97	2130	<.004	<.020	.008	<.003	<.024	<.004	<.018
11075620	1/28/97	0930	<.004	<.005	.008	<.003	<.024	<.004	E.013
11075620	9/15/97	0010	<.004	<.005	.011	<.003	<.024	<.004	E.009
11075620	9/15/97	0310	<.004	.029	.012	<.003	<.024	<.004	E.015
11075620	9/15/97	0610	<.004	<.005	.011	<.003	<.024	<.004	E.010
11075620	9/15/97	0910	<.004	.053	.010	<.003	<.024	<.004	E.008
11075620	9/15/97	1115	<.004	.009	.011	<.003	<.024	<.004	E.011
11075620	9/15/97	2350	<.004	.029	.010	<.003	<.024	<.004	.038
11075620	9/24/97	2030	<.004	<.005	.010	<.003	—	<.004	E.010
11075620	9/24/97	2200	—	—	—	—	<.024	—	—
11075620	9/25/97	0230	<.004	.018	.011	<.003	—	<.004	E.013
11075620	9/25/97	0400	—	—	—	—	<.024	—	—
11075620	9/25/97	0530	<.004	.020	.012	<.003	—	<.004	E.010
11075620	9/25/97	0700	—	—	—	—	<.024	—	—
11075620	9/25/97	0830	<.004	.073	.011	<.003	—	<.004	E.012
11075620	9/25/97	1000	—	—	—	—	<.024	—	—
11075620	9/25/97	1130	<.004	.079	.012	<.003	—	<.004	E.013
11075620	9/25/97	1300	—	—	—	—	<.024	—	—
11075620	9/25/97	1430	<.004	.098	.010	<.003	—	<.004	E.009
11075620	9/25/97	1600	—	—	—	—	<.024	—	—
11075620	9/25/97	1900	<.004	.052	.010	<.003	—	<.004	E.011
11075620	9/25/97	2030	—	—	—	—	<.024	—	—
11075620	9/26/97	0100	<.004	.059	.012	<.003	—	<.004	.045
11075620	9/26/97	0230	—	—	—	—	<.024	—	—
11075620	9/26/97	1200	<.004	.068	<.002	.085	—	<.004	.054
11075620	9/26/97	1330	—	—	—	—	<.024	—	—
11075620	2/3/98	0603	.013	<.005	.004	<.003	<.024	<.004	.021
11075620	2/3/98	0800	.012	<.005	E.004	<.003	<.024	<.004	.020
11075620	2/3/98	1000	<.01	.075	E.004	<.003	<.024	.015	E.0145
11075620	2/3/98	1200	<.004	.051	E.003	<.003	<.024	.018	E.014
11075620	2/3/98	1400	<.004	.045	<.002	<.003	<.024	<.004	E.014
11075620	2/3/98	1700	<.004	.049	E.003	<.003	<.024	.011	E.013
11075620	2/3/98	2000	<.004	.018	<.002	<.003	—	<.004	.020
11075620	2/3/98	2300	—	—	—	—	<.024	—	—
11075620	2/4/98	0200	<.004	.029	.005	<.003	<.024	<.004	.049

Appendix E. Data for pesticides detected in the Santa Ana River below Prado Dam and at the diversion downstream from Imperial Highway, southern California—Continued

USGS station number	Data	Time	Pronamide (µg/L)	Propoxur (µg/L)	Simazine (µg/L)	Tebuthiuron (µg/L)	Triclopyr (µg/L)	Trifluralin (µg/L)
11075620	1/26/97	0400	<0.003	<0.035	0.243	<0.01	<0.05	<0.002
11075620	1/26/97	0930	<.003	<.035	.195	<.01	<.05	<.002
11075620	1/26/97	2130	<.003	<.035	.315	<.01	<.05	<.002
11075620	1/27/97	1230	<.003	<.035	.580	<.01	<.05	<.002
11075620	1/27/97	2130	<.003	<.035	.381	<.01	<.05	<.002
11075620	1/28/97	0930	<.003	<.035	.384	<.01	<.05	<.002
11075620	9/15/97	0010	<.003	<.035	.046	<.01	<.05	<.002
11075620	9/15/97	0310	<.003	<.035	.052	<.01	<.05	<.002
11075620	9/15/97	0610	<.003	<.035	.047	<.01	<.05	<.002
11075620	9/15/97	0910	<.003	<.035	.041	<.01	<.05	<.002
11075620	9/15/97	1115	<.003	<.035	.045	<.01	<.05	<.002
11075620	9/15/97	2350	<.003	<.035	.048	<.01	<.05	<.002
11075620	9/24/97	2030	<.003	—	.039	<.01	—	<.002
11075620	9/24/97	2200	—	<.035	—	—	<.05	—
11075620	9/25/97	0230	<.003	—	.040	<.01	—	<.002
11075620	9/25/97	0400	—	<.035	—	—	<.05	—
11075620	9/25/97	0530	<.003	—	.040	<.01	—	<.002
11075620	9/25/97	0700	—	<.035	—	—	.580	—
11075620	9/25/97	0830	<.003	—	.038	<.01	—	<.002
11075620	9/25/97	1000	—	<.035	—	—	.230	—
11075620	9/25/97	1130	<.003	—	.035	<.01	—	<.002
11075620	9/25/97	1300	—	<.035	—	—	.930	—
11075620	9/25/97	1430	<.003	—	.031	<.01	—	<.002
11075620	9/25/97	1600	—	<.035	—	—	.440	—
11075620	9/25/97	1900	<.003	—	.042	<.01	—	<.002
11075620	9/25/97	2030	—	<.035	—	—	E.25	—
11075620	9/26/97	0100	<.003	—	.042	<.01	—	<.002
11075620	9/26/97	0230	—	<.035	—	—	.460	—
11075620	9/26/97	1200	<.003	—	.078	<.01	—	<.002
11075620	9/26/97	1330	—	<.035	—	—	<.05	—
11075620	2/3/98	0603	<.003	<.035	.104	<.01	<.25	<.002
11075620	2/3/98	0800	<.003	<.035	.096	<.01	<.25	<.002
11075620	2/3/98	1000	.019	<.035	.048	<.01	.190	E.004
11075620	2/3/98	1200	<.003	<.035	.029	<.01	<.25	E.002
11075620	2/3/98	1400	<.003	<.035	.068	<.01	<.25	<.002
11075620	2/3/98	1700	<.003	<.035	.103	<.01	<.25	<.002
11075620	2/3/98	2000	<.003	—	.144	<.01	—	<.002
11075620	2/3/98	2300	—	<.035	—	—	<.25	—
11075620	2/4/98	0200	<.003	<.035	.419	<.01	<.25	E.002

NOTE: When "E" is reported, the compound has passed all criteria used to identify its presence, and only the concentration is estimated (Connor and others, 1998).

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APPENDIX F

Data for Volatile Organic Compounds

Appendix F. Data for volatile organic compounds detected in the Santa Ana River below Prado Dam, at the diversion downstream from Imperial Highway, and in a storm drain tributary to the Santa Ana River near Imperial Highway, southern California

[USGS, U.S. Geological Survey; µg/L, microgram per liter; E, estimated value; <, less than]

Station name	USGS station number	Date	Time	2-Methoxy-2-methylpropane (MTBE) (µg/L)	Bromodichloromethane (µg/L)	Dichloromethane (Methylene chloride) (µg/L)	Methylbenzene (Toluene) (µg/L)	Trichloromethane (Chloroform) (µg/L)
Santa Ana River below Prado Dam	11074000	9/15/97	0640	0.3	0.4	<0.4	<0.4	1.3
		9/15/97	1040	.3	.4	<.4	<.4	1.8
		9/15/97	1250	.4	.4	<.4	<.4	1.8
		11/10/97	0900	.3	.4	<.2	<.2	1.8
		11/10/97	1300	.3	.4	<.2	<.2	1.8
		11/10/97	1700	<.8	.6	1.1	3.9	3.4
		2/3/98	1530	.4	.5	<.2	<.2	1.6
		2/4/98	1405	E.7	<.2	<.2	<.2	.5
Santa Ana River at the diversion downstream from Imperial Highway	11075620	9/15/97	0010	.2	<.2	<.2	<.2	.4
		9/15/97	0610	.2	<.2	<.2	<.2	.3
		9/15/97	0910	.3	<.4	<.4	<.4	.3
		9/15/97	1115	.3	<.2	<.2	<.2	.3
		11/10/97	1000	.4	<.4	.9	<.4	.3
		11/10/97	1230	<.8	<.8	1.3	.6	<.8
		2/3/98	0603	.5	<.4	<.4	<.4	.4
		2/3/98	0800	.3	<.4	<.4	<.4	.5
		2/3/98	1000	.2	<.4	<.4	<.4	<.4
		2/3/98	1200	.2	<.2	<.2	<.2	<.2
		2/3/98	1400	.3	<.2	<.2	<.2	<.2
		2/3/98	1700	.3	<.2	<.2	<.2	<.2
		2/3/98	2000	.4	<.2	<.2	<.2	<.2
		2/3/98	2300	E.6	<.2	<.2	<.2	.2
		2/4/98	0200	.6	<.4	<.4	<.4	<.4
		2/4/98	1218	E.6	<.2	<.2	<.2	<.2
Storm drain near Imperial Highway	335129117472101	2/3/98	0730	E.9	<.4	<.4	<.4	<.4
		2/3/98	0940	.4	<.2	<.2	<.2	<.2
		2/3/98	1150	.3	<.4	<.4	<.4	<.4
		2/3/98	1350	.4	<.4	<.4	<.4	<.4
		2/3/98	1650	.3	<.4	<.4	<.4	<.4