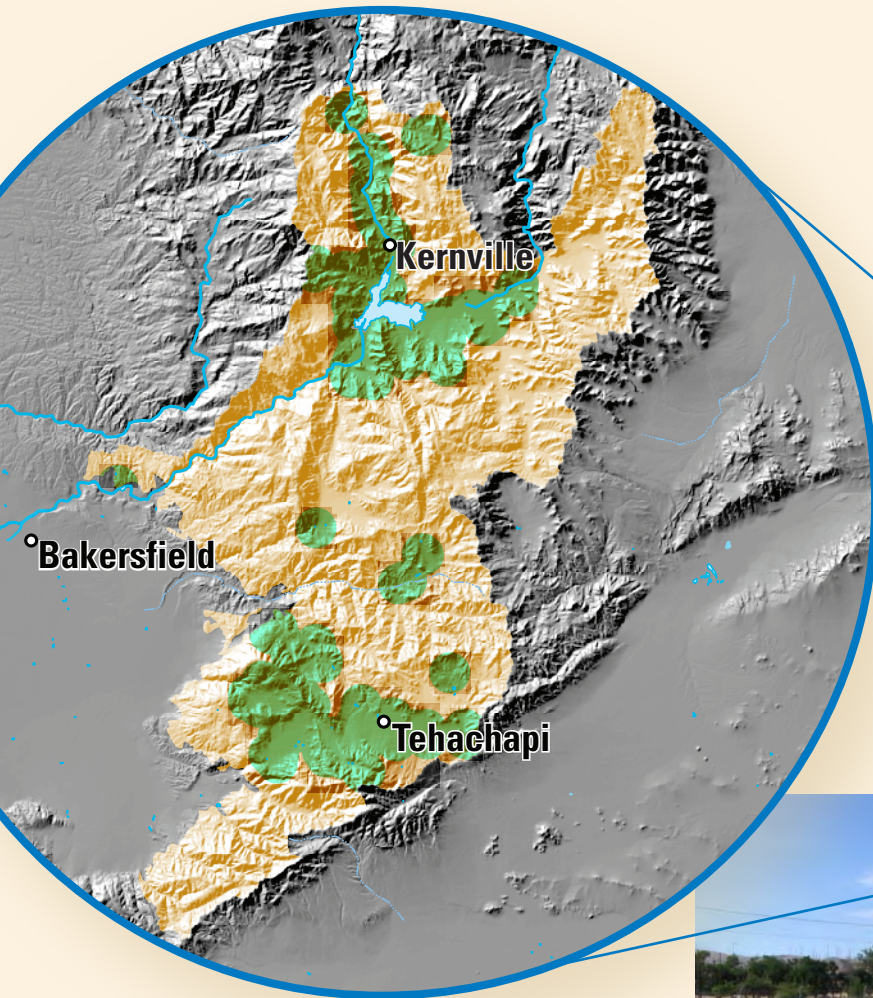


In cooperation with the California State Water Resources Control Board

Ground-Water Quality Data in the Southern Sierra Study Unit, 2006—Results from the California GAMA Program



Data Series 301

Photographs by Justin Kulongoski, U.S. Geological Survey.

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By Miranda S. Fram and Kenneth Belitz

Prepared in cooperation with the California State Water Resources Control Board

Data Series 301

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Abbreviations and Acronyms

AB	Assembly Bill (through the California State Assembly)
AL	action level
CAS	Chemical Abstract Service (American Chemical Society)
CSU	combined standard uncertainty
E	estimated or having a higher degree of uncertainty
GAMA	Groundwater Ambient Monitoring and Assessment program
GPS	Global Positioning System
HAL-US	lifetime health advisory (USEPA)
HPLC	high-performance liquid chromatography
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL-US	maximum contaminant level (USEPA)
MCL-CA	maximum contaminant level (CDHS)
MD	method detection level
MDL	method detection limit
MRL	minimum reporting level
MU	method uncertainty
N	Normal (1-gram-equivalent per liter of solution)
na	not available
nc	sample not collected
NL-CA	notification level (CDHS)
NWIS	National Water Information System (USGS)
PCFF-GAMA	personal computer field forms program designed for GAMA sampling
QC	quality control
RPD	relative percent difference
RSD	relative standard deviation
RSD5	risk-specific dose at 10^{-5} (USEPA)
SMCL	secondary maximum contaminant level (USEPA)
SMCL-CA	secondary maximum contaminant level (CDHS)
SMCL-US	secondary maximum contaminant level (USEPA)
SOSA	Southern Sierra study unit
SOSA FP	Southern Sierra study unit flow path
SSMDC	sample-specific minimum detectable concentration
TT-US	treatment technique (USEPA)
US	United States

Organizations

CDHS	California Department of Health Services
USEPA	U.S. Environmental Protection Agency
LLNL	Lawrence Livermore National Laboratory
MWH	Montgomery Watson-Harza
NAWQA	National Water Quality Assessment (USGS)
NWQL	National Water Quality Laboratory (USGS)
SWRCB	State Water Resources Control Board
TCCWD	Tehachapi-Cummings County Water District
USGS	U.S. Geological Survey

Selected chemical names

CaCO ₃	calcium carbonate
CFC	chlorofluorocarbon
CO ₃ ⁻²	carbonate
DOC	dissolved organic carbon
HCl	hydrochloric acid
HCO ₃ ⁻	bicarbonate
MTBE	methyl <i>tert</i> -butyl ether
NDMA	<i>N</i> -nitrosodimethylamine
PCE	tetrachloroethene
TCP	trichloropropane
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound

Units of Measure

cm ³ STP/g	cubic centimeters of gas at standard temperature and pressure (0 degrees Celsius and 1 atmosphere of pressure) per gram of water
ft	foot (feet)
in	inch
L	liter
mg	milligram
mg/L	milligrams per liter (parts per million)
mi	mile
mL	milliliter
µg/L	micrograms per liter (parts per billion)
µL	microliter
µm	micrometer
pCi/L	picocurie per liter

Notes

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is equivalent to parts per million (ppm) and micrograms per liter is equivalent to parts per billion (ppb).

Ground-Water Quality Data in the Southern Sierra Study Unit, 2006—Results from the California GAMA Program

By Miranda S. Fram and Kenneth Belitz

Abstract

Ground-water quality in the approximately 1,800 square-mile Southern Sierra study unit (SOSA) was investigated in June 2006 as part of the Statewide Basin Assessment Project of the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The GAMA Statewide Basin Assessment Project was developed in response to the Groundwater Quality Monitoring Act of 2001 and is being conducted by the U.S. Geological Survey (USGS) in cooperation with the California State Water Resources Control Board (SWRCB).

The Southern Sierra study was designed to provide a spatially unbiased assessment of raw ground-water quality within SOSA, as well as a statistically consistent basis for comparing water quality throughout California. Samples were collected from fifty wells in Kern and Tulare Counties. Thirty-five of the wells were selected using a randomized grid-based method to provide statistical representation of the study area, and fifteen were selected to evaluate changes in water chemistry along ground-water flow paths.

The ground-water samples were analyzed for a large number of synthetic organic constituents [volatile organic compounds (VOCs), pesticides and pesticide degradates, pharmaceutical compounds, and wastewater-indicator compounds], constituents of special interest [perchlorate, *N*-nitrosodimethylamine (NDMA), and 1,2,3-trichloropropane (1,2,3-TCP)], naturally occurring inorganic constituents [nutrients, major and minor ions, and trace elements], radioactive constituents, and microbial indicators. Naturally occurring isotopes [tritium, and carbon-14, and stable isotopes of hydrogen and oxygen in water], and dissolved noble gases also were measured to help identify the source and age of the sampled ground water.

Quality-control samples (blanks, replicates, and samples for matrix spikes) were collected for approximately one-eighth of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Assessment of the quality-control information resulted in censoring of less than 0.2 percent of the data collected for ground-water samples.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, or blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to treated water that is served to the consumer, not

to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH) and thresholds established for aesthetic concerns (secondary maximum contaminant levels, SMCL-CA) by CDPH.

VOCs and pesticides were detected in less than one-third of the grid wells, and all detections in samples from SOSA wells were below health-based thresholds. All detections of trace elements and nutrients in samples from SOSA wells were below health-based thresholds, with the exception of four detections of arsenic that were above the USEPA maximum contaminant level (MCL-US) and one detection of boron that was above the CDPH notification level (NL-CA). All detections of radioactive constituents were below health-based thresholds, although four samples had activities of radon-222 above the proposed MCL-US. Most of the samples from SOSA wells had concentrations of major elements, total dissolved solids, and trace elements below the non-enforceable thresholds set for aesthetic concerns. A few samples contained iron, manganese, or total dissolved solids at concentrations above the SMCL-CA thresholds.

Introduction

Ground water comprises nearly half of the water used for public supply in California (Hutson and others, 2004). To assess the quality of ground water in aquifers used for drinking-water supply and to establish a program for monitoring trends in ground-water quality, the State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory (LLNL), implemented the Groundwater Ambient Monitoring and Assessment (GAMA) Program (<http://www.waterboards.ca.gov/gama>). The GAMA program consists of three projects: Statewide Basin Assessment, conducted by the USGS (<http://ca.water.usgs.gov/gama/>); Voluntary Domestic Well Assessment, conducted by the SWRCB; and Special Studies, conducted by LLNL.

2 Ground-Water Quality Data in the Southern Sierra Study Unit, 2006—Results from the California GAMA Program

The SWRCB initiated the GAMA Statewide Basin Assessment project in response to the Groundwater Quality Monitoring Act of 2001 (Sections 10780-10782.3 of the California Water Code, Assembly Bill 599). AB 599 is a public mandate to assess and monitor the quality of ground water used as public supply for municipalities in California. The project is a comprehensive assessment of statewide ground-water quality designed to help better understand and identify risks to ground-water resources, and to increase the availability of information about ground-water quality to the public. As part of the AB 599 process, the USGS, in collaboration with the SWRCB, developed the monitoring plan for the project (Belitz and others, 2003; State Water Resources Control Board, 2003). Key aspects of the project are inter-agency collaboration and cooperation with local water agencies and well owners. Local participation in the project is entirely voluntary.

The GAMA Statewide Basin Assessment project is unique because the data collected during the study include analyses for an extensive number of chemical constituents at very low concentrations, analyses that are not normally available. A broader understanding of ground-water composition will be especially useful for providing an early indication of changes in water quality, and for identifying the natural and human factors affecting water quality. Additionally, the GAMA Statewide Basin Assessment project will analyze a broader suite of constituents than required by the California Department of Public Health (CDPH). An understanding of the occurrence and distribution of these constituents is important for the long-term management and protection of ground-water resources.

The range of hydrologic, geologic, and climatic conditions that exist in California must be considered in an assessment of ground-water quality. Belitz and others (2003) partitioned the state into ten hydrogeologic provinces, each with distinctive hydrologic, geologic, and climatic characteristics (fig. 1), and representative regions in all ten provinces were included in the project design. Eighty percent of California's approximately 16,000 public-supply wells are located in ground-water basins within these hydrologic provinces. These ground-water basins, defined by the California Department of Water Resources, generally consist of relatively permeable, unconsolidated deposits of alluvial or volcanic origin (California Department of Water Resources, 2003). Ground-water basins were prioritized for sampling based upon the number of public-supply wells in the basin, with secondary consideration given to municipal ground-water use, agricultural pumping, the number of leaking underground fuel tanks, and pesticide applications within the basins (Belitz and others, 2003). In addition, some ground-water basins or groups of adjacent similar basins with relatively few public-supply wells were assigned high priority so that all hydrogeologic provinces would be represented in the subset of basins sampled. The

116 priority basins were grouped into 35 study units. Some areas not in the defined ground-water basins were included in several of the study units to achieve representation of the 20 percent of public-supply wells not located in the ground-water basins.

Three types of water-quality assessments are being conducted with the data collected in each study unit: (1) Status: assessment of the current quality of the ground-water resource, (2) Trends: detection of changes in ground-water quality, and (3) Understanding: identification of the natural and human factors affecting ground-water quality (Kulongoski and Belitz, 2004). This report is one of a series of reports presenting assessments of current water-quality conditions in each study unit (Wright and others, 2005; Kulongoski and others, 2006; Bennett and others, 2006; Dawson and others, 2007; Kulongoski and Belitz, 2007). Subsequent interpretive reports will address the trends and understanding aspects of the water-quality assessments.

The Southern Sierra GAMA study unit, hereafter referred to as SOSA, contains six small ground-water basins and also encompasses areas outside of the defined ground-water basins. SOSA was considered high priority for sampling to provide adequate representation of the Sierra Nevada hydrogeologic province (Belitz and others, 2003).

Purpose and Scope

The purposes of this report are: (1) to describe the hydrogeologic setting of SOSA, (2) to detail the sampling and analytical methods, and quality assurance used during the study, (3) to present the results of quality-control tests, and (4) to present the analytical results for ground-water samples collected in SOSA. Ground-water samples were analyzed for organic, inorganic, and microbial constituents, field parameters, and chemical tracers. The chemical and microbial data presented in this report were evaluated by comparison to state and federal drinking water regulatory and other health-based standards that are applied to treated drinking water. Regulatory thresholds considered for this report are those established by the United States Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH). The data presented in this report are intended to characterize the quality of untreated ground-water resources within the study unit, not the treated drinking water delivered to consumers by water purveyors. Discussions of the factors that influence the distribution and occurrence of the constituents detected in ground-water samples will be the subject of subsequent publications.



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006, Albers Equal Area Conic Projection

Provinces from Belitz and others, 2003

Figure 1. The hydrogeologic provinces of California and the location of the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study unit (black area). Modified from Belitz and others (2003).

Acknowledgments

The authors thank the following cooperators for their support: the State Water Resources Control Board (SWRCB), California Department of Public Health, California Department of Water Resources, and Lawrence Livermore National Laboratory. We especially thank the well owners and water purveyors for their generosity in allowing the USGS to collect samples from their wells. Two reviewers, Jan Stepek (SWRCB) and Justin Kulongoski (USGS), provided comments to improve this work. Funding for this work was provided by State bonds authorized by Proposition 50 and administered by the SWRCB.

Hydrogeologic Setting

The Southern Sierra study unit (SOSA) covers approximately 1,800 square miles in Kern and Tulare Counties, California, at the southern end of the Sierra Nevada hydrogeologic province (fig. 1). The study unit area is defined by the watersheds of Tejon Creek, Tehachapi Creek, the middle and upper Kern River, and the East Tehachapi closed drainage basin. SOSA includes 6 small ground-water basins, as defined by the California Department of Water Resources (fig. 2) (California Department of Water Resources, 2003). The wells sampled in the southern part of SOSA are in or nearby the Cummings Valley, Brite Valley, Tehachapi Valley West, and Tehachapi Valley East ground-water basins. The wells sampled in the northern part of SOSA are in or near the Kern River Valley ground-water basin.

SOSA has approximately 8,000 ft of topographic relief. The Cummings and Tehachapi basins are relatively flat with an altitude of approximately 4,000 ft. The Tehachapi Mountains rise to 7,700 ft south of the Cummings basin, and to over 8,000 ft south of the Tehachapi basin. Water level in Lake Isabella is 2,600 ft, and the peaks of the Sierra Nevada rise up to 10,000 ft as near as 40 mi north of the lake. The climate in SOSA is characterized by hot, dry summers and cold, wet winters, although the temperatures and precipitation are strongly controlled by elevation. Precipitation at Lake Isabella Dam (2,635 ft) and in the city of Tehachapi (4,017 ft) averages 11 inches per year, with 80 to 90 percent falling between November and April (California Department of Water Resources, 2007). Winter precipitation falls mostly as snow at elevations above 5,000 ft.

The Cummings, Brite, Tehachapi West, and Tehachapi East basins are all bounded by the Tehachapi Mountains to the south and the Sierra Nevada to the north, and are separated by north to northwest trending low bedrock ridges or alluvial divides (California Department of Water Resources, 2006a, b, c, d). The primary water-bearing units are Pleistocene to Recent alluvial fans around the margins of the basins deposited by creeks draining the Tehachapi Mountains and Sierra

Nevada, and floodplain deposits in the centers of the basins (Dibblee and Warne, 1970; Dibblee and Louke, 1970; Michael and McCann, 1962). The sediments are arkosic cobbles, gravels, sands, silts, and clays, with the coarser materials in the alluvial fans and the finer sediments in the floodplains. In the Tehachapi East basin, water is also found in Miocene to Pliocene sedimentary and volcanic units.

Cummings, Brite, Tehachapi West, and Tehachapi East are all adjudicated basins and are managed collectively by the Tehachapi-Cummings County Water District (TCCWD). Beginning in 1973, TCCWD has imported water from the State Water Project via a pipeline just upstream of the A.D. Edmiston pumping plant (Tehachapi-Cummings County Water District, 2004a,b). The system for distributing this water to the TCCWD area has expanded over the years so that Cummings, Brite, Tehachapi, and Bear Valleys are all now supplied with imported water.

The 124-square-mile Kern River basin has an irregular shape that follows the dendritic drainage pattern of the Kern River and its tributary creeks. The western arm of the basin lies in the trace of the Kern Canyon fault. The primary water-bearing units are the Pleistocene to Recent fluvial deposits in the channel of the Kern River and around Lake Isabella (California Department of Water Resources, 2006e).

Examination of driller's logs for wells in areas of SOSA outside of the alluvial basins showed that the wells were completed in fractured hard-rock. The Mesozoic granitic rocks and Paleozoic to Mesozoic metamorphic rocks of the Sierra Nevada range are apparently locally water-bearing. Little is known about these aquifers.

Methods

Methods used for the GAMA program were selected to achieve the following objectives: (1) Design a sampling plan suitable for statistical analysis; (2) collect samples in a consistent manner; (3) analyze samples using proven and reliable laboratory methods; (4) assure the quality of the ground-water data; and, (5) maintain data securely and with relevant documentation.

Study Design

The wells selected for sampling in this study reflect the combination of two well selection strategies. Thirty-five wells were selected to provide a statistically unbiased, spatially distributed assessment of the quality of ground-water resources used for public drinking-water supply, and fifteen additional wells were selected to provide greater sampling density in several areas to address specific ground-water quality issues in the study unit.

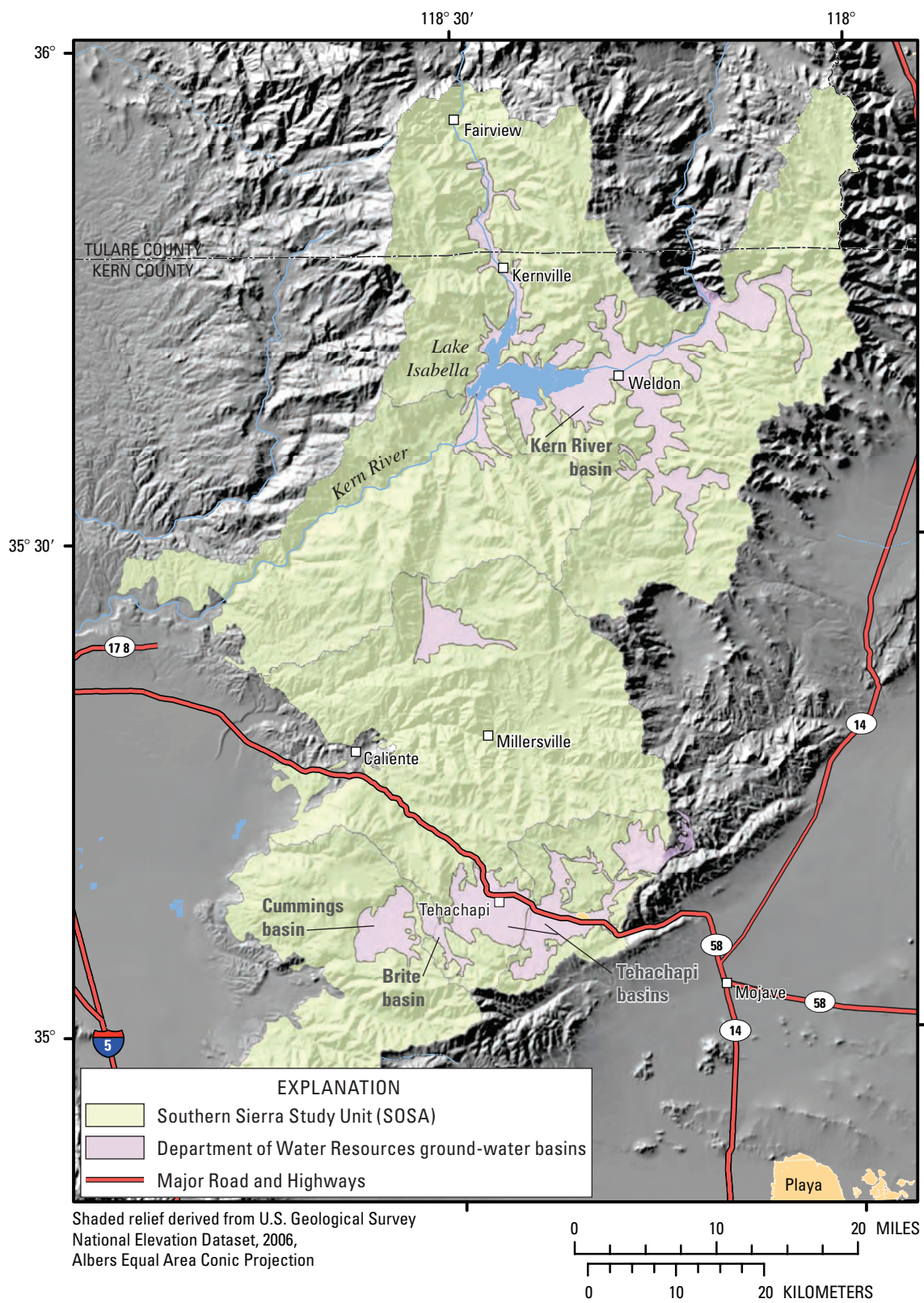


Figure 2. The Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the California Department of Water Resources ground-water basins within the study unit and major hydrologic features.

The spatially distributed wells were selected using a randomized grid-based method (Scott, 1990). SOSA had relatively few public-supply wells, and these wells were not evenly distributed. To minimize the number of cells without any wells, only the portion of SOSA in close proximity to a public-supply well was included in the gridded area. Locations of wells listed in statewide databases maintained by the CDPH and USGS were plotted and 1.86-mi (3-kilometer) radius circles were drawn around each well. The area encompassed by the circles was then divided into forty 10-mi² grid cells (fig. 3). The objective was to select one public-supply well per grid cell. Thirty-five of the forty grid cells were sampled in SOSA; the other five grid cells did not contain accessible wells. If a grid cell contained more than one public-supply well, each well was randomly assigned a rank. The lowest ranking well that met basic sampling criteria (for example, sampling point located prior to treatment, capability to pump for several hours, and available well-construction information), and for which permission to sample could be obtained, was then sampled. If a grid cell contained no accessible public-supply wells, domestic and irrigation wells were considered for sampling. An attempt was made to select domestic and irrigation wells with depths and screened intervals similar to those in public-supply wells in the area. In this fashion, a well was selected in each cell to provide a spatially distributed, randomized monitoring network for each study area. Wells sampled as part of the randomized grid-cell network are hereafter referred to as “grid wells.” Grid wells in SOSA were numbered in the order of sample collection with the prefix “SOSA.”

Additional wells were sampled along the axis of the Tehachapi basin (SOSAFP-05, -04, -15, -03, -01, -06, -14, -13), in the central portion of the Cummings basin (SOSAFP-07, -08, -09, -10, -11, -12), and along the Kern River (SOSAFP-02 (fig. 4)). These wells were sampled to assess movement of water and dissolved constituents along ground-water flow paths in these areas in combination with selected wells that were sampled on the grid. Wells sampled as part of these studies for better understanding were not included in the statistical characterization of water quality in SOSA. These additional wells were numbered in the order of sample collection with the prefix “SOSAFP” (“FP” indicating “flow path”).

Table 1 (all tables shown in back of report) provides the GAMA alphanumeric identification number for each well, along with the date sampled, sampling schedule, well elevation, and well-construction information. Ground-water samples were collected from 40 public-supply wells, 5 irrigation wells, and 5 domestic wells during June 2006.

Well locations and identifications were verified using GPS, 1:24,000 scale USGS topographic maps, comparison with existing well information in USGS and CDPH databases, and information provided by well owners. Driller’s logs for wells were obtained when available. Well information was recorded by hand on field sheets and electronically

using specialized software on field laptop computers. All information was verified and then uploaded into the USGS National Water Information System (NWIS). In order to maintain confidentiality of well owners and well locations, the standard USGS protocol for identifying sites in NWIS with a site-id containing latitude and longitude was modified for new sites established in this study, and all data are currently inaccessible from NWIS’s public website.

The wells in SOSA were sampled using a tiered analytical approach. All wells were sampled for a standard set of constituents, including VOCs, pesticides and pesticide degradates, pharmaceutical compounds, perchlorate, hexavalent chromium, stable isotopes of water, and dissolved noble gases and tritium/helium age dates. The standard set of constituents was termed the “fast” schedule (table 2). Wells on the “intermediate” schedule were sampled for all the constituents on the fast schedule, plus NDMA, 1,2,3-TCP, nutrients and dissolved organic carbon, major and minor ions and trace elements, and tritium. Wells on the “slow” schedule were sampled for all the constituents on the intermediate schedule, plus radioactive and microbial constituents (table 2). Fast, intermediate, and slow refer to the time required to sample the well for all the analytes on the schedule. Generally, one slow or two intermediate or four fast wells could be sampled in one day. In SOSA, twenty-eight of the ground-water wells were sampled on the fast schedule, fifteen were sampled on the intermediate schedule, and seven on the slow schedule.

Sample Collection and Analysis

Samples were collected in accordance with the protocols established by the USGS National Water Quality Assessment (NAWQA) program (Koterba and others, 1995) and the USGS National Field Manual (U.S. Geological Survey, variously dated). These sampling protocols ensure that a representative sample of ground water is collected at each site and that the samples are collected and handled in a way that minimizes the potential for contamination of samples. The methods used for sample collection are described in the Appendix.

Tables 3A–L list the compounds analyzed in each constituent class. Ground-water samples were analyzed for eighty-five VOCs (table 3A), eight gasoline oxygenates and degradates (table 3B), sixty-three pesticides and pesticide degradates (table 3C), fourteen pharmaceutical compounds (table 3D), sixty-two wastewater-indicator compounds (table 3E), three constituents of special interest (table 3F), five nutrients and dissolved organic carbon (table 3G), ten major and minor ions and total dissolved solids (table 3H), twenty-five trace elements (table 3H), arsenic, iron, and chromium species (table 3I), stable isotopes of water, eight radioactive constituents, including tritium and carbon-14 (table 3J), five dissolved noble gases, and helium stable isotope ratios (table 3K), and four microbial constituents (table 3L). The methods used for sample analysis are described in the Appendix.

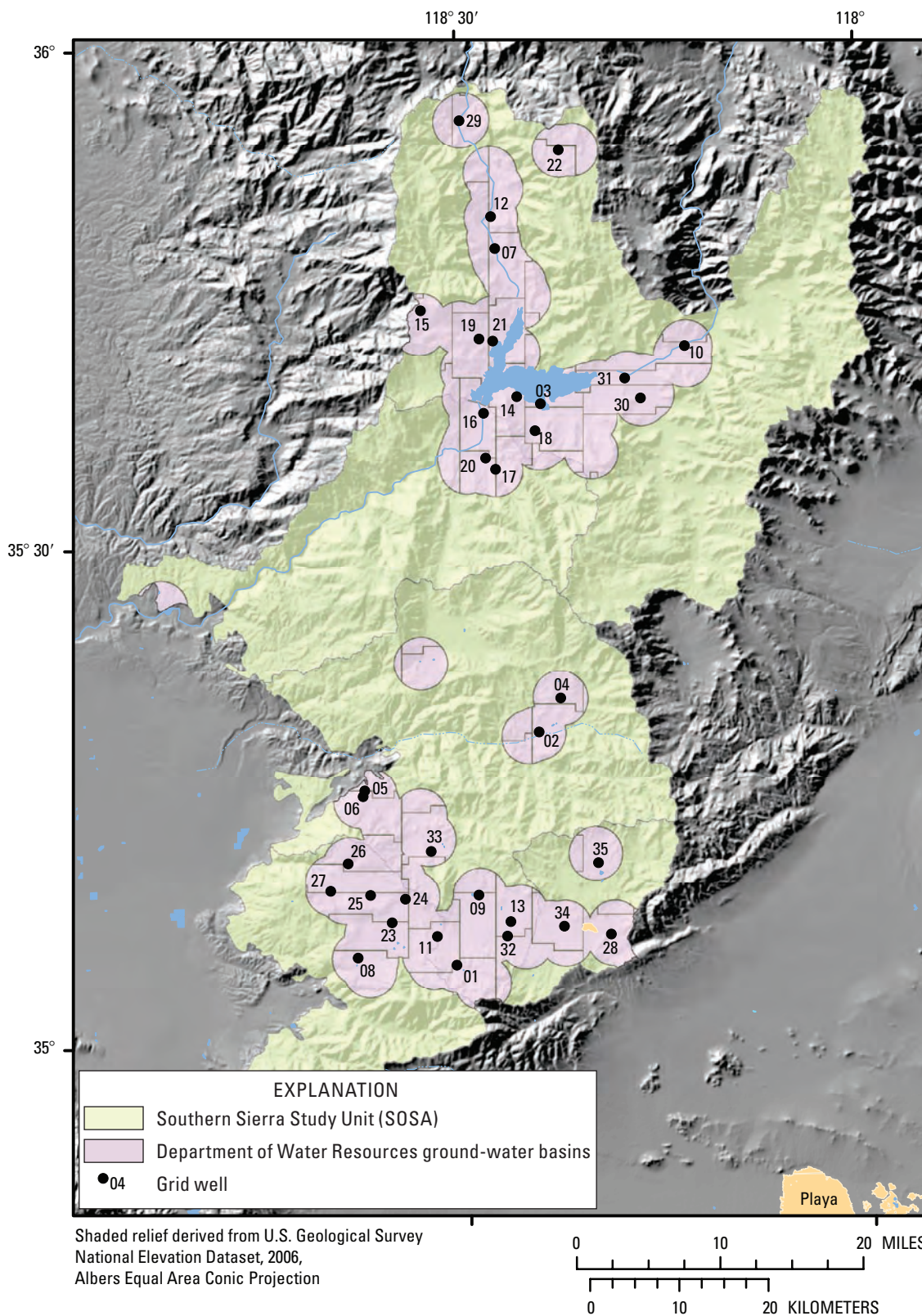


Figure 3. The Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the 1.86-mile buffer zones around all public-supply wells, the distribution of study area grid cells, and the location of sampled grid wells. Alphanumeric identification numbers for grid wells have the prefix “SOSA”; only the numeric portions are shown on the map.

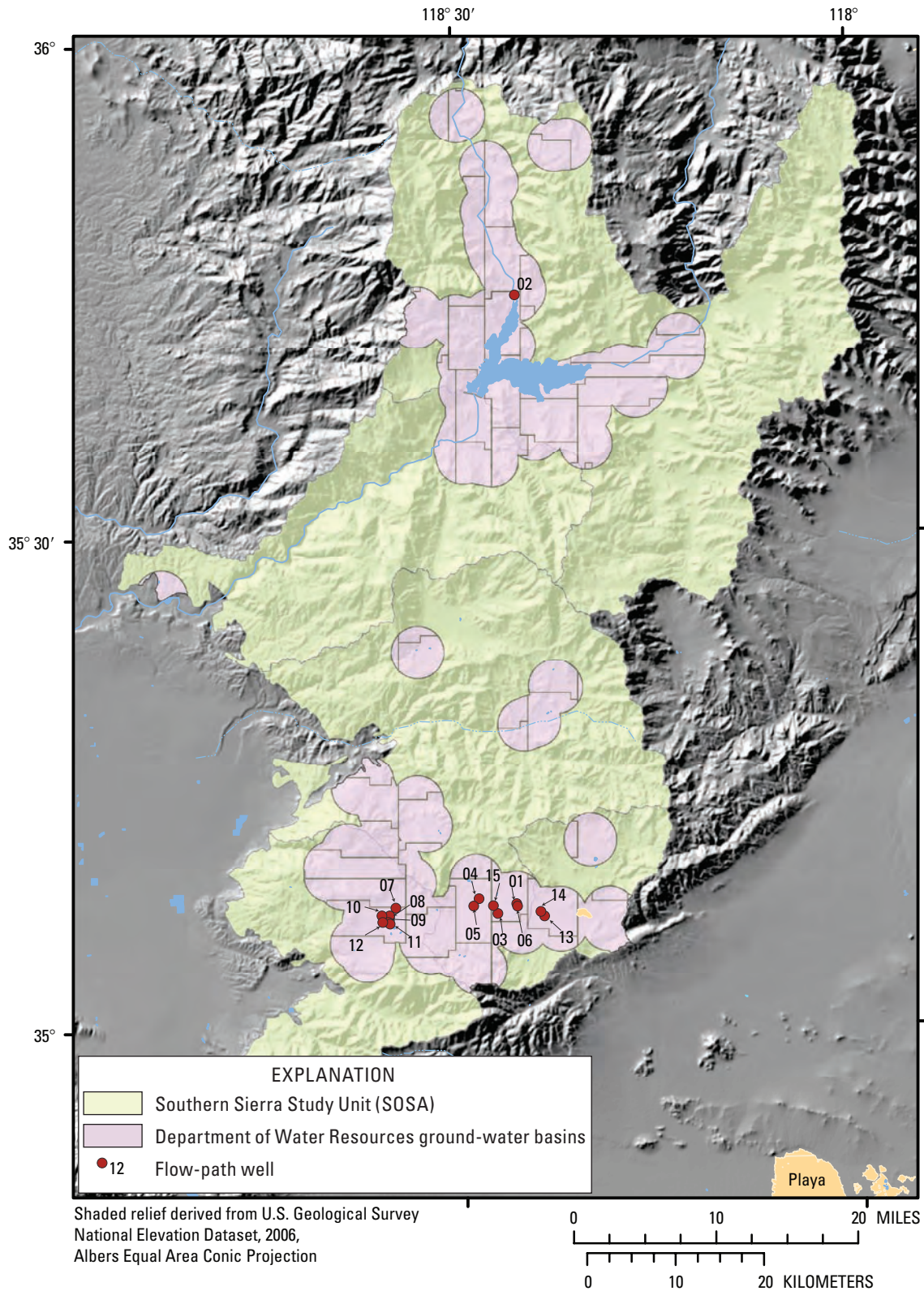


Figure 4. The Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the 1.86-mile buffer zones around all public-supply wells, the distribution of study area grid cells, and the location of sampled flow-path wells. Alphanumeric identification numbers for flow-path wells have the prefix "SOSFP"; only the numeric portions are shown on the map.

Data Reporting

The methods and conventions used for reporting the data are described in the Appendix. Nineteen constituents analyzed in this study were measured by more than one method at the USGS National Water Quality Laboratory (NWQL), but only the results from the preferred method are reported. Arsenic, iron, and chromium concentrations, and tritium activities were measured by more than one laboratory, and both sets of results are reported.

Quality Assurance

The quality-assurance plan used for this study follows the protocols described in the NWQL quality-assurance plan (Maloney, 2005; Pirkey and Glodt, 1998) and the protocols used by the USGS NAWQA program (Koterba and others, 1995). Quality-control (QC) samples collected in the SOSA study include source-solution blanks, field blanks, replicates, and matrix and surrogate spikes. QC samples were collected to evaluate contamination, and bias and variability of the water chemistry data that may have resulted from sample collection, processing, storage, transportation, and laboratory analysis. The quality-assurance plan is described in the [Appendix](#).

Ground-Water Quality Results

Results from analyses of raw (untreated) ground-water samples from SOSA are presented in tables 4 through 15. Ground-water samples collected in SOSA were analyzed for up to 300 constituents, and 210 of those constituents were not detected in any of the samples (tables 3A–L). The results tables present only the constituents that were detected, and list only samples that had at least one constituent detected. For constituent classes that were analyzed at all of the grid wells, the tables include the number of wells at which each analyte was detected, the frequency at which it was detected (in relation to the number of grid wells), and the total number of constituents detected at each well. Results from the flow-path wells are presented in the tables, but these results were excluded from the detection frequency calculations to avoid statistically over-representing the areas in the vicinity of the flow-paths.

Table 4 includes water-quality indicators measured in the field and at the NWQL, while tables 5 through 15 present the results of ground-water analyses organized by compound classes:

- Organic constituents
 - VOCs and gasoline oxygenates and degradates ([table 5](#))
 - Pesticides and pesticide degradates ([table 6](#))
 - Pharmaceutical compounds ([table 7](#))

- Constituents of special interest ([table 8](#))
- Inorganic constituents
 - Nutrients and dissolved organic carbon ([table 9](#))
 - Major and minor ions and dissolved solids ([table 10](#))
 - Trace elements ([table 11](#))
 - Arsenic, iron, and chromium speciation ([table 12](#))
- Inorganic tracer constituents ([table 13](#))
- Radioactive constituents ([table 14](#))
- Microbial indicators ([table 15](#))

The wastewater-indicator compounds have no summary table because the only compound detected, tetrachloroethene (PCE), also was analyzed on the volatile organic compound analytical schedule ([table 3A](#)) that is the preferred method for this compound (see [Appendix](#)). PCE results appear on [table 5](#).

Quality-Control Sample Results

Results of quality-control analyses (blanks, replicates, matrix spikes, and surrogates) were used to evaluate the quality of the data for the ground-water samples. Assessment of the blanks resulted in censoring of less than 0.2 percent of the data for the ground-water samples. Matrix-spike recoveries for a number of organic constituents were lower than the lower end of the acceptable limits, which may indicate that these constituents might not have been detected in some samples if they were present at very low concentrations. The quality-control results are described in the [Appendix](#).

Comparison Thresholds

Detected concentrations in ground-water samples were compared with CDPH and USEPA drinking-water health-based thresholds (California Department of Public Health, 2007a; U.S. Environmental Protection Agency, 2006). The chemical and microbial data presented in this report are meant to characterize the quality of the untreated ground-water resources within SOSA, and are not intended to represent the treated drinking water delivered to consumers by water purveyors. The chemical and microbial composition of treated drinking water may differ from untreated ground water because treated drinking water may be subjected to disinfection, filtration, mixing with other waters, and exposure to the atmosphere prior to its delivery to consumers.

The following thresholds were used for comparisons:

- **MCL – Maximum Contaminant Level.** Legally enforceable standards that apply to public water systems and are designed to protect public health by limiting the levels of contaminants in drinking water. MCLs established by the USEPA are the minimum standards with which states are required to comply, and individual states may choose to set more stringent standards. CDPH has established MCLs for additional constituents not regulated by the USEPA, as well as lowered the threshold concentration for a number of constituents with MCLs established by the USEPA. In this report, a threshold set by the USEPA and adopted by CDPH is labeled “MCL-US”, and one set by CDPH that is more stringent than the MCL-US is labeled “MCL-CA”. CDPH is notified when constituents are detected at concentrations exceeding MCL-US or MCL-CA thresholds in samples collected for the GAMA Statewide Basin Assessment project.
- **AL – Action Level.** Legally enforceable standards that apply to public water systems and are designed to protect public health by limiting the levels of copper and lead in drinking water. Detections of copper or lead above thresholds trigger requirements for mandatory water treatment to reduce the corrosiveness of water to water pipes. The action levels established by the USEPA and CDPH are the same, thus the thresholds are labeled “AL-US” in this report.
- **TT – Treatment Technique.** Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of microbial constituents in drinking water. Detections of microbial constituents above thresholds trigger requirements for mandatory additional disinfection during water treatment. The action levels established by the USEPA and CDPH are the same, thus the thresholds are labeled “TT-US” in this report.
- **SMCL – Secondary Maximum Contaminant Level.** Non-enforceable standards applied to constituents that affect the aesthetic qualities of drinking water, such as taste, odor, and color, or technical qualities of drinking water, such as scaling and staining. Both the USEPA and CDPH define SMCLs, but unlike MCLs, SMCLs established by CDPH are not required to be at least as stringent as those established by USEPA. SMCLs established by CDPH are used in this report (SMCL-CA) for all constituents that have SMCL-CA values. The SMCL-US is used for pH because no SMCL-CA has been defined.

- **NL – Notification Level.** Health-based notification levels established by CDPH for some of the constituents in drinking water that lack MCLs (NL-CA). If a constituent is detected above its NL-CA, State law requires timely notification of local governing bodies and recommends consumer notification.
- **HAL – Lifetime Health Advisory Level.** The maximum concentration of a constituent at which its presence in drinking water is not expected to cause any adverse carcinogenic effects for a lifetime of exposure. HALs are established by the USEPA (HAL-US) and are calculated assuming consumption of 2 liters (2.1 quarts) of water per day over a 70-year lifetime by a 70-kilogram (154-pound) adult and that 20 percent of a person’s exposure comes from drinking water.
- **RSD5 – Risk-Specific Dose.** The concentration of a constituent in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 100,000. RSD5 is an acronym for risk-specific dose at 10^{-5} . RSD5s are calculated by dividing the 10^{-4} Cancer risk concentrations established by the USEPA by 10 (RSD5-US).

For constituents with MCLs, detections in ground-water samples were compared to the MCL-US or MCL-CA. Constituents with SMCLs were compared with the SMCL-CA. For chloride, sulfate, specific conductance, and total dissolved solids, CDPH defines a “recommended” and an “upper” SMCL-CA; detections of these constituents in ground-water samples were compared with both levels. The SMCL-US for these constituents corresponds to the recommended SMCL-CA. Detected concentrations of constituents that lack an MCL or SMCL were compared to the NL-CA. For constituents that lack an MCL, SMCL, or NL-CA, detected concentrations were compared with the HAL-US. For constituents that lack an MCL, SMCL, NL-CA, or HAL-CA, detected concentrations were compared with the RSD5-US. Note that this hierarchy of selection of comparison thresholds means that for constituents that have multiple types of established thresholds, the threshold used for comparison purposes may not be the one with the lowest concentration. The comparison thresholds used in this report are listed in [tables 3A–L](#) for all constituents and in [tables 4–15](#) for constituents detected in ground-water samples from SOSA. Not all constituents analyzed for this study have established thresholds available. Detections of constituents at concentrations greater than the selected comparison threshold are marked with asterisks in [tables 4–15](#).

Water-Quality Data

Field Parameters

Field and laboratory measurements of dissolved oxygen, pH, specific conductance, alkalinity, and associated parameters (turbidity and water temperature) are presented in [table 4](#). Dissolved oxygen and alkalinity are used as indicators of natural processes that control water chemistry. Specific conductance is the unit electrical conductivity of the water, and is proportional to amount of total dissolved solids (TDS) in the water. The pH value indicates the acidity or basicity of the water. Two wells had specific conductance values above the recommended SMCL-CA, although only one well was also above the upper threshold and this well was not a public-supply well. Three wells had pH values outside of the SMCL-US range for pH. Laboratory pH values may be higher than field pH values because the pH of ground water often increases upon exposure to the atmosphere (see [Appendix](#)).

Organic Constituents

Volatile organic compounds (VOCs) are present in paints, solvents, fuels, fuel additives, refrigerants, fumigants, and disinfected water, and are characterized by their tendency to evaporate. VOCs generally persist longer in ground water than in surface water because ground water is isolated from the atmosphere. All detections of VOCs in samples from SOSA were below health-based thresholds, and most were less than one one-hundredth of the threshold values ([table 5](#)). Approximately 30 percent of the grid wells sampled had at least one detection of a VOC. The only VOCs detected in more than 10 percent of the grid wells were chloroform, a byproduct of drinking-water disinfection, and tetrachloroethene (PCE), a solvent used for dry-cleaning.

Pesticides include herbicides, insecticides, and fungicides, and are used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. All detections of pesticides in samples from SOSA were below health-based thresholds, and all were less than one one-hundredth of the threshold values ([table 6](#)). Approximately 25 percent of the grid wells sampled had at least one detection of a pesticide. The only pesticides detected in more than 10 percent of the wells were the herbicides atrazine and simazine, and deethylatrazine, a degradate of atrazine. These three compounds are among the most commonly detected pesticide compounds in ground water nationally (Gilliom and others, 2006).

Two pharmaceutical compounds were detected in samples from three wells in SOSA at very low concentrations ([table 7](#)). The concentrations were less than one hundred-millionth of the concentration of a typical daily dose dissolved in one cup of water.

Constituents of Special Interest

Perchlorate, NDMA, and 1,2,3-TCP are constituents of special interest in California because they recently have been found to be widely distributed in water supplies (California Department of Public Health, 2007b). Perchlorate was detected in approximately 10 percent of the grid wells, and all concentrations measured in SOSA wells were less than one-third of the NL-CA ([table 8](#)). Only one sample contained 1,2,3-TCP, but the concentration was greater than the NL-CA. NDMA was not detected in any samples.

Inorganic Constituents

Unlike the organic constituents and the constituents of special interest, most of the inorganic constituents are naturally present in ground water, although their concentrations may be influenced by human activities.

The nutrients, nitrogen and phosphorus, and the dissolved organic carbon present in ground water can affect biological activity in aquifers and in surface-water bodies that receive ground-water discharge. Nitrogen may be present in the form of ammonia, nitrite, or nitrate depending on the oxidation-reduction state of the ground water. High concentrations of nitrate can adversely affect human health, particularly the health of infants. All concentrations of nitrate, nitrite, and ammonia measured in samples from SOSA wells were below health-based thresholds ([table 9](#)). Concentrations of phosphorus and dissolved organic carbon were also low.

The major-ion composition, total dissolved solids (TDS) content, and levels of certain trace elements in ground water affect the aesthetic properties of water, such as taste, color, and odor, and the technical properties, such as scaling and staining. Although there are no adverse health effects associated with these properties, they may reduce consumer satisfaction with the water or may have economic impacts. CDPH has established non-enforceable thresholds (SMCL-CAs) that are based on aesthetic or technical properties rather than health-based concerns for the major ions chloride and sulfate, TDS, and several trace elements.

The concentrations of chloride and sulfate measured in samples from SOSA wells were all below the recommended SMCL-CAs ([table 10](#)). Two samples contained TDS above the recommended SMCL-CA, but only one was also above the upper SMCL-CA and this well was not a public-supply well.

Eighteen of the twenty-five trace elements analyzed in this study have health-based thresholds. Detections of all trace elements in samples from SOSA wells were below health-based thresholds, with the exception of arsenic and boron ([table 11](#)). Samples from four wells had arsenic concentrations above the MCL-US. One of these samples also had a boron concentration above the NL-CA, although the sample was not from a public-supply well.

Iron and manganese are trace elements whose concentrations are affected by the oxidation-reduction state of the ground water. Precipitation of minerals containing iron or manganese may cause orange, brown, or black staining of surfaces. Iron was detected in less than half of the samples, but two wells had concentrations above the SMCL-CA (table 11). Concentrations of manganese in SOSA wells were typically very low, but three wells had concentrations above the SMCL-CA.

Arsenic, iron, and chromium occur in different species depending on the oxidation-reduction state of the ground water. The oxidized and reduced species have different solubilities in ground water and may have different effects on human health. The relative proportions of the oxidized and reduced species of each element also are used to aid in interpretation of the oxidation-reduction state of the aquifer. Concentrations of total arsenic, iron, and chromium, and the concentrations of either the reduced or the oxidized species of each element are reported in table 12. The concentration of the other species can be calculated by difference. The concentrations of arsenic, iron, and chromium reported in table 12 may be different than those reported in table 11 because different analytical methods were used (see Appendix). The concentrations reported in table 11 are considered to be more accurate.

Inorganic Tracer Constituents

Stable isotope ratios, tritium and carbon-14 activities, and noble gas concentrations can be used as tracers of natural processes affecting ground-water composition. Hydrogen and oxygen stable isotope ratios of water (table 13) can aid in interpretation of ground-water recharge sources. The stable isotope ratios of water depend on the altitude, latitude, and temperature of precipitation and on the extent of evaporation of surface water or soil water. Noble gas concentrations can be used to aid in interpretation of ground-water recharge sources because the concentrations of the different noble gases depend on water temperature. Noble gas analyses were not completed in time for inclusion in this report; they will be presented in a subsequent report.

Tritium and carbon-14 activities (table 13), and helium isotope ratios can provide information about the age of the ground water. Tritium is a radioactive isotope of hydrogen that is incorporated into the water molecule. Low levels of tritium are continuously produced by cosmic ray bombardment of water in the atmosphere, and a large amount of tritium was produced by atmospheric testing of nuclear weapons between 1952 and 1963. Thus, concentrations of tritium above background generally indicate the presence of water recharged since the early 1950s. Helium isotope ratios can be used in conjunction with tritium concentrations to estimate ages for young ground water. Helium isotope analyses were not completed in time for inclusion in this report; they will be presented in a subsequent report.

Carbon-14 (table 13) is a radioactive isotope of carbon that is incorporated into dissolved carbonate species in water. Low levels of carbon-14 are continuously produced by cosmic ray bombardment of nitrogen in the atmosphere. Because carbon-14 decays with a half-life of approximately 5,700 years, low activities of carbon-14 relative to modern values generally indicate presence of ground water that is at least several thousand years old, or has interacted with carbonate-rich sediments in the aquifer.

Of the inorganic tracer constituents analyzed for this study, the only one with a health-based threshold is tritium. All measured tritium activities in samples from SOSA wells were less than one one-thousandth of the MCL-CA (table 13).

Radioactive Constituents

Radioactivity is the release of energy or energetic particles during changes in the structure of the nucleus of an atom. Most of the radioactivity in ground water comes from decay of naturally-occurring isotopes of uranium and thorium that are present in minerals in the sediments or fractured rocks of the aquifer. Both uranium and thorium decay in a series of steps, eventually forming stable isotopes of lead. Radium-226, radium-228, and radon-222 are radioactive isotopes formed during the uranium or thorium decay series. In each step in the decay series, one radioactive element turns into a different radioactive element by emitting an alpha or a beta particle from its nucleus. For example, radium-226 emits an alpha particle and therefore turns into radon-222. Radium-228 decays to form actinium-228 by emission of a beta particle. The alpha and beta particles emitted during radioactive decay are hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA may increase the risk of getting cancer.

Activity is often used instead of concentration for reporting the presence of radioactive constituents. Activity of radioactive constituents in ground water is measured in units of picocuries per liter (pCi/L), and one picocurie is approximately equal to two atoms decaying per minute. The number of atoms decaying is equal to the number of alpha or beta particles emitted.

The seven SOSA samples analyzed for radioactive constituents had activities of radium and of gross alpha and beta emitters less than established health-based standards (table 14). Activities of radon-222 in samples from four wells were above the proposed MCL-US of 300 pCi/L, although only one sample had an activity that was also above the proposed alternative MCL-US of 4,000 pCi/L. The alternative MCL-US will apply if the State or local water agency has an approved multimedia mitigation program to address radon

levels in indoor air (U.S. Environmental Protection Agency, 1999a).

Microbial Indicators

Water is disinfected during drinking-water treatment to prevent diseases that may be spread by water-borne microbial constituents derived from human or animal wastes. The specific viruses and bacteria responsible for diseases generally are not measured because routine analytical methods are not available. Measurements are made of more easily analyzed microbial constituents that serve as indicators of the presence of human or animal waste in water. Drinking-water purveyors respond to detections of microbial indicators by applying additional disinfection to the water.

Samples from seven SOSA wells were analyzed for microbial indicators. No samples contained the viral indicators F-specific and somatic coliphage and none contained the bacterial indicator *Escherichia coli* (*E. coli*), but there were three detections of low levels of the bacterial indicator total coliforms (table 15). The threshold for total coliforms is based on recurring detections; thus, the detections reported here do not necessarily constitute an exceedance of the MCL-US.

Future Work

Future work will interpret the data presented in this report using a variety of statistical, qualitative, and quantitative approaches to assess the natural and human factors affecting ground-water quality. Water-quality data contained in the CDPH and USGS NWIS databases, and water-quality data available from other State and local water agencies will be compiled, evaluated, and used to complement the data presented in this report.

Summary

Ground-water quality in the approximately 1,800-square-mile Southern Sierra study unit (SOSA) was investigated in June 2006 as part of the Statewide Basin Assessment Project of Groundwater Ambient Monitoring and Assessment (GAMA) Program. The California State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and the Lawrence Livermore National Laboratory, is implementing the GAMA Program (<http://www.waterboards.ca.gov/gama/>). The Statewide Basin Assessment Project was designed by the SWRCB and the USGS in response to the Groundwater Quality Monitoring Act of 2001 (Belitz and others, 2003; State Water Resources Control Board, 2003). The project is a comprehensive assessment of statewide ground-water quality designed to identify and characterize risks to ground-water resources, and to increase the availability of information about ground-water quality to

the public. SOSA was the eleventh study unit sampled as part of the project.

SOSA is in the southern portion of the Sierra Nevada hydrogeologic province and includes within it six small ground-water basins defined by the California Department of Water Resources (California Department of Water Resources, 2003). The SOSA study included assessment of the ground-water quality from fifty wells in Kern and Tulare Counties. Thirty-five of the wells were selected using a randomized grid approach to achieve statistically unbiased representation of ground water used for public drinking-water supplies. Fifteen of the wells were selected to provide additional sampling density to aid in understanding processes affecting ground-water quality. Ground-water samples were analyzed for VOCs, pesticides and pesticide degradates, pharmaceutical compounds, wastewater-indicator compounds, nutrients, major and minor ions, trace elements, radioactivity, and microbial indicators. Naturally occurring isotopes (stable isotopes of hydrogen, oxygen, and carbon, and activities of tritium and carbon-14) and dissolved noble gases also were measured to provide a data set that will be used to help interpret the source and age of the sampled ground water. This report describes the hydrogeologic setting of the SOSA region, details the sampling, analytical, and quality assurance used in the study, and presents the results of the chemical and microbial analyses made of the ground-water samples collected during June 2006.

Quality-control samples (blanks, replicates, and samples for matrix spikes) were collected at 10 to 18 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Assessment of the quality-control information resulted in censoring of less than 0.2 percent of the ground-water quality data.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, and blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH).

All detections of VOCs and pesticides were below health-based thresholds, and most were less than one one-hundredth of the threshold values. All detections of perchlorate, nitrate, and radioactive constituents were below established thresholds. Only one constituent, arsenic, was detected above a maximum contaminant level (MCL-US), although radon-222 was detected above the proposed MCL-US. Boron and 1,2,3-TCP each had one detection above the CDPH notification level (NL-CA). Total dissolved solids, specific conductance, pH, iron, and manganese were detected at concentrations above secondary maximum contaminant levels (SMCL-CAs), non-enforceable thresholds set for aesthetic concerns, in samples from several of the wells. Future work will interpret the data

presented in this report using a variety of statistical, qualitative, and quantitative approaches to assess the natural and human factors affecting ground-water quality.

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Table 1. Identification, sampling, and construction information for wells sampled for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; ft, foot; LSD, land surface datum; NAVD88, North American Vertical Datum 1988; na, not available]

GAMA well identification number	Sampling information			Construction information		
	Date (m/dd/yyyy)	Sampling schedule ¹	Elevation of LSD (ft above NAVD88) ²	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
Grid Wells						
SOSA-01	6/5/2006	Fast	5,049	na	na	na
SOSA-02	6/6/2006	Fast	2,822	102	54	102
SOSA-03	6/6/2006	Slow	2,606	270	130	270
SOSA-04	6/6/2006	Fast	3,333	540	300	540
SOSA-05	6/7/2006	Fast	2,940	470	370	470
SOSA-06	6/7/2006	Fast	3,245	580	300	580
SOSA-07	6/7/2006	Slow	2,800	70	na	na
SOSA-08	6/7/2006	Fast	3,770	700	300	700
SOSA-09	6/8/2006	Fast	3,840	300	60	300
SOSA-10	6/8/2006	Slow	2,720	174	90	174
SOSA-11	6/8/2006	Fast	4,335	332	50	332
SOSA-12	6/12/2006	Fast	3,000	na	na	na
SOSA-13	6/12/2006	Slow	4,010	520	280	510
SOSA-14	6/12/2006	Fast	2,600	305	150	195
SOSA-15	6/12/2006	Intermediate	5,060	na	na	na
SOSA-16	6/13/2006	Fast	2,549	na	na	na
SOSA-17	6/13/2006 ³	Fast	3,330	150	20	150
SOSA-18	6/13/2006	Fast	3,025	na	na	na
SOSA-19	6/13/2006	Fast	3,045	na	na	na
SOSA-20	6/14/2006 ³	Fast	2,964	165	140	165
SOSA-21	6/14/2006	Fast	2,671	na	na	na
SOSA-22	6/15/2006	Intermediate	7,200	na	na	na
SOSA-23	6/19/2006	Fast	3,845	460	200	460
SOSA-24	6/19/2006	Fast	4,226	350	243	350
SOSA-25	6/19/2006	Fast	4,124	180	84	180
SOSA-26	6/20/2006	Fast	4,633	490	140	490
SOSA-27	6/20/2006	Fast	4,094	600	140	400
SOSA-28	6/20/2006	Fast	3,914	200	80	200
SOSA-29	6/21/2006	Fast	3,533	31	23	27
SOSA-30	6/29/2006	Fast	2,770	375	220	375
SOSA-31	6/29/2006	Fast	2,650	120	78	120
SOSA-32	6/29/2006	Fast	4,180	400	200	400
SOSA-33	6/30/2006	Fast	3,100	195	115	195
SOSA-34	6/30/2006	Fast	3,970	180	84	174
SOSA-35	6/30/2006	Intermediate	4,260	na	na	na

Table 1. Identification, sampling, and construction information for wells sampled for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006—Continued.

[SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; ft, foot; LSD, land surface datum; NAVD88, North American Vertical Datum 1988; na, not available]

GAMA well identification number	Sampling information			Construction information		
	Date (m/dd/yyyy)	Sampling schedule ¹	Elevation of LSD (ft above NAVD88) ²	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
Flow-path wells						
SOSAFP-01	6/5/2006	Intermediate	4,029	546	267	546
SOSAFP-02	6/5/2006	Slow	2,640	55	10	55
SOSAFP-03	6/5/2006	Intermediate	4,072	604	400	590
SOSAFP-04	6/8/2006	Intermediate	3,940	290	50	285
SOSAFP-05	6/13/2006	Slow	4,040	480	180	480
SOSAFP-06	6/14/2006	Slow	4,045	420	na	na
SOSAFP-07	6/22/2006	Intermediate	3,862	472	202	472
SOSAFP-08	6/26/2006	Intermediate	3,840	402	54	396
SOSAFP-09	6/26/2006	Intermediate	3,850	300	na	na
SOSAFP-10	6/26/2006	Intermediate	3,820	357	119	na
SOSAFP-11	6/27/2006	Intermediate	3,850	300	na	na
SOSAFP-12	6/27/2006	Intermediate	3,838	550	na	na
SOSAFP-13	6/28/2006	Intermediate	4,060	478	212	478
SOSAFP-14	6/28/2006	Intermediate	4,055	500	180	500
SOSAFP-15	6/28/2006	Intermediate	3,980	294	114	288

¹Sampling schedules are described in [table 2](#).²Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The elevation of the LSD is described in feet above the North American Vertical Datum 1988.³Also sampled 6/29/2006.

Table 2. Classes of chemical and microbial constituents and water-quality indicators collected for the slow, intermediate, and fast well sampling schedules in the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

Analyte classes	Analyte list table	Slow schedule	Intermediate schedule	Fast schedule
Water-quality indicators				
Dissolved oxygen, temperature, specific conductance		X	X	X
pH, alkalinity		X	X	
Turbidity		X		
Organic constituents				
Volatile organic compounds	3A	X	X	X
Gasoline additives and oxygenates	3B	X	X	X
Pesticides and pesticide degradates	3C	X	X	X
Pharmaceutical compounds	3D	X	X	X
Wastewater-indicator compounds	3E		X ¹	
Constituents of special interest				
Perchlorate	3F	X	X	X
N-nitrosodimethylamine (NDMA)	3F	X	X	
1,2,3-Trichloropropane	3F	X	X	
Inorganic constituents				
Nutrients and dissolved organic carbon	3G	X	X	
Major and minor ions and trace elements	3H	X	X	
Chromium abundance and speciation	3I	X	X	X
Arsenic and iron abundances and speciation	3I	X	X	
Stable isotopes				
Stable isotopes of hydrogen and oxygen in water	3J	X	X	X
Stable isotopes of carbon and carbon-14 abundance	3J	X	X	
Radioactivity and noble gases				
Tritium	3J	X	X	
Tritium and noble gases	3K	X	X	X
Radium isotopes	3J	X		
Radon-222	3J	X		
Gross alpha and beta radiation	3J	X		
Microbial constituents				
Bacterial indicators	3L	X		
Viral indicators	3L	X		

¹Only 6 of the 14 intermediate wells.

Table 3A. Volatile organic compounds and gasoline additives, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2020.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk-specific factor of 10^{-5} ; THM, trihalomethane; D, detected in ground-water samples (table 5); na, not available; $\mu\text{g/L}$, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL ($\mu\text{g/L}$)	Threshold type ¹	Threshold value ($\mu\text{g/L}$)	Detection
Acetone	Solvent	81552	67-64-1	6	na	na	—
Acrylonitrile	Organic synthesis	34215	107-13-1	0.8	RSD5-US	0.6	—
Benzene	Gasoline hydrocarbon	34030	71-43-2	0.021	MCL-CA	1	—
Bromobenzene	Solvent	81555	108-86-1	0.028	na	na	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.12	HAL-US	90	—
Bromodichloromethane	Disinfection by-product (THM)	32101	75-27-4	0.028	MCL-US	² 80	—
Bromoform (Tribromomethane)	Disinfection by-product (THM)	32104	75-25-2	0.10	MCL-US	² 80	—
2-Butanone (MEK, Methyl ethyl ketone)	Solvent	81595	78-93-3	2	HAL-US	4,000	—
<i>n</i> -Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.12	NL-CA	260	—
<i>sec</i> -Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.06	NL-CA	260	—
<i>tert</i> -Butylbenzene	Gasoline hydrocarbon	77353	98-06-6	0.06	NL-CA	260	—
Carbon disulfide	Organic synthesis	77041	75-15-0	0.038	NL-CA	160	—
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.06	MCL-CA	0.5	D
Chlorobenzene	Solvent	34301	108-90-7	0.028	MCL-CA	70	—
Chloroethane	Solvent	34311	75-00-3	0.12	na	na	—
Chloroform (Trichloromethane)	Disinfection by-product (THM)	32106	67-66-3	0.024	MCL-US	² 80	D
Chloromethane	Refrigerant/organic synthesis	34418	74-87-3	0.17	HAL-US	30	—
3-Chloro-1-propene	Organic synthesis	78109	107-05-1	0.5	na	na	— ⁽⁴⁾
2-Chlorotoluene	Solvent	77275	95-49-8	0.04	NL-CA	140	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.05	NL-CA	140	—
Dibromochloromethane	Disinfection by-product (THM)	32105	124-48-1	0.10	MCL-US	² 80	—
1,2-Dibromo-3-chloropropane (DBCP)	Fumigant	82625	96-12-8	0.51	MCL-US	0.2	—
1,2-Dibromoethane (EDB)	Fumigant	77651	106-93-4	0.036	MCL-US	0.05	—
Dibromomethane	Solvent	30217	74-95-3	0.050	na	na	—
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.048	MCL-CA	600	D
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.03	HAL-US	600	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.034	MCL-CA	5	—
<i>trans</i> -1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	0.70	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.18	NL-CA	1,000	— ⁽⁵⁾
1,1-Dichloroethane	Solvent	34496	75-34-3	0.035	MCL-CA	5	—
1,2-Dichloroethane	Solvent	32103	107-06-2	0.13	MCL-CA	0.5	—
1,1-Dichloroethene (DCE)	Organic synthesis	34501	75-35-4	0.024	MCL-CA	6	—
<i>cis</i> -1,2-Dichloroethene	Solvent	77093	156-59-2	0.024	MCL-CA	6	D

Table 3A. Volatile organic compounds and gasoline additives, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2020—Continued.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk-specific factor of 10^5 ; THM, trihalomethane; D, detected in ground-water samples (table 5); na, not available; $\mu\text{g/L}$, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL ($\mu\text{g/L}$)	Threshold type ¹	Threshold value ($\mu\text{g/L}$)	Detection
<i>trans</i> -1,2-Dichloroethene	Solvent	34546	156-60-5	0.032	MCL-CA	10	—
Dichloromethane (Methylene chloride)	Solvent	34423	75-09-2	0.06	MCL-US	5	— ⁽⁵⁾
1,2-Dichloropropane	Fumigant	34541	78-87-5	0.029	MCL-US	5	D
1,3-Dichloropropane	Fumigant	77173	142-28-9	0.06	na	na	— ⁽⁴⁾
2,2-Dichloropropane	Fumigant	77170	594-20-7	0.05	na	na	—
1,1-Dichloropropene	Organic synthesis	77168	563-58-6	0.026	na	na	— ⁽⁴⁾
<i>cis</i> -1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.05	RSD5-US	³ 4	—
<i>trans</i> -1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.09	RSD5-US	³ 4	—
Diethyl ether	Solvent	81576	60-29-7	0.08	na	na	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.10	na	na	—
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.030	MCL-CA	300	—
Ethyl <i>tert</i> -butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.030	na	na	—
Ethyl methacrylate	Organic synthesis	73570	97-63-2	0.18	na	na	—
1-Ethyl-2-methylbenzene (<i>o</i> -Ethyl toluene)	Gasoline hydrocarbon	77220	611-14-3	0.06	na	na	—
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.14	RSD5-US	9	—
Hexachloroethane	Solvent	34396	67-72-1	0.14	HAL-US	1	—
2-Hexanone (<i>n</i> -Butyl methyl ketone)	Solvent	77103	591-78-6	0.4	na	na	—
Isopropylbenzene (Cumene)	Gasoline hydrocarbon	77223	98-82-8	0.038	NL-CA	770	—
4-Isopropyl-1-methylbenzene	Gasoline hydrocarbon	77356	99-87-6	0.08	na	na	—
Methyl acrylate	Organic synthesis	49991	96-33-3	1.0	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.40	na	na	—
Methyl bromide (Bromomethane)	Fumigant	34413	74-83-9	0.33	HAL-US	10	—
Methyl <i>tert</i> -butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.10	MCL-CA	13	D
Methyl iodide (Iodomethane)	Organic synthesis	77424	74-88-4	0.50	na	na	—
Methyl isobutyl ketone (MIBK)	Solvent	78133	108-10-1	0.37	NL-CA	120	—
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.20	na	na	—
Methyl <i>tert</i> -pentyl ether (<i>tert</i> -Amyl methyl ether, TAME)	Gasoline oxygenate	50005	994-05-8	0.04	na	na	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.52	NL-CA	17	—
<i>n</i> -Propylbenzene	Solvent	77224	103-65-1	0.042	NL-CA	260	—
Styrene	Gasoline hydrocarbon	77128	100-42-5	0.042	MCL-US	100	—
1,1,1,2-Tetrachloroethane	Solvent	77562	630-20-6	0.03	HAL-US	70	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.08	MCL-CA	1	—
Tetrachloroethene (PCE)	Solvent	34475	127-18-4	0.030	MCL-US	5	D
Tetrahydrofuran	Solvent	81607	109-99-9	1.2	na	na	—
1,2,3,4-Tetramethylbenzene	Gasoline hydrocarbon	49999	488-23-3	0.14	na	na	— ⁽⁵⁾
1,2,3,5-Tetramethylbenzene	Gasoline hydrocarbon	50000	527-53-7	0.18	na	na	— ⁽⁵⁾
Toluene	Gasoline hydrocarbon	34010	108-88-3	0.02	MCL-CA	150	—

Table 3A. Volatile organic compounds and gasoline additives, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2020—Continued.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk-specific factor of 10⁵; THM, trihalomethane; D, detected in ground-water samples (table 5); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type ¹	Threshold value (µg/L)	Detection
1,2,3-Trichlorobenzene	Organic synthesis	77613	87-61-6	0.18	na	na	— ⁽⁵⁾
1,2,4-Trichlorobenzene	Solvent	34551	120-82-1	0.12	MCL-CA	5	—
1,1,1-Trichloroethane (TCA)	Solvent	34506	71-55-6	0.032	MCL-CA	200	—
1,1,2-Trichloroethane	Solvent	34511	79-00-5	0.04	MCL-CA	5	—
Trichloroethene (TCE)	Solvent	39180	79-01-6	0.038	MCL-US	5	D
Trichlorofluoromethane (CFC-11)	Refrigerant	34488	75-69-4	0.08	MCL-CA	150	D
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.18	NL-CA	0.005	—
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.038	MCL-CA	1,200	D
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.09	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	0.056	NL-CA	330	—
1,3,5-Trimethylbenzene	Organic synthesis	77226	108-67-8	0.044	NL-CA	330	—
Vinyl bromide (Bromoethene)	Fire retardant	50002	593-60-2	0.10	na	na	—
Vinyl chloride (Chloroethene)	Organic synthesis	39175	75-01-4	0.08	MCL-CA	0.5	—
<i>m</i> - and <i>p</i> -Xylene	Gasoline hydrocarbon	85795	108-38-3 / 106-42-3	0.06	MCL-CA	1,750	— ⁽⁴⁾
<i>o</i> -Xylene	Gasoline hydrocarbon	77135	95-47-6	0.038	MCL-CA	1,750	—

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The MCL-US thresholds for trihalomethanes is the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

³The RSD5 threshold for 1,3-dichloropropene is the sum of its isomers (cis and trans).

⁴The median matrix-spike recovery was greater than 130 percent.

⁵The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

⁶The preferred method for 1,2,3-Trichloropropane is MWH (table 3F).

Table 3B. Gasoline oxygenates and degradates, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 4024.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; D, detected in ground-water samples (table 5); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type ¹	Threshold value (µg/L)	Detection
Acetone	Degradate	81552	67-64-1	1.2	na	na	—
<i>tert</i> -Amyl alcohol	Oxygenate	77073	75-85-4	1.0	na	na	—
<i>tert</i> -Butyl alcohol (TBA)	Degradate	77035	75-65-0	1	NL-CA	12	—
Diisopropyl ether	Oxygenate	81577	108-20-3	0.06	na	na	—
Ethyl <i>tert</i> -butyl ether (ETBE)	Oxygenate	50004	637-92-3	0.06	na	na	—
Methyl acetate	Degradate	77032	79-20-9	0.43	na	na	—
Methyl <i>tert</i> -butyl ether (MTBE)	Oxygenate	78032	1634-04-4	0.05	MCL-US	13	D
Methyl <i>tert</i> -pentyl ether	Oxygenate	50005	994-05-8	0.05	na	na	—

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2003.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; RSD5-US, U.S. Environmental Protection Agency risk-specific dose at a risk factor of 10⁻⁵; D, detected in ground-water samples (table 6); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type ¹	Threshold value (µg/L)	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.006	na	na	—
Alachlor	Herbicide	46342	15972-60-8	0.005	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.007	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.05	na	na	—
Azinphos-methyl-oxon	Insecticide degradate	61635	961-22-8	0.042	na	na	—
Benfluralin	Herbicide	82673	1861-40-1	0.01	na	na	— ⁽²⁾
Carbaryl	Insecticide	82680	63-25-2	0.041	RSD5-US	400	—
2-Chloro-2,6-diethylacetanilide	Herbicide degradate	61618	6967-29-9	0.0065	na	na	—
4-Chloro-2-methylphenol	Herbicide degradate	61633	1570-64-5	0.0050	na	na	— ⁽²⁾
Chlorpyrifos	Insecticide	38933	2921-88-2	0.005	HAL-US	2	—
Chlorpyrifos, oxygen analog	Insecticide degradate	61636	5598-15-2	0.0562	na	na	— ⁽²⁾
Cyfluthrin	Insecticide	61585	68359-37-5	0.053	na	na	— ⁽²⁾
Cypermethrin	Insecticide	61586	52315-07-8	0.046	na	na	— ⁽²⁾
Dacthal (DCPA)	Herbicide	82682	1861-32-1	0.003	HAL-US	70	—
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-s-triazine)	Herbicide degradate	04040	6190-65-4	0.014	na	na	D ⁽²⁾
Desulfinylfipronil	Insecticide degradate	62170	na	0.012	na	na	—
Desulfinylfipronil amide	Insecticide degradate	62169	na	0.029	na	na	—
Diazinon	Insecticide	39572	333-41-5	0.005	HAL-US	1	—
Diazinon, oxon	Insecticide degradate	61638	962-58-3	0.006	na	na	—
3,4-Dichloroaniline	Herbicide degradate	61625	95-76-1	0.0045	na	na	—
Dichlorvos	Insecticide	38775	62-73-7	0.013	na	na	— ⁽²⁾
Dicrotophos	Insecticide	38454	141-66-2	0.0843	na	na	— ⁽²⁾
Dieldrin	Insecticide	39381	60-57-1	0.009	RSD5-US	0.02	—
2,6-Diethylaniline	Herbicide degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.0061	na	na	— ⁽²⁾
Ethion	Insecticide	82346	563-12-2	0.016	na	na	—
Ethion monoxon	Insecticide degradate	61644	17356-42-2	0.021	na	na	—
2-Ethyl-6-methylaniline	Herbicide degradate	61620	24549-06-2	0.010	na	na	—
Fenamiphos	Insecticide	61591	22224-92-6	0.029	HAL-US	0.7	—
Fenamiphos sulfone	Insecticide degradate	61645	31972-44-8	0.053	na	na	—
Fenamiphos sulfoxide	Insecticide degradate	61646	31972-43-7	0.040	na	na	—
Fipronil	Insecticide	62166	120068-37-3	0.016	na	na	—
Fipronil sulfide	Insecticide degradate	62167	120067-83-6	0.013	na	na	D
Fipronil sulfone	Insecticide degradate	62168	120068-36-2	0.024	na	na	— ⁽²⁾
Fonofos	Insecticide	04095	944-22-9	0.0053	HAL-US	10	—
Hexazinone	Herbicide	04025	51235-04-2	0.026	HAL-US	400	—
Iprodione	Fungicide	61593	36734-19-7	0.026	na	na	—
Isofenphos	Insecticide	61594	25311-71-1	0.011	na	na	—
Malaoxon	Insecticide degradate	61652	1634-78-2	0.039	na	na	—
Malathion	Insecticide	39532	121-75-5	0.027	HAL-US	100	—
Metalaxyl	Fungicide	61596	57837-19-1	0.0069	na	na	—
Methidathion	Insecticide	61598	950-37-8	0.0087	na	na	—
Metolachlor	Herbicide	39415	51218-45-2	0.006	HAL-US	700	—
Metribuzin	Herbicide	82630	21087-64-9	0.028	HAL-US	70	—
Myclobutanil	Fungicide	61599	88671-89-0	0.033	na	na	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2003—Continued.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; RSD5-US, U.S. Environmental Protection Agency risk-specific dose at a risk factor of 10⁻⁵; D, detected in ground-water samples (table 6); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type ¹	Threshold value (µg/L)	Detection
1-Naphthol	Insecticide degradate	49295	90-15-3	0.0882	na	na	— ²
Paraoxon-methyl	Insecticide degradate	61664	950-35-6	0.019	na	na	— ²
Parathion-methyl	Insecticide	82667	298-00-0	0.015	HAL-US	1	—
Pendimethalin	Herbicide	82683	40487-42-1	0.022	na	na	—
<i>cis</i> -Permethrin	Insecticide	82687	54774-45-7	0.006	na	na	— ⁽²⁾
Phorate	Insecticide	82664	298-02-2	0.055	na	na	—
Phorate oxon	Insecticide degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.0079	na	na	— ⁽²⁾
Phosmet oxon	Insecticide degradate	61668	3735-33-9	0.0511	na	na	— ⁽²⁾
Prometon	Herbicide	04037	1610-18-0	0.01	HAL-US	100	D
Prometryn	Herbicide	04036	7287-19-6	0.0059	na	na	—
Pronamide (Propyzamide)	Herbicide	82676	23950-58-5	0.004	RSD5-US	20	—
Simazine	Herbicide	04035	122-34-9	0.005	MCL-US	4	D
Tebuthiuron	Herbicide	82670	34014-18-1	0.016	HAL-US	500	—
Terbufos	Insecticide	82675	13071-79-9	0.017	HAL-US	0.4	—
Terbufos oxon sulfone	Insecticide degradate	61674	56070-15-6	0.045	na	na	—
Terbutylazine	Herbicide	04022	5915-41-3	0.0083	na	na	—
Trifluralin	Herbicide	82661	1582-09-8	0.009	HAL-US	10	—

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

Table 3D. Pharmaceutical compounds, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2080.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; D, detected in ground-water samples (table 7); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Acetaminophen	Analgesic	62000	103-90-2	0.024	na	na	—
Caffeine	Stimulant	50305	58-08-2	0.015	na	na	—
Carbamazepine	Anticonvulsant; analgesic; mood stabilizer	62793	298-46-4	0.018	na	na	D
Codeine	Opioid narcotic	62003	76-57-3	0.022	na	na	—
Cotinine	Nicotine metabolite	62005	486-56-6	0.028	na	na	—
Dehydronifedipine	Antianginal metabolite	62004	67035-22-7	0.022	na	na	—
Diltiazem	Antianginal; antihypertensive	62008	42399-41-7	0.018	na	na	— ⁽¹⁾
1,7-Dimethylxanthine	Caffeine metabolite	62030	611-59-6	0.021	na	na	—
Diphenhydramine	Antihistamine	62796	58-73-1	0.023	na	na	D ⁽¹⁾
Salbutamol (albuterol)	Anti-inflammatory; bronchodilator	62020	18559-94-9	0.014	na	na	—
Sulfamethoxazole	Antibacterial, antiprotozoal	62021	723-46-6	0.024	na	na	D ⁽¹⁾
Thiabendazole	Anthelmintic	62801	148-79-8	0.025	na	na	—
Trimethoprim	Antibacterial	62023	738-70-5	0.020	na	na	—
Warfarin	Anticoagulant	62024	81-81-2	0.002	na	na	—

¹The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

Table 3E. Wastewater-indicator compounds, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 1433.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk-specific dose at a risk factor of 10^{-5} ; D, detected; na, not available; $\mu\text{g/L}$, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL ($\mu\text{g/L}$)	Threshold type ¹	Threshold value ($\mu\text{g/L}$)	Detection
Acetophenone	Fragrance, flavor additive	62064	98-86-2	0.5	na	na	—
Acetyl hexamethyl tetrahydro-naphthalene (AHTN)	Musk fragrance	62065	21145-77-7	0.5	na	na	—
Anthracene	Wood preservative, combustion product	34221	120-12-7	0.5	na	na	—
Anthraquinone	Dye/textiles, seed treatment	62066	84-65-1	0.5	na	na	—
Benzo[a]pyrene	Combustion product	34248	50-32-8	0.5	MCL-US	0.2	— ⁽³⁾
Benzophenone	Fixative for perfumes and soaps	62067	119-61-9	0.5	na	na	—
Bisphenol A	Polycarbonate resins, flame retardant	62069	80-05-7	1	na	na	— ⁽³⁾
Bromacil	Herbicide	04029	314-40-9	0.5	HAL-US	70	—
Bromoform (tribromomethane)	Disinfection by-product	34288	75-25-2	0.5	MCL-US	80	—
3- <i>tert</i> -Butyl-4-hydroxy anisole (BHA)	Antioxidant, general preservative	62059	25013-16-5	5	na	na	— ⁽³⁾
Caffeine	Beverages	50305	58-08-2	0.5	na	na	— ⁽⁴⁾
Camphor	Flavor, odorant, ointments	62070	76-22-2	0.5	na	na	—
Carbaryl	Insecticide	82680	63-25-2	1	RSD5-US	400	—
Carbazole	Insecticide	62071	86-74-8	0.5	na	na	—
Chlorpyrifos	Insecticide	38933	2921-88-2	0.5	HAL-US	2	—
Cholesterol	Fecal indicator, plant sterol	62072	57-88-5	2	na	na	—
3-beta-Coprostanol	Carnivore fecal indicator	62057	360-68-9	2	na	na	— ⁽³⁾
Cotinine	Primary nicotine metabolite	62005	486-56-6	1	na	na	—
<i>para</i> -Cresol	Wood preservative	62084	106-44-5	1	na	na	—
4-Cumylphenol	Nonionic detergent metabolite	62060	599-64-4	1	na	na	—
<i>N,N</i> -diethyl- <i>meta</i> -toluamide (DEET)	Insecticide	62082	134-62-3	0.5	na	na	—
1,4-Dichlorobenzene	Moth repellent, fumigant, deodorant	34572	106-46-7	0.5	MCL-CA	5	— ⁽³⁾
2,6-Dimethylnaphthalene	Diesel/kerosene	62055	581-42-0	0.5	na	na	— ⁽³⁾
Diazinon	Insecticide	39572	333-41-5	0.5	HAL-US	1	—
4-Nonylphenol diethoxylates	Nonionic detergent metabolite	62083	na	5	na	na	— ⁽²⁾
4-Octylphenol diethoxylates	Nonionic detergent metabolite	61705	na	1	na	na	—
4-Octylphenol monoethoxylates	Nonionic detergent metabolite	61706	na	1	na	na	—
Fluoranthene	Component of coal tar and asphalt	34377	206-44-0	0.5	na	na	—
Hexahydrohexamethylcyclopentabenzopyran (HHCb)	Musk fragrance	62075	1222-05-5	0.5	na	na	—
Indole	Pesticide ingredient	62076	120-72-9	0.5	na	na	—
Isoborneol	Fragrance in perfumery	62077	124-76-5	0.5	na	na	—
Isophorone	Solvent	34409	78-59-1	0.5	HAL-US	100	—
Isopropylbenzene	Fuels, paint thinner	62078	98-82-8	0.5	NL-CA	770	— ⁽³⁾
Isoquinoline	Flavors and fragrances	62079	119-65-3	0.5	na	na	—
<i>d</i> -Limonene	Fungicide	62073	5989-27-5	0.5	na	na	— ⁽³⁾

Table 3E. Wastewater-indicator compounds, primary uses or sources, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 1433—Continued.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; RSD5-US, U.S. Environmental Protection Agency risk-specific dose at a risk factor of 10^{-5} ; D, detected; na, not available; $\mu\text{g/L}$, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL ($\mu\text{g/L}$)	Threshold type ¹	Threshold value ($\mu\text{g/L}$)	Detection
Menthol	Cigarettes, cough drops, liniment	62080	89-78-1	0.5	na	na	—
Metalaxyl	Herbicide, fungicide	50359	57837-19-1	0.5	na	na	—
3-Methyl-1(H)-indole (Skatole)	Fragrance, stench in feces	62058	83-34-1	1	na	na	—
5-Methyl-1H-benzotriazole	Antioxidant in antifreeze and deicers	62063	136-85-6	2	na	na	— ⁽³⁾
1-Methylnaphthalene	Gasoline, diesel fuel, or crude oil	62054	90-12-0	0.5	na	na	— ⁽³⁾
2-Methylnaphthalene	Gasoline, diesel fuel, or crude oil	62056	91-57-6	0.5	na	na	— ⁽³⁾
Methyl salicylate	Liniment, UV-absorbing lotion	62081	119-36-8	0.5	na	na	—
Metolachlor	Herbicide	39415	51218-45-2	0.5	HAL-US	700	—
Naphthalene	Fumigant, moth repellent, gasoline	34443	91-20-3	0.5	NL-CA	17	—
<i>para</i> -Nonylphenol (total)	Nonionic detergent metabolite	62085	84852-15-3	5	na	na	—
4- <i>n</i> -Octylphenol	Nonionic detergent metabolite	62061	1806-26-4	1	na	na	— ⁽³⁾
4- <i>tert</i> -Octylphenol	Nonionic detergent metabolite	62062	140-66-9	1	na	na	—
Pentachlorophenol	Herbicide, wood preservative	34459	87-86-5	2	MCL-US	1	— ⁽³⁾
Phenanthrene	Explosives, oil, combustion product	34462	85-01-8	0.5	na	na	—
Phenol	Disinfectant, organic synthesis	34466	108-95-2	0.5	HAL-US	2000	—
Prometon	Herbicide	04037	1610-18-0	0.5	HAL-US	100	—
Pyrene	Component of coal tar and asphalt	34470	129-00-0	0.5	na	na	—
<i>beta</i> -Sitosterol	Plant sterol	62068	83-46-5	2	na	na	— ⁽³⁾
<i>beta</i> -Stigmastanol	Plant sterol	62086	19466-47-8	2	na	na	— ⁽³⁾
Tetrachloroethene (PCE)	Solvent, degreaser	34476	127-18-4	0.5	MCL-US	5	D ⁵
Tributyl phosphate	Antifoaming agent, flame retardant	62089	126-73-8	0.5	na	na	—
Triclosan	Disinfectant, antimicrobial	62090	3380-34-5	1	na	na	—
Triethyl citrate (ethyl citrate)	Cosmetics, pharmaceuticals	62091	77-93-0	0.5	na	na	—
Triphenyl phosphate	Plasticizer, resin, flame retardant	62092	115-86-6	0.5	na	na	—
Tri(2-butoxyethyl)phosphate	Flame retardant	62093	78-51-3	0.5	na	na	—
Tri(2-chloroethyl)phosphate	Plasticizer, flame retardant	62087	115-96-8	0.5	na	na	—
Tri(dichlorisopropyl)phosphate	Flame retardant	62088	13674-87-8	0.5	na	na	—

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The median matrix-spike recovery was greater than 130 percent.

³The median matrix-spike recovery was less than 70 percent. Low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations.

⁴The preferred analytical schedule for caffeine is schedule 2080 (table 3D).

⁵The preferred analytical schedule for tetrachloroethene (PCE) is schedule 2020 (table 3A).

Table 3F. Constituents of special interest, primary uses or sources, comparative thresholds, and reporting information for the Montgomery Watson-Harza Laboratory.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the Montgomery Watson-Harza Laboratory in the USGS National Water Information System (NWIS) is CA-MWHL. CAS, Chemical Abstract Service; MRL, minimum reporting level; NL-CA, California Department of Public Health notification level; D, detected in ground-water samples ([table 8](#)); µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	MRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Perchlorate	Rocket fuel, fireworks, flares	61209	14797-73-0	0.5	NL-CA	6	D
1,2,3-Trichloropropane (TCP)	Industrial solvent	77443	96-18-4	0.005	NL-CA	0.005	D
<i>N</i> -Nitrosodimethylamine (NDMA)	Rocket fuel, plasticizer	64176	62-75-9	0.002	NL-CA	0.010	—

Table 3G. Nutrients and dissolved organic carbon, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 2755 and parameter code 2613.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; HAL-US, U.S. Environmental Protection Agency lifetime health advisory level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; D, detected in ground-water samples (table 9); na, not available; mg/L, milligrams per liter]

Constituent	USGS parameter code	CAS number	LRL (mg/L)	Threshold type ¹	Threshold value (mg/L)	Detection
Ammonia	00608	7664-41-7	0.010	HAL-US	30	D
Nitrite (as nitrogen)	00613	14797-65-0	0.002	MCL-US	1	D
Nitrate plus nitrite (as nitrogen)	00631	na	0.060	MCL-US	10	D
Total nitrogen (ammonia, nitrite, nitrate, organic nitrogen)	62854	17778-88-0	0.06	na	na	D
Phosphorus, phosphate, orthophosphate (as phosphorus)	00671	14265-44-2	0.006	na	na	D
Dissolved organic carbon (DOC)	00681	na	0.33	na	na	D

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 3H. Major and minor ions and trace elements, comparative thresholds, and reporting information for the USGS National Water Quality Laboratory schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstract Service; LRL, laboratory reporting level; AL-US, U.S. Environmental Protection Agency action level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; SMCL-CA, California Department of Public Health secondary maximum contaminant level; D, detected in ground-water samples (tables 10 and 11); na, not available; mg/L, milligrams per liter; µg/L, micrograms per liter; —, not detected]

Constituent	USGS parameter code	CAS number	LRL	Threshold type ¹	Threshold value	Detection
Major and minor ions (mg/L)						
Bromide	71870	24959-67-9	0.02	na	na	D
Calcium	00915	7440-70-2	0.02	na	na	D
Chloride	00940	16887-00-6	0.2	SMCL-CA	² 250 (500)	D
Fluoride	00950	16984-48-8	0.10	MCL-CA	2	D
Iodide	78165	7553-56-2	0.002	na	na	D
Magnesium	00925	7439-95-4	0.008	na	na	D
Potassium	00935	7440-09-7	0.16	na	na	D
Silica	00955	7631-86-9	0.04	na	na	D
Sodium	00930	7440-23-5	0.20	na	na	D
Sulfate	00945	14808-79-8	0.18	SMCL-CA	250 (500)	D
Residue on evaporation (total dissolved solids, TDS)	70300	na	10	SMCL-US	² 500 (1,000)	D
Trace elements (µg/L)						
Aluminum	01106	7429-90-5	1.6	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.2	MCL-US	6	D
Arsenic	01000	7440-38-2	0.12	MCL-US	10	D
Barium	01005	7440-39-3	0.2	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.06	MCL-US	4	D
Boron	01020	7440-42-8	8	NL-CA	1,000	D
Cadmium	01025	7440-43-9	0.04	MCL-US	5	D
Chromium	01030	7440-47-3	0.04	MCL-CA	50	D
Cobalt	01035	7440-48-4	0.04	na	na	D
Copper	01040	7440-50-8	0.4	AL-US	1,300	D
Iron	01046	7439-89-6	6	SMCL-CA	300	D
Lead	01049	7439-92-1	0.08	AL-US	15	D
Lithium	01130	7439-93-2	0.6	na	na	D
Manganese	01056	7439-96-5	0.2	SMCL-CA	50	D
Mercury	71890	7439-97-6	0.010	MCL-US	2	—
Molybdenum	01060	7439-98-7	0.4	HAL-US	40	D
Nickel	01065	7440-02-0	0.06	MCL-CA	100	D
Selenium	01145	7782-49-2	0.08	MCL-US	50	D
Silver	01075	7440-22-4	0.20	SMCL-CA	100	D
Strontium	01080	7440-24-6	0.4	HAL-US	4,000	D
Thallium	01057	7440-28-0	0.04	MCL-US	2	D
Tungsten	01155	7440-33-7	0.06	na	na	D
Uranium	22703	7440-61-1	0.04	MCL-US	30	D
Vanadium	01085	7440-62-2	0.10	NL-CA	50	D
Zinc	01090	7440-66-6	0.6	HAL-US	2,000	D

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The recommended SMCL-CA thresholds for chloride, sulfate, and TDS are listed with the upper SMCL-CA thresholds in parentheses.

Table 31. Arsenic, chromium, and iron species, comparative thresholds, and reporting information for the USGS Trace Metal Laboratory, Boulder, Colorado.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the USGS Trace Metal Laboratory in the USGS National Water Information System (NWIS) is USGSTMCO. CAS, Chemical Abstract Service; MD, method detection level; HAL-US, U.S. Environmental Protection Agency lifetime health advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; na, not available; mg/L, micrograms per liter; D, detected in ground-water samples ([table 12](#))]

Constituent (valence state)	USGS parameter code	CAS number	MD (µg/L)	Threshold type ¹	Threshold level (µg/L)	Detection
Arsenic (III)	99034	22569-72-8	1	na	na	D
Arsenic (total)	01000	7440-38-2	0.5	MCL-US	10	D
Chromium (VI), hexavalent	01032	18540-29-9	1	na	na	D
Chromium (total)	01030	7440-47-3	1	MCL-CA	50	D
Iron (II)	01047	7439-89-6	2	na	na	D
Iron (total)	01046	7439-89-6	2	HAL-US	300	D

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 3J. Isotopic and radioactive constituents, comparative thresholds, and reporting information for laboratories.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Laboratory entity codes are listed in the footnotes. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. CAS, Chemical Abstract Service; CSU, combined standard uncertainty; CV, critical value; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MRL, minimum reporting level; MU, method uncertainty; na, not available; pCi/L, picocuries per liter; SSMDC, sample specific minimum detectable concentration; D, detected in ground-water samples (tables 13 and 14)]

Constituent	USGS parameter code	CAS number	Reporting level type	Reporting level or uncertainty	Threshold type ¹	Threshold value	Detection
Stable isotope ratios (per mil)							
$\delta^2\text{H}$ of water ²	82082	na	MU	2	na	na	D
$\delta^{18}\text{O}$ of water ²	82085	na	MU	0.20	na	na	D
$\delta^{13}\text{C}$ of dissolved carbonates ³	82081	na	1 sigma	0.05	na	na	D
Radioactive constituents (percent modern)							
Carbon-14 ⁴	49933	14762-75-5	1 sigma	0.002	na	na	D
Radioactive constituents (pCi/L)							
Radon-222 ⁵	82303	14859-67-7	SSMDC	CSU and CV	Prop. MCL-US	⁶ 300 (4,000)	D
Tritium ⁷	07000	10028-17-8	MRL	1	MCL-CA	20,000	D
Gross-alpha radioactivity, 72-hour and 30-day counts ⁸	62636, 62639	12587-46-1	SSMDC	CSU and CV	MCL-US	15	D
Gross-beta radioactivity, 72-hour and 30-day counts ⁸	62642, 62645	12587-47-2	SSMDC	CSU and CV	MCL-CA	50	D
Radium-226 ⁸	09511	13982-63-3	SSMDC	CSU and CV	MCL-US	⁹ 5	D
Radium-228 ⁸	81366	15262-20-1	SSMDC	CSU and CV	MCL-US	⁹ 5	D

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

³University of Waterloo (contract laboratory) (CAN-UWIL).

⁴University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

⁵USGS National Water Quality Laboratory (USGSNWQL).

⁶Two MCLs have been proposed for Radon-222. The proposed Alternative MCL is in parentheses.

⁷USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

⁸Eberline Analytical Services (contract laboratory) (CA-EBERL).

⁹The MCL-US threshold for radium is the sum of radium-226 and radium-228.

Table 3K. Noble gases and tritium, comparison thresholds, and reporting information for the Lawrence Livermore National Laboratory.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the Lawrence Livermore National Laboratory in the USGS National Water Information System (NWIS) is CA-LLNL. CAS, Chemical Abstract Service; MU, method uncertainty; MCL-CA, California Department of Public Health maximum contaminant level; na, not available; cm³ STP/g, cubic centimeters of gas at standard temperature and pressure per gram of water; pCi/L, picocuries per liter; D, detected in ground-water samples]

Constituent	USGS parameter code	CAS number	MU (percent)	Reporting units	Threshold type ¹	Threshold value (pCi/L)	Detection
Helium-3/Helium-4	61040	na/7440-59-7	0.75	atom ratio	na	na	D
Argon	85563	7440-37-1	2	cm ³ STP/g	na	na	D
Helium-4	85561	7440-59-7	2	cm ³ STP/g	na	na	D
Krypton	85565	7439-90-9	2	cm ³ STP/g	na	na	D
Neon	61046	7440-01-09	2	cm ³ STP/g	na	na	D
Xenon	85567	7440-63-3	2	cm ³ STP/g	na	na	D
Tritium	07000	10028-17-8	1	pCi/L	MCL-CA	20,000	D

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 3L. Microbial constituents, comparison thresholds, and reporting information for the USGS Ohio Microbiology Laboratory parameter codes 90901, 90900, 99335, and 99332.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. MDL, method detection limit; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; TT-US, U.S. Environmental Protection Agency treatment technique - a required process intended to reduce the level of contamination in drinking water; na, not available; mL, milliliters; D, detected in ground-water samples (table 15); —, not detected]

Constituent	USGS parameter code	Primary source	MDL	Threshold type ¹	Threshold value	Detection
Escherichia coli ²	90901	Sewage and animal waste indicator	1 colony/100 mL	TT-US	Zero	—
Total coliform—including fecal coliform and E. coli) ²	90900	Sewage and animal waste indicator	1 colony/100 mL	MCL-US	5 percent of samples positive per month	D
F-specific coliphage ³	99335	Sewage and animal waste indicator	na	TT-US	99.99 percent killed/inactivated	—
Somatic coliphage ³	99332	Sewage and animal waste indicator	na	TT-US	99.99 percent killed/inactivated	—

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²Analyzed in the field.

³Analyzed by the USGS Ohio Microbiology Laboratory (laboratory entity code USGSOHML).

Table 4. Water-quality indicators in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property; SMCL-CA, California Department of Public Health secondary maximum contaminant level; SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; C, celsius; E, estimated value; mg/L, milligrams per liter; mm, millimeter; nc, sample not collected; na, not available; NTU, nephelometric turbidity unit; µS/cm, microsiemens per centimeter; CaCO₃, calcium carbonate]

GAMA identification No.	Turbidity, field (NTU) (63676)	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (degrees C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as CaCO ₃) (29801)	Alkalinity, field (mg/L as CaCO ₃) (29802)
Threshold type	na	na	na	SMCL-US	SMCL-US	SMCL-CA ¹	SMCL-CA ¹	na	na
Threshold level	na	na	na	6.5 - 8.5	6.5 - 8.5	900 (1,600)	900 (1,600)	na	na
Grid wells									
SOSA-01	nc	1.4	15.7	nc	nc	nc	85	nc	nc
SOSA-02	nc	4.3	15.8	nc	nc	nc	nc	nc	nc
SOSA-03	0.3	11.6	20.1	7.3	6.9	661	656	248	239
SOSA-04	nc	2.2	22.8	nc	nc	nc	nc	nc	nc
SOSA-05	nc	4.7	19.4	nc	nc	nc	337	nc	nc
SOSA-06	nc	0.1	19.2	nc	nc	nc	301	nc	nc
SOSA-07	0.5	0.1	15.4	7.5	6.5	127	135	60	55
SOSA-08	nc	0.6	19.9	nc	nc	nc	649	nc	nc
SOSA-09	nc	0.6	14.8	nc	nc	nc	* 1,020	nc	nc
SOSA-10	0.4	0.8	16.7	6.6	* 6.0	365	367	144	140
SOSA-11	nc	10.5	18.1	nc	nc	nc	501	nc	nc
SOSA-12	nc	2.1	14.6	nc	nc	nc	86	nc	nc
SOSA-13	0.2	7.0	17.5	7.8	7.6	490	485	186	180
SOSA-14	nc	6.0	21.5	nc	nc	nc	168	nc	nc
SOSA-15	nc	7.8	8.1	6.8	nc	242	241	121	nc
SOSA-16	nc	7.0	20.0	nc	nc	nc	422	nc	nc
SOSA-17	nc	1.2	19.5	nc	nc	nc	315	nc	nc
SOSA-18	nc	5.4	20.0	nc	nc	nc	856	nc	nc
SOSA-19	nc	1.4	20.5	nc	nc	nc	352	nc	nc
SOSA-20	nc	5.1	18.5	nc	nc	nc	337	nc	nc
SOSA-21	nc	1.2	21.0	nc	nc	nc	570	nc	nc
SOSA-22	nc	6.6	6.5	6.1	nc	39	37	17	nc
SOSA-23	nc	E 8.0	17.5	nc	nc	nc	549	nc	nc
SOSA-24	nc	0.2	22.5	nc	nc	nc	457	nc	nc
SOSA-25	nc	4.2	15.5	nc	nc	nc	457	nc	nc

Table 4. Water-quality indicators in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006—Continued.

[The five-digit number below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property; SMCL-CA, California Department of Public Health secondary maximum contaminant level; SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; C, celsius; E, estimated value; mg/L, milligrams per liter; mm, millimeter; nc, sample not collected; na, not available; NTU, nephelometric turbidity unit; $\mu\text{S}/\text{cm}$, microsiemens per centimeter; CaCO_3 , calcium carbonate]

GAMA identification No.	Turbidity, field (NTU) (63676)	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (degrees C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab ($\mu\text{S}/\text{cm}$ at 25°C) (90095)	Specific conductance, field ($\mu\text{S}/\text{cm}$ at 25°C) (00095)	Alkalinity, lab (mg/L as CaCO_3) (29801)	Alkalinity, field (mg/L as CaCO_3) (29802)
Threshold type	na	na	na	SMCL-US	SMCL-US	SMCL-CA ¹	SMCL-CA ¹	na	na
Threshold level	na	na	na	6.5 - 8.5	6.5 - 8.5	900 (1,600)	900 (1,600)	na	na
SOSA-26	nc	2.1	15.3	nc	nc	nc	469	nc	nc
SOSA-27	nc	E 2	17.0	nc	nc	nc	404	nc	nc
SOSA-28	nc	6.3	16.5	nc	nc	nc	897	nc	nc
SOSA-29	nc	1.4	18.0	nc	nc	nc	377	nc	nc
SOSA-30	nc	6.6	21.3	nc	nc	nc	507	nc	nc
SOSA-31	nc	7.8	16.7	nc	nc	nc	836	nc	nc
SOSA-32	nc	8.4	17.8	nc	7.4	nc	474	nc	nc
SOSA-33	nc	< 0.1	18.0	nc	7.2	nc	469	nc	nc
SOSA-34	nc	11.6	16.6	nc	7.2	nc	731	nc	nc
SOSA-35	nc	0.2	19.8	* 8.7	* 8.6	* 1,730	* 1,730	710	nc
Flow-path wells									
SOSAFP-01	nc	5.2	18.7	7.8	nc	508	479	150	nc
SOSAFP-02	2.2	< 0.1	18.9	6.7	* 6.2	518	513	254	256
SOSAFP-03	nc	3.8	19.9	8.1	nc	386	391	138	nc
SOSAFP-04	0.4	8.3	18.5	7.9	nc	527	543	182	nc
SOSAFP-05	0.2	3.5	18.5	7.9	7.7	419	419	155	150
SOSAFP-06	0.2	7.9	18.5	7.8	7.7	476	477	172	167
SOSAFP-07	nc	8.5	17.0	7.6	nc	850	862	235	nc
SOSAFP-08	nc	3.1	18.3	7.4	nc	683	686	197	nc
SOSAFP-09	nc	12.3	17.3	7.6	7.0	679	676	214	nc
SOSAFP-10	nc	4.0	17.6	7.4	nc	523	526	161	nc
SOSAFP-11	nc	5.2	17.1	7.7	nc	460	377	179	nc
SOSAFP-12	nc	3.3	18.8	7.5	7.3	543	537	150	nc
SOSAFP-13	nc	7.0	18.7	7.8	nc	439	348	159	nc
SOSAFP-14	nc	9.7	17.7	7.7	nc	532	517	187	nc
SOSAFP-15	nc	9.4	16.6	7.7	nc	577	522	197	nc

*Value above threshold level.

¹The SMCL-CA for specific conductance has recommended and upper threshold values. The upper value is shown in parentheses.

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all fifty wells were analyzed, but only samples with detections are listed. Analytes are listed in order of decreasing detection frequency in the thirty-five grid wells. All analytes are listed in tables 3A and 3B. SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; LRL, laboratory reporting level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA; California Department of Public Health maximum contaminant level; E, estimated value; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality assessment; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Chloroform (trichloromethane) (µg/L) (32106)	Tetra-chloro-ethene (PCE) (µg/L) (34475)	Carbon tetra-chloride (tetra-chloro-methane) (µg/L) (32102)	Methyl tert-butyl ether (MTBE) (µg/L) (78032)	Trichloro-ethene (TCE) (µg/L) (39180)	Trichloro-fluoro-methane (CFC-11) (µg/L) (34488)	1,1,2-Tri-chloro-1,2,2-tri-fluoro-ethane (CFC-113) (µg/L) (77652)	1,2-Di-chloro-benzene (µg/L) (34536)	cis-1,2-Dichloro-ethene (µg/L) (77093)	1,2-Di-chloro-propane (µg/L) (34541)	Toluene (µg/L) (34010)	VOC detections per well
	LRL	0.024	0.030	0.06	0.10	0.04	0.08	0.038	0.048	0.024	0.029	0.02
Threshold type ¹	MCL-US	MCL-US	MCL-CA	MCL-CA	MCL-US	MCL-CA	MCL-CA	MCL-US	MCL-CA	MCL-CA	MCL-CA	
Threshold level	² 80	5	0.5	13	5	150	1200	600	6	5	150	
Grid wells												
SOSA-02	—	—	—	—	—	—	E0.05	—	—	—	—	1
SOSA-03	0.13	E0.02	—	—	—	—	—	—	—	—	—	2
SOSA-04	—	—	—	—	—	0.1	—	—	—	—	—	1
SOSA-09	0.13	—	—	—	—	—	—	—	—	—	—	1
SOSA-13	—	—	—	—	—	—	—	—	—	—	V0.02	0
SOSA-14	0.14	—	—	—	—	—	—	—	—	—	—	1
SOSA-16	0.11	0.35	E0.23	—	—	—	—	—	—	—	—	3
SOSA-17	E0.06	—	—	—	—	—	—	—	—	—	—	1
SOSA-21	—	E0.05	—	E0.1	E0.02	—	—	—	—	—	—	3
SOSA-22	—	—	—	—	—	—	—	—	—	—	V0.02	0
SOSA-25	—	E0.04	—	—	—	—	—	—	—	—	—	1
SOSA-29	E0.02	—	—	—	—	—	—	—	—	—	—	1
SOSA-34	—	E0.04	—	—	—	—	—	—	—	—	—	1
Number of detections	6	5	1	1	1	1	1	0	0	0		16
Detection frequency (percent)	17	14	3	3	3	3	3					³ 31
Flow-path wells												
SOSAFP-01	—	E0.02	—	—	—	—	—	—	—	—	—	1
SOSAFP-04	E0.02	3.44	—	—	—	—	—	E0.01	E0.03	—	—	4
SOSAFP-05	—	0.24	—	—	—	—	—	—	—	—	—	1
SOSAFP-07	—	0.16	—	—	—	E0.05	—	—	—	—	—	2
SOSAFP-08	—	E0.09	—	—	—	—	—	—	—	—	—	1
SOSAFP-09	—	—	—	—	—	—	—	—	—	0.18	—	1
SOSAFP-15	—	E0.04	—	—	—	—	—	—	—	—	—	1

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The MCL-US threshold for trihalomethanes is the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

³Frequency of detection of at least one VOC in the grid wells. Detections with V remark codes are not included.

Table 6. Pesticides and pesticide degradates detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all fifty wells were analyzed, but only samples with detections are listed. Analytes are listed in order of decreasing detection frequency in the thirty-five grid wells. All analytes are listed in [table 3C](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA; California Department of Public Health maximum contaminant level; E, estimated value; LRL, laboratory reporting level; na, not available; µg/L, microgram per liter; —, not detected.]

GAMA well identification number	Atrazine (µg/L) (39632)	Deethyl- atrazine (µg/L) (04040)	Simazine (µg/L) (04035)	Prometon (µg/L) (04037)	Fipronil sulfide (µg/L) (62167)	Pesticide detections per well
LRL	0.007	0.014	0.005	0.01	0.013	
Threshold type¹	MCL-CA	na	MCL-US	HAL-US	na	
Threshold level	1	na	4	100	na	
Grid Wells						
SOSA-03	E0.005	E0.005	—	—	—	2
SOSA-07	—	—	—	—	E0.005	1
SOSA-08	—	—	—	E0.01	—	1
SOSA-11	E0.006	E0.01	0.008	—	—	3
SOSA-14	E0.005	E0.011	E0.005	—	—	3
SOSA-16	0.008	E0.015	E0.007	E0.01	—	4
SOSA-31	—	—	E0.003	—	—	1
SOSA-34	E0.005	E0.013	—	—	—	2
Number of detections	5	5	4	2	1	17
Detection frequency (percent)	14	14	11	6	3	² 23
Flow-path wells						
SOSAFP-04	E0.008	E0.012	—	—	—	2
SOSAFP-07	E0.004	E0.005	—	—	—	2
SOSAFP-08	—	E0.005	—	—	—	1
SOSAFP-09	E0.007	E0.007	E0.003	—	—	3
SOSAFP-15	E0.004	E0.006	E0.006	—	—	3

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²Frequency of detection of at least one pesticide or pesticide degradate in the grid wells.

Table 7. Pharmaceutical compounds detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from all fifty wells were analyzed, but only samples with detections are listed. Analytes are listed in order of decreasing detection frequency in the thirty-five grid wells. All analytes are listed in [table 3D](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; E, estimated value; LRL, laboratory reporting level; na, not available; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality assessment; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Carbamazapine (µg/L) (62793)	Sulfameth-oxazole (µg/L) (62021)	Diphen-hydramine (µg/L) (62796)	Pharma ceutical detections per well
LRL	0.018	0.024	0.023	
Threshold type	na	na	na	
Threshold level	na	na	na	
Grid wells				
SOSA-10	—	—	V0.004	0
SOSA-16	—	0.103	—	1
SOSA-21	E0.009	—	—	1
SOSA-23	—	—	V0.005	0
Number of detections	1	1	0	2
Detection frequency (percent)	3	3		16
Flow-path wells				
SOSAFP-04	E0.004	—	—	1

¹Frequency of detection of at least one pharmaceutical compound in the grid wells.

Table 8. Constituents of special interest [Perchlorate, *N*-Nitrosodimethylamine (NDMA), and 1,2,3-Trichloropropane (1,2,3-TCP)] detected in samples collected in the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Analyses done by the Montgomery Watson-Harza laboratory (laboratory entity code CA-MWHL). Information about analytes given in [table 3F](#). Samples from all fifty wells were analyzed for perchlorate, samples from the twenty-two intermediate and slow wells were sampled for NDMA and 1,2,3-TCP; only wells with at least one detection are listed. SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MRL, method reporting level; NL-CA, California Department of Public Health notification level; µg/L, microgram per liter; na, not analyzed; —, analyzed but not detected]

GAMA well identification number	Perchlorate (µg/L) (61209)	N-Nitroso- dimethylamine (NDMA) (µg/L) (64176)	1,2,3-Trichloro- propane (µg/L) (77443)
Threshold type	NL-CA	NL-CA	NL-CA
Threshold level	6	0.01	0.005
MRL	0.5	0.002	0.005
Grid wells ¹			
SOSA-30	0.96	na	na
SOSA-31	.51	na	na
SOSA-32	.79	na	na
SOSA-34	1.7	na	na
Number of wells with detections	4		
Detection frequency (percent)	11		
Flow-path wells			
SOSAFP-01	1.1	—	—
SOSAFP-10	.92	—	—
SOSAFP-11	1.1	—	*.02
SOSAFP-12	.8	—	—
SOSAFP-14	.69	—	—
SOSAFP-15	1.0	—	—

^{*}Value above threshold level.

¹SOSA-35 was analyzed with an MRL of 5 µg/L for perchlorate.

Table 9. Nutrients and dissolved organic carbon detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from the twenty-two slow and intermediate wells were analyzed. Information about analytes given in [table 3G](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; E, estimated value; LRL, laboratory reporting level; mg/L, milligram per liter; na, not available; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality assessment; —, not detected]

GAMA well identification number	Ammonia, as nitrogen (mg/L) (00608)	Nitrite plus nitrate, as nitrogen (mg/L) (00631)	Nitrite, as nitrogen (mg/L) (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-nitrogen) as nitrogen (mg/L) (62854)	Phosphorous, as orthophosphate (mg/L) (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
Threshold type¹	HAL-US	MCL-US	MCL-US	na	na	na
Threshold level	30	10	1	na	na	na
LRL	0.01	0.06	0.002	0.06	0.006	0.33
Grid wells						
SOSA-03	—	5.10	—	² 4.88	0.055	0.4
SOSA-07	0.040	0.07	E0.002	0.15	0.062	1.4
SOSA-10	0.013	0.93	E0.001	0.96	0.054	0.7
SOSA-13	E0.006	6.28	—	6.53	0.029	V0.3
SOSA-15	E0.006	0.10	—	0.11	0.025	0.4
SOSA-22	—	0.47	—	0.49	0.068	0.8
SOSA-35	0.112	0.06	—	0.11	0.129	na
Flow-path wells						
SOSAFP-01	E0.006	9.02	—	² 8.50	0.040	V0.2
SOSAFP-02	0.081	—	—	0.09	0.014	0.7
SOSAFP-03	—	4.08	—	² 3.91	0.026	V0.2
SOSAFP-04	—	5.48	—	² 5.38	0.031	0.4
SOSAFP-05	E0.007	1.75	—	1.89	0.021	V0.2
SOSAFP-06	—	7.21	—	7.93	0.038	V0.3
SOSAFP-07	—	5.66	—	5.85	0.112	V0.3
SOSAFP-08	E0.006	3.86	—	4.01	0.080	0.4
SOSAFP-09	E0.006	8.08	—	9.03	0.078	0.6
SOSAFP-10	E0.009	3.31	—	3.42	0.093	V0.3
SOSAFP-11	E0.008	2.20	E0.001	2.27	0.058	0.5
SOSAFP-12	E0.007	3.38	E0.002	3.48	0.055	V0.3
SOSAFP-13	E0.007	4.27	E0.002	4.34	0.039	V0.3
SOSAFP-14	—	5.44	—	² 5.31	0.035	0.4
SOSAFP-15	E0.006	6.17	—	6.29	0.066	0.5

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes, but falls within the U.S. Geological Survey National Water Quality Laboratory acceptance criteria of a 10 percent relative percent difference.

Table 10. Major and minor ions and dissolved solids detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from the twenty-two slow and intermediate wells were analyzed. Information about analytes given in [table 3H](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MCL-CA, California Department of Public Health maximum contaminant level; SMCL-CA, California Department of Health Services secondary maximum contaminant level; LRL, laboratory reporting level; mg/L, milligrams per liter; E, estimated value; na, not available; —, not detected]

GAMA well identifica- tion number	Cal- cium (mg/L) (00915)	Magne- sium (mg/L) (00925)	Potas- sium (mg/L) (00935)	Sodium (mg/L) (00930)	Bi- carbo- nate ² (mg/L)	Carbo- nate ² (mg/L)	Bro- mide (mg/L) (71870)	Chlo- ride (mg/L) (00940)	Fluo- ride (mg/L) (00950)	Iodide (mg/L) (71865)	Silica (mg/L) (00955)	Sulfate (mg/L) (00945)	Total dis- solved solids (TDS) (mg/L) (70300)
Threshold type ¹	na	na	na	na	na	na	na	SMCL- CA ³	MCL- CA	na	na	SMCL- CA ³	SMCL- CA ³
Threshold level	na	na	na	na	na	na	na	250 (500)	2	na	na	250 (500)	500 (1,000)
LRL	0.02	0.008	0.16	0.2	1	1	0.02	0.2	0.1	0.002	0.04	0.18	10
Grid wells													
SOSA-03	65.2	19.8	4.64	40.6	302	—	0.07	25.6	0.5	0.004	50.5	47.6	425
SOSA-07	13.6	2.12	1.42	9.32	73	—	E0.01	2.24	0.3	0.004	19.4	3.8	86
SOSA-10	32.7	8.16	2.83	30.7	176	—	0.05	13.5	1.8	0.017	37.7	20.4	241
SOSA-13	62.3	9.03	1.02	25.3	225	—	0.07	13.2	0.1	—	22.8	27.4	300
SOSA-15	37.2	4.06	1.36	6.89	147	—	—	2.05	E0.1	—	33.3	5.3	163
SOSA-22	3.07	0.307	0.80	3.59	21	—	—	0.77	—	—	20.8	0.6	47
SOSA-35	1.84	1.52	4.03	411	825	20	0.25	42.3	0.6	0.011	27.8	171	**1,130
Flow-path wells													
SOSAFP-01	59.5	7.48	0.92	28.6	181	—	0.14	22.7	0.2	—	22.7	41.0	315
SOSAFP-02	56.7	11.1	5.94	31.9	309	—	0.03	11.3	0.4	0.03	36.4	8.5	329
SOSAFP-03	34.6	4.02	1.19	39.3	166	—	0.07	11.2	0.4	—	18.8	28.5	242
SOSAFP-04	61	10.5	1.45	31.0	220	—	0.10	25.0	0.2	—	22.5	41.4	340
SOSAFP-05	42.5	6.95	1.36	35.4	187	—	0.09	14.7	0.4	—	22.7	33.8	266
SOSAFP-06	62.9	8.34	1.00	25.9	208	—	0.10	14.2	0.1	—	23.2	28.8	302
SOSAFP-07	103	26.9	3.08	37.6	285	—	0.20	63.3	0.4	—	35.7	105	*558
SOSAFP-08	80.2	16.7	3.93	31.1	240	—	0.13	37.4	0.4	E0.002	41.2	86.4	456
SOSAFP-09	70.5	20.5	2.51	37.5	261	—	0.15	32.4	0.4	E0.001	25.8	61.0	426
SOSAFP-10	56.3	15.2	3.40	24.1	196	—	0.10	17.7	0.3	—	46.7	66.6	354
SOSAFP-11	42.3	12.3	2.61	38.0	217	—	0.16	24.2	0.4	E0.001	25.4	20.4	267
SOSAFP-12	66.3	13.1	4.37	27.4	183	—	0.12	19.0	0.5	—	42.3	85.1	371
SOSAFP-13	49.7	6.96	0.64	34.9	193	—	0.09	13.4	0.9	—	24.4	31.2	280
SOSAFP-14	66.5	9.06	0.78	33.1	227	—	0.11	17.2	0.4	—	23.9	45.4	341
SOSAFP-15	77.8	12.3	1.11	24.5	239	—	0.11	28.4	0.2	E0.001	24.2	39.4	361

¹Value above recommended threshold level.

²Value above upper threshold level.

³Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

⁴Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values (table 4) using the advanced speciation method (<http://or.water.usgs.gov/alk/methods.html>) with pK1 = 6.35, pK2 = 10.33, and pKW = 14.

⁵The SMCL-CA for chloride, sulfate, and total dissolved solids have recommended and upper threshold values. The upper value is shown in parentheses.

Table 11. Trace elements detected in ground-water samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, July to September 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from the twenty-two slow and intermediate wells were analyzed. All analytes are listed in [table 3H](#). SOSA, Southern Sierra study unit grid-well; SOSAFP, Southern Sierra study unit flow-path well; AL-US, U.S. Environmental Protection Agency action level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; SMCL-CA, California Department of Public Health secondary maximum contaminant level; E, estimated value; LRL, laboratory reporting level; na, not available; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality analyses; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Beryllium (µg/L) (01010)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
Threshold type ¹	MCL-CA	MCL-US	MCL-US	MCL-CA	MCL-US	NL-CA	MCL-US	MCL-CA	na	AL-US	SMCL-CA	AL-US
Threshold level	1,000	6	10	1,000	4	1,000	5	50	na	1,300	300	15
LRL	1.6	0.20	0.12	0.2	0.06	8	0.04	0.040	0.040	0.4	6	0.08
Grid wells												
SOSA-03	E1	E0.12	*10.7	55	—	511	—	1.3	0.172	2.2	11	1.19
SOSA-07	—	—	*23.7	16	—	54	—	0.04	0.133	—	*934	0.22
SOSA-10	2.0	—	0.42	21	—	359	0.05	0.05	0.523	E0.3	239	1.03
SOSA-13	—	—	0.81	78	—	15	—	5.0	0.096	2.3	—	0.88
SOSA-15	—	—	E0.10	38	—	E8	E0.02	0.08	0.058	V0.8	—	4.07
SOSA-22	23	—	—	3	E0.05	E5	—	—	—	1.2	E3	0.08
SOSA-35	E1.0	—	*13.7	2	—	*1,280	E0.02	0.06	E0.029	1.7	229	0.35
Flow-path wells												
SOSAFP-01	—	—	0.92	74	—	51	—	5.8	0.153	V0.8	—	0.33
SOSAFP-02	—	—	*13.2	56	—	226	E0.04	0.05	0.447	E0.4	*4,200	0.43
SOSAFP-03	E0.9	—	1.90	33	—	74	—	3.2	0.087	V0.5	—	E0.04
SOSAFP-04	E1.0	—	1.20	99	—	30	—	2.7	0.142	1.2	—	0.52
SOSAFP-05	E1.0	—	1.30	78	—	42	—	1.4	0.062	1.9	—	1.69
SOSAFP-06	—	—	0.86	73	—	16	—	5.5	0.109	1.2	—	0.71
SOSAFP-07	—	0.25	0.95	76	—	68	0.29	2.6	0.24	1.3	—	0.29
SOSAFP-08	E0.9	—	0.82	74	—	57	0.05	3.3	0.186	2.2	—	0.25
SOSAFP-09	—	—	0.51	201	—	20	0.06	2.4	0.207	4.9	—	0.75
SOSAFP-10	—	—	1.10	49	—	23	0.07	8.4	0.14	V0.9	—	0.20
SOSAFP-11	—	—	0.68	108	—	28	E0.03	1.4	0.106	V0.9	E3	0.18
SOSAFP-12	—	—	0.89	44	—	64	E0.02	3.3	0.161	1.8	—	0.78
SOSAFP-13	—	—	0.59	77	—	116	E0.02	0.86	0.126	V0.9	14	0.75
SOSAFP-14	—	—	0.63	109	—	40	E0.02	2.1	0.144	1.4	9	2.03
SOSAFP-15	E1.0	—	0.85	118	—	22	—	5.4	0.226	1.4	E4	0.63

Table 11. Trace elements detected in ground-water samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, July to September 2006—Continued.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from the twenty-two slow and intermediate wells were analyzed. All analytes are listed in [table 3H](#). SOSA, Southern Sierra study unit grid-well; SOSAFP, Southern Sierra study unit flow-path well; AL-US, U.S. Environmental Protection Agency action level; HAL-US, U.S. Environmental Protection Agency Lifetime Health Advisory; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; NL-CA, California Department of Public Health notification level; SMCL-CA, California Department of Public Health secondary maximum contaminant level; E, estimated value; LRL, laboratory reporting level; na, not available; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality analyses; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Silver (µg/L) (01075)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Threshold type¹	na	SMCL-CA	HAL-US	MCL-CA	MCL-US	SMCL-CA	HAL-US	MCL-US	na	MCL-US	NL-CA	SMCL-CA
Threshold level	na	50	40	100	50	100	4,000	2	na	30	50	5,000
LRL	0.6	0.2	0.4	0.06	0.08	0.2	0.4	0.04	0.06	0.04	0.10	0.6
Grid wells												
SOSA-03	46.2	0.4	2.8	3.19	0.23	—	425	—	0.46	3.98	7.1	7.2
SOSA-07	11.7	*329	6.3	0.47	—	—	86.6	—	1.3	0.55	0.30	15.6
SOSA-10	91.1	*90.7	21.4	1.50	0.30	—	253	—	0.06	3.52	0.94	2.1
SOSA-13	1.0	E0.1	1.1	0.42	0.71	—	294	—	0.2	1.51	11.2	3.8
SOSA-15	5.5	—	0.4	V0.25	0.10	—	334	—	0.12	1.17	0.70	13.5
SOSA-22	2.8	0.4	—	V0.07	—	—	69.1	—	—	0.07	0.24	V0.9
SOSA-35	98.6	3.6	14	V0.25	—	—	29.7	—	1.0	0.06	—	15.4
Flow-path wells												
SOSAFP-01	1.0	—	1.5	2.73	1.8	—	261	—	0.88	1.29	10.5	V1.2
SOSAFP-02	126	*2,250	4.3	2.99	—	—	368	—	0.09	7.59	0.15	5.4
SOSAFP-03	2.2	—	7.8	1.67	0.59	—	223	—	5.8	0.84	15.9	2.0
SOSAFP-04	1.1	—	4.9	1.85	1.5	—	334	—	1.1	1.50	12.8	12.0
SOSAFP-05	1.7	E0.1	4.9	0.36	0.37	—	220	—	22	1.17	11.5	3.4
SOSAFP-06	1.1	—	1.2	0.68	1.1	—	260	—	0.14	1.28	11.3	1.8
SOSAFP-07	1.6	0.2	16.8	2.97	1.7	0.5	344	—	—	4.75	13.6	4.8
SOSAFP-08	4.5	E0.1	14.6	2.59	1.3	—	243	—	—	2.97	15.0	2.3
SOSAFP-09	—	E0.1	11.0	2.70	1.1	—	313	E0.02	—	2.60	14.4	3.5
SOSAFP-10	1.5	E0.1	27.1	2.74	2.3	—	158	—	—	1.31	18.8	V0.9
SOSAFP-11	E0.5	E0.1	10.4	1.76	0.31	—	202	—	E0.04	0.77	16.1	3.3
SOSAFP-12	8.7	E0.1	23.8	2.94	1.6	—	173	—	0.07	0.96	16.4	2.6
SOSAFP-13	5.8	1.5	7.8	1.86	0.74	—	253	0.07	0.11	3.04	4.7	18.0
SOSAFP-14	3.5	3.2	3.8	1.94	1.3	—	310	—	0.48	4.47	6.8	2.6
SOSAFP-15	E0.4	0.3	2.8	3.83	2.4	—	263	—	0.09	2.04	7.9	15.4

*Value above lower threshold level.

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 12. Species of inorganic arsenic, iron, and chromium in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Analyses made by the U.S. Geological Survey Trace Metals Laboratory (laboratory entity code USGSTMCO). Samples from all fifty wells were analyzed for chromium; samples from the twenty-two slow and intermediate wells were analyzed for arsenic and iron; only wells with at least one detection are listed. Information about analytes given in [table 31](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level; MDL, method detection limit; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality assessment; nc, not collected; µg/L, microgram per liter; —, not detected]

GAMA well identification number	Iron (µg/L) (01046)	Iron (II) (µg/L) (01047)	Arsenic (µg/L) (99033)	Arsenic (III) (µg/L) (99034)	Chromium (µg/L) (01030)	Chromium (VI) (µg/L) (01032)
Threshold type ¹	SMCL-CA	na	MCL-US	na	MCL-CA	na
Threshold level [MDL]	300	na	10	na	50	na
	2	2	0.5	1	1	1
Grid wells						
SOSA-02	nc	nc	nc	nc	2	—
SOSA-03	4	19	*11	—	1	—
SOSA-07	*872	854	*25	12	—	—
SOSA-10	223	215	V1.7	—	—	—
SOSA-11	nc	nc	nc	nc	2	2
SOSA-13	—	—	V1.6	—	6	5
SOSA-15	—	—	—	—	—	—
SOSA-22	2	—	—	—	—	—
SOSA-23	nc	nc	nc	nc	7	5
SOSA-25	nc	nc	nc	nc	4	5
SOSA-28	nc	nc	nc	nc	3	2
SOSA-32	nc	nc	nc	nc	2	—
SOSA-34	nc	nc	nc	nc	8	6
Number of detections					9	6
Detection frequency (percent)					26	17
Flow-path wells						
SOSAFP-01	—	—	V2.4	—	7	4
SOSAFP-02	*4,190	4,190	*23	7.7	—	—
SOSAFP-03	3	—	2.7	—	4	3
SOSAFP-04	—	—	V2.4	—	3	2
SOSAFP-05	—	—	2.6	—	2	1
SOSAFP-06	2	—	9.9	—	6	5
SOSAFP-07	nc	nc	nc	nc	2	—
SOSAFP-08	—	—	—	—	4	3
SOSAFP-09	—	—	3.4	—	3	3
SOSAFP-10	2	—	—	—	11	9
SOSAFP-11	3	—	3.1	—	2	2
SOSAFP-12	—	—	—	—	4	4
SOSAFP-13	14	—	V1.6	—	1	—
SOSAFP-14	nc	nc	nc	nc	2	—
SOSAFP-15	4	—	4.0	—	6	6

*Value above threshold level.

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Table 13. Results for analyses of stable isotope ratios and tritium and carbon-14 activities in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Laboratory entity codes are listed in the footnotes. Information about analytes given in [table 3J](#). Samples from all fifty wells were analyzed for stable isotopes of water; samples from twenty-one of the slow and intermediate wells were analyzed for tritium and carbon. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MCL-CA, California Department of Public Health maximum contaminant level; na, not available; nc, sample not collected; pCi/L, picocuries per liter; <, less than]

GAMA well identification number	$\delta^2\text{H}$ (per mil) (82082) ²	$\delta^{18}\text{O}$ (per mil) (82085) ²	Tritium (pCi/L) (99914) ³	$\delta^{13}\text{C}$ (per mil) (82081) ⁴	Carbon-14 (percent modern) (49933) ⁵
Threshold type¹	na	na	MCL-CA	na	na
Threshold level	na	na	20,000	na	na
Grid wells					
SOSA-01	-74.5	-10.44	nc	nc	nc
SOSA-02	-70.8	-9.95	nc	nc	nc
SOSA-03	-87.4	-11.58	10.9	-8.76	70.2
SOSA-04	-78.0	-10.06	nc	nc	nc
SOSA-05	-60.6	-8.60	nc	nc	nc
SOSA-06	-61.8	-8.92	nc	nc	nc
SOSA-07	-101	-13.94	7.7	-11.05	89.3
SOSA-08	-64.2	-8.67	nc	nc	nc
SOSA-09	-71.9	-9.98	nc	nc	nc
SOSA-10	-94.7	-12.70	8.0	-4.97	49.3
SOSA-11	-71.8	-9.87	nc	nc	nc
SOSA-12	-104	-14.20	nc	nc	nc
SOSA-13	-75.6	-10.55	<1	-12.41	81.9
SOSA-14	-80.3	-10.57	nc	nc	nc
SOSA-15	-75.5	-11.07	14.4	-16.11	90.8
SOSA-16	-79.6	-10.54	nc	nc	nc
SOSA-17	-78.8	-10.84	nc	nc	nc
SOSA-18	-76.2	-10.39	nc	nc	nc
SOSA-19	-74.2	-10.05	nc	nc	nc
SOSA-20	-77.6	-10.62	nc	nc	nc
SOSA-21	-77.1	-10.52	nc	nc	nc
SOSA-22	-92.0	-12.95	9.0	-20.75	99.4
SOSA-23	-68.8	-9.53	nc	nc	nc
SOSA-24	-68.8	-9.61	nc	nc	nc
SOSA-25	-67.0	-9.41	nc	nc	nc
SOSA-26	-65.9	-9.57	nc	nc	nc
SOSA-27	-64.6	-9.37	nc	nc	nc
SOSA-28	-75.4	-9.98	nc	nc	nc
SOSA-29	-92.8	-12.72	nc	nc	nc
SOSA-30	-82.2	-10.99	nc	nc	nc
SOSA-31	-83.6	-11.09	nc	nc	nc
SOSA-32	-74.1	-10.56	nc	nc	nc
SOSA-33	-69.3	-9.40	nc	nc	nc
SOSA-34	-70.8	-9.56	nc	nc	nc
SOSA-35	-84.8	-10.61	nc	nc	nc

Table 13. Results for analyses of stable isotope ratios and tritium and carbon-14 activities in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006—Continued.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Laboratory entity codes are listed in the footnotes. Information about analytes given in [table 3J](#). Samples from all fifty wells were analyzed for stable isotopes of water; samples from twenty-one of the slow and intermediate wells were analyzed for tritium and carbon. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MCL-CA, California Department of Public Health maximum contaminant level; na, not available; nc, sample not collected; pCi/L, picocuries per liter; <, less than]

GAMA well identification number	$\delta^2\text{H}$ (per mil) (82082) ²	$\delta^{18}\text{O}$ (per mil) (82085) ²	Tritium (pCi/L) (99914) ³	$\delta^{13}\text{C}$ (per mil) (82081) ⁴	Carbon-14 (percent modern) (49933) ⁵
Threshold type¹	na	na	MCL-CA	na	na
Threshold level	na	na	20,000	na	na
Flow-path wells					
SOSAFP-01	-74.9	-10.08	<1	-11.21	63.8
SOSAFP-02	-100	-13.34	10.2	-3.35	25.0
SOSAFP-03	-75.5	-10.55	<1	-13.01	65.4
SOSAFP-04	-73.7	-10.10	1.6	-12.62	84.4
SOSAFP-05	-75.4	-10.64	<1	-13.23	63.3
SOSAFP-06	-74.5	-10.30	1.3	-10.06	76.0
SOSAFP-07	-68.3	-9.00	5.8	-11.81	103.2
SOSAFP-08	-69.4	-9.34	1.0	-12.82	83.1
SOSAFP-09	-69.1	-9.21	3.2	-12.83	98.8
SOSAFP-10	-69.0	-9.57	<1	-13.61	77.6
SOSAFP-11	-66.6	-9.12	3.2	-12.60	85.1
SOSAFP-12	-71.3	-9.78	<1	nc	nc
SOSAFP-13	-75.0	-10.38	1.3	nc	nc
SOSAFP-14	-75.4	-10.31	1.9	-14.59	69.5
SOSAFP-15	-73.2	-10.13	4.5	-15.42	89.8

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

³USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

⁴University of Waterloo (contract laboratory) (CAN-UWIL).

⁵University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

Table 14. Radioactive constituents detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Analyses made by Eberline Services (laboratory entity code CA-EBRL). Information about analytes given in [table 3J](#). Samples from the seven slow wells were analyzed. SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow-path well; MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; E, estimated value; pCi/L, picocuries per liter; V, analyte detected in sample and an associated blank thus data are not included in ground-water quality assessment; <, less than]

GAMA well identification number	Radium-226 (pCi/L) (09511)	Radium-228 (pCi/L) (81366)	Radon-222 (pCi/L) (82303)	Alpha radioactivity, 72-hour count (pCi/L) (62636)	Alpha radioactivity, 30-day count (pCi/L) (62639)	Beta radioactivity, 72-hour count (pCi/L) (62642)	Beta radioactivity, 30-day count (pCi/L) (62645)
Threshold type¹	MCL-US	MCL-US	proposed MCL-US	MCL-US	MCL-US	MCL-CA	MCL-CA
Threshold value	25	25	³300(4,000)	15	15	50	50
SOSA-03	0.15	E0.34	*E1,670	E2.6	E2.1	E3.9	E3.7
SOSA-07	0.084	E0.45	*2,240	<2.4	<2.2	E1.8	E2.4
SOSA-10	0.24	0.69	*1,480	E3.3	E2.1	E2.7	E2.3
SOSA-13	VE0.019	<0.46	250	E1.1	<3.6	<1.9	<2.9
SOSAFP-02	0.72	1.1	**4,670	11.8	E5.9	7.4	8.9
SOSAFP-05	E0.053	<0.44	E290	E0.7	<2.0	E1.6	<2.5
SOSAFP-06	E0.034	<0.59	210	E1.2	E2.5	<1.2	<2.9

*Value above lower threshold level.

**Value above upper threshold level.

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

²The MCL-US threshold for radium is the sum of radium-226 and radium-228.

³Two MCLs have been proposed for Radon-222. The proposed Alternative MCL is in parentheses.

Table 15. Microbial indicators detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[The five-digit number in parentheses below the constituent name is the U.S. Geological Survey parameter code used to uniquely identify a specific constituent or property. Samples from the seven slow wells were analyzed. Information about analytes given in [table 3L](#). SOSA, Southern Sierra study unit grid well; SOSAFP, Southern Sierra study unit flow path well; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; mL, milliliter]

GAMA well identification number	Total coliforms colonies/100mL (90900)
Threshold type¹	MCL-US
Threshold level	5% of samples per month
SOSA-03	3
SOSA-07	1
SOSAFP-05	1

¹Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

Appendix

Sample Collection and Analysis

Ground-water samples were collected using standard and modified USGS protocols (Koterba and others, 1995; U.S. Geological Survey, variously dated), and protocols described by Weiss, 1968; Shelton and others, 2001; Ball and McClesky, 2003a,b; and Wright and others, 2005. Prior to sampling, each well was pumped continuously in order to purge at least three casing-volumes of water from the well (Wilde and others, 1999). Wells were sampled using Teflon tubing with brass and stainless-steel fittings attached to a sampling point on the well discharge pipe as close to the well as possible. The sampling point was always located upstream of any well-head treatment system or water storage tank. If a chlorinating system was attached to the well, the chlorinator was shut off at least 24 hours prior to purging and sampling the well in order to clear all chlorine out of the system. For the fast and intermediate schedules, samples were collected at the well head using a foot-long length of Teflon tubing. For the slow schedule, the samples were collected inside an enclosed chamber located inside a mobile laboratory and connected to the well head by a 10- to 50- foot length of the Teflon tubing (Lane and others, 2003). All fittings and lengths of tubing were cleaned between samples (Wilde, 2004).

For the field measurements, ground water was pumped through a flow-through chamber fitted with a multi-probe meter that simultaneously measures the water-quality indicators—dissolved oxygen, temperature, pH, turbidity, and specific conductance. Field measurements were made in accordance with protocols in the USGS National Field Manual (Wilde and Radtke, 2005; Wilde, 2006; Lewis, 2006; Radtke and others, 2005; Wilde and others, 2006). All sensors on the multi-probe meter were calibrated daily. Measured temperature, dissolved oxygen, pH, and specific conductance values were recorded at 5-minute intervals for at least 30 minutes, and when these values remained stable for 20 minutes, samples for laboratory analyses were then collected. Field measurements and instrument calibrations were recorded by hand on field record sheets and electronically in PCFF-GAMA, a software package designed by the USGS with support from the GAMA program. Analytical service requests were also managed by PCFF-GAMA. Information from PCFF-GAMA was uploaded directly into NWIS at the end of every week of sample collection.

For analyses requiring filtered water, ground water was diverted through a 0.45- μm pore size vented capsule filter, a disk filter, or a baked glass-fiber filter depending on the protocol for the analysis (Wilde and others, 1999; Wilde and others, 2004). Prior to sample collection, polyethylene sample bottles were pre-rinsed two times using deionized water, and then once with sample water before sample collection. Samples requiring acidification were acidified to a pH of 2 or less with the appropriate acids using ampoules of certified, traceable concentrated acids obtained from the USGS National Water Quality Laboratory (NWQL).

Temperature-sensitive samples were stored on ice prior to, and during, daily shipping to the various laboratories. The non-temperature sensitive samples for tritium, noble gases, chromium speciation, and stable isotopes were shipped monthly, while volatile organic compounds, pesticides, compounds of special interest, dissolved organic carbon, radium isotopes, gross alpha and beta radioactivity, and radon-222 samples were shipped daily.

Detailed sampling protocols for individual analyses and groups of analytes are described in Koterba and others (2005) and the USGS National Field Manual (Wilde and others, 1999; Wilde and others, 2004) and in the references for analytical methods listed in [table A1](#); only brief descriptions are given here. Volatile organic compounds (VOCs) and gasoline oxygenates and degradates, and 1,2,3-trichloropropane (1,2,3-TCP) samples were collected in 40-mL sample vials that were purged with three vial volumes of sample water before bottom filling to eliminate atmospheric contamination. Six normal (6 N) hydrochloric acid (HCl) was added as a preservative to the VOC samples, but not to the gasoline oxygenate and degradate samples, or the 1,2,3-TCP samples. The perchlorate sample was collected in a 125-mL polyethylene bottle. Tritium samples were collected by bottom filling two 1-L polyethylene bottles with unfiltered ground water, after first overfilling the bottle with three volumes of water. Stable isotopes of water were collected in 60-mL clear glass bottles filled with unfiltered water, sealed with a conical cap, and secured with electrical tape to prevent leakage and evaporation.

Pesticides and pesticide degradation products, wastewater-indicator constituents, pharmaceutical compounds, and *N*-nitrosodimethylamine (NDMA) samples were collected in 1-L baked amber bottles. Pesticide, wastewater-indicator, and pharmaceutical samples were filtered through a glass fiber during collection, whereas the NDMA samples were filtered at the Montgomery Watson-Harza Laboratory prior to analysis.

Ground-water samples for major and minor ions, trace elements, alkalinity, and total dissolved solids analyses required filling one 250-mL polyethylene bottle with raw ground water, and one 500-mL and one 250-mL polyethylene bottle with filtered ground water (Wilde and others, 2004). Filtration was done using a Whatman capsule filter. The 250-mL filtered sample was then preserved with 7.5 N nitric acid. Mercury samples were collected by filtering ground water into a 250-mL glass bottle and preserving with 6 N hydrochloric acid. Arsenic and iron speciation samples were filtered into a 250-mL polyethylene bottle that was covered with tape to prevent light exposure, and preserved with 6 N hydrochloric acid. The nutrient sample was filtered into a 125-mL brown polyethylene bottle. Radium isotopes and gross alpha and beta radiation samples were filtered into 1-L polyethylene bottles and acidified with nitric acid. Carbon isotope samples were filtered and bottom filled into two 500-mL glass bottles that were first overfilled with three bottle volumes of ground water. These samples had no headspace, and were sealed with a conical cap to avoid atmospheric contamination. Samples for alkalinity titrations were collected by filtering ground water into a 500-mL polyethylene bottle.

DOC, chromium, radon-222, dissolved gases, and microbial constituents were collected from the hose bib at the well head, regardless of the sampling schedule (fast, intermediate, or slow). DOC was collected after rinsing the sampling equipment with universal blank water (Wilde and others, 2004). Using a 50-mL syringe and 0.45- μ m disk filter, the ground-water sample then was filtered into a 125-mL baked glass bottle and preserved with 4.5 N sulfuric acid. Chromium speciation samples were collected using a 10-mL syringe with an attached 0.45- μ m disk filter. After the syringe was thoroughly rinsed and filled with ground water, 4 mL was forced through the disk filter; the next 2 mL of the ground water was slowly filtered into a small centrifuge vial for analysis of total chromium. Hexavalent chromium, Cr (VI), was then collected by attaching a small cation exchange column to the syringe filter, and after conditioning the column with 2 mL of sample water, 2 mL was collected in a second centrifuge vial. Both vials were preserved with 10 μ L of 7.5 N nitric acid (Ball and McClesky, 2003a,b).

For the collection of radon-222, a stainless steel and Teflon valve assembly was attached to the sampling port at the well head (Wilde and others, 2004). The valve was partially closed to create back pressure, and a 10-mL sample was taken through a Teflon septum on the valve assembly using a glass syringe affixed with a stainless steel needle. The sample was then injected into a 25-mL vial partially filled with scintillation mixture (mineral oil) and shaken. The vial was then placed in a cardboard tube in order to shield it from light during shipping.

Noble gases were collected in 3/8-in copper tubes using reinforced nylon tubing connected to the hose bib at the well-head. Ground water was flushed through the tubing to dislodge bubbles before flow was restricted with a back pressure valve. Clamps on either side of the copper tube were then tightened, trapping a sample of ground water for analyses of noble gases (Weiss, 1968).

Samples for analysis of microbial constituents also were collected at the well head (Myers, 2004; Bushon, 2003). Prior to the collection of samples, the sampling port was sterilized using isopropyl alcohol, and ground water was run through the sampling port for at least three minutes to remove any traces of the sterilizing agent. Two sterilized 250-mL bottles were then filled with ground water for coliform analyses (total and *Escherichia coli* coliform determinations), and one sterilized 3-L carboy was filled for coliphage analyses (F specific and somatic coliphage determinations).

Ten laboratories performed chemical and microbial analyses for this study (see [table A1](#)), although most of the analyses were performed at the NWQL or by labs contracted by the NWQL. The NWQL maintains a rigorous quality assurance program (Maloney, 2005; Pirkey and Glodt, 1998). Laboratory quality control samples, including method blanks, continuing calibration verification standards, standard reference samples, reagent spikes, external certified reference materials, and external blind proficiency samples, are analyzed regularly. Method detection limits are continuously tested and laboratory reporting levels updated accordingly. NWQL maintains National Environmental Laboratory Accreditation Program (NELAP) and other certifications (<http://nwql.usgs.gov/Public/Performance/publiclabcertcoverpage.html>). In addition, the Branch of Quality Systems within the USGS Office of Water Quality maintains independent oversight of quality assurance at the NWQL and labs contracted by the NWQL. The Branch of Quality Systems also runs a national field quality assurance program that includes annual testing of all USGS field personnel for proficiency in making field water-quality measurements (<http://nfqa.cr.usgs.gov/>). Results for analyses made at the NWQL or by laboratories contracted by the NWQL are uploaded directly into NWIS by the NWQL. Laboratory quality-control data are also stored in NWIS.

Turbidity, alkalinity, and total coliforms and *Escherichia coli* coliform (*E. coli*) were measured in the mobile laboratory at the well site. Turbidity was measured in the field with a calibrated turbidity meter. Total coliforms and *E. coli* plates were prepared using sterilized equipment and reagents (Myers, 2004). Plates were counted under an ultraviolet light, following a 22–24 hour incubation time. Alkalinity and the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) were measured on filtered samples by Gran's titration method (Rounds, 2006).

Concentrations of HCO_3^- and CO_3^{2-} were also calculated from the laboratory alkalinity and pH measurements. Calculations were made using the advanced speciation method (<http://or.water.usgs.gov/alk/methods.html>) with $\text{p}K_1 = 6.35$, $\text{p}K_2 = 10.33$, and $\text{p}K_w = 14$.

Data Reporting

Laboratory Reporting Conventions

The USGS NWQL uses the laboratory reporting level (LRL) as a threshold for reporting analytical results. The LRL is set to minimize the reporting of false negatives (not detecting a compound when it is actually present in a sample) to less than 1 percent (Childress and others, 1999). The LRL is set at two times the long-term method detection level (LT-MDL). The LT-MDL is derived from the standard deviation of at least 24 MDL determinations made over an extended period of time. LT-MDLs are continually monitored and updated. The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the concentration is greater than zero (at MDL there is less than 1 percent chance of a false positive) (U.S. Environmental Protection Agency, 2002a). The USGS NWQL updates LRL values regularly and the values listed in this report were in effect during the period analyses were made for ground-water samples from the SOSA study (June and July, 2006).

Some compound concentrations in this study are reported using minimum reporting levels (MRLs) or method uncertainties. The MRL is the smallest measurable concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995). The method uncertainty generally indicates the precision of a particular analytical measurement; it gives a range of values wherein the true value will be found.

Detections between the LRL and the LT-MDL are reported as estimated concentrations (designated with an “E” before the values in the tables and text). For information-rich methods, detections below the LRL have high certainty of detection, but the precise concentration is uncertain. Information-rich methods are those that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection (VOCs, gasoline oxygenates and degradates, pesticides, pharmaceuticals, and wastewater-indicators). Compounds are identified by presence of characteristic fragmentation patterns in their mass spectra in addition to being quantified by measurement of peak areas at their associated chromatographic retention times. E-values also may result from detections outside the range of calibration standards, for detections that did not meet all laboratory quality-control criteria, and for samples that were diluted prior to analysis (Childress and others, 1999).

Detections that may have resulted from sample contamination are reported with a “V” before the values in the tables. The potential for sample contamination was assessed using results from field, source, and laboratory blanks.

The reporting levels for radiochemical constituents (gross-alpha radioactivity, gross-beta radioactivity, radium-226, and radium-228) are based on a sample-specific minimum detectable concentration (SSMDC), a sample-specific critical value, and the combined standard uncertainty (CSU) (U.S. Environmental Protection Agency, 2004; Bennett and others, 2006). A result above the critical value represents a greater-than-95-percent certainty that the result is greater than zero (significantly different from the instrument’s background response to a blank sample), and a result above the SSMDC represents a greater-than-95-percent certainty that the result is greater than the critical value. Using these reporting level elements, three unique cases are possible when screening the raw analytical data. If the analytical result is less than the critical value (case 1), the analyte is considered not detected, and the concentration is reported as less than the SSMDC. If the analytical result is greater than the critical value, the ratio of the CSU to the analytical result is calculated as a percent (percent relative CSU). For those samples with percent relative CSU greater than 20 percent, concentrations are reported as estimated values (designated by an “E” preceding the value) (case 2). For those samples with percent relative CSU less than 20 percent, concentrations are reported unqualified (case 3).

Stable isotopic compositions of oxygen, hydrogen, and carbon are reported as relative isotope ratios in units of per mil using the standard delta notation (Coplen and others, 2002):

$$\delta^i E = \left[\frac{R_{\text{sample}}}{R_{\text{reference}}} - 1 \right] \cdot 1000$$

where

- | | | |
|------------------------|----|---|
| $^i E$ | is | the heavier isotope (oxygen-18, carbon-13, or hydrogen-2) |
| R_{sample} | is | the ratio of the abundance of the heavier isotope to the lighter isotope (oxygen-16, carbon-12, or hydrogen-1) in the sample and, |
| $R_{\text{reference}}$ | is | the ratio of the abundance of the heavier isotope to the lighter isotope in the reference material |

The reference material for oxygen and hydrogen is Vienna Standard Mean Ocean Water (VSMOW), which is assigned $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values of 0 per mil (note that ^2H is also written as δD because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium). The reference material for carbon is Vienna Pee Dee Belemnite (VPDB), which is assigned a $\delta^{13}\text{C}$ value of 0 per mil. Positive values indicate enrichment of the heavier isotope and negative values indicate depletion of the heavier isotope, compared to the ratios observed in the standard reference material.

Constituents on Multiple Analytical Schedules

Twenty-seven constituents targeted in this study are measured by more than one analytical schedule or more than one laboratory (table A2). Results from certain analytical schedules are preferred over others because the methodology is more accurate or precise and generally yields greater sensitivity for a given compound.

The preferred methods for the nineteen constituents analyzed under multiple analytical schedules at the NWQL were selected based on the procedure recommended by the NWQL (http://www.nwql.cr.usgs.gov/USGS/Preferred_method_selection_procedure.html). This procedure generally results in the preferred method being the one with the lower reporting limit. The nineteen constituents each appear on two of the following analytical schedules: VOCs (Schedule 2020), gasoline oxygenates and degradates (Schedule 4024), pesticides (Schedule 2003), pharmaceutical compounds (Schedule 2080), and wastewater-indicator compounds (Schedule 1433) (table A2). Only the values determined by the preferred method are reported. This report uses Schedule 2080 (table 3D) as the preferred method for caffeine because it has the lower detection limit and for data consistency; however, as of 2007, NWQL considered Schedule 1433 (table 3E) the preferred method because Schedule 2080 only became an NWQL method in 2005 and therefore has a relatively short history of quality-assurance data. All ground-water samples were analyzed for pharmaceuticals (Schedule 2080), but only six were analyzed for wastewater-indicator constituents (Schedule 1433).

The water-quality indicators—pH, specific conductance, and alkalinity—were measured in the field and at the NWQL. The field measurements are the preferred method for all three constituents; however, laboratory alkalinity results were used in this report because fewer samples had field alkalinity measurements.

The field and laboratory data were compared using the Wilcoxon signed-rank test, a non-parametric statistical test that is analogous to the parametric statistical test, the paired t-test (Helsel and Hirsch, 2002). A non-parametric test was used because the data are not normally distributed. The Wilcoxon signed-rank test evaluates the null hypothesis that the median of the paired differences between the two data sets is zero. Results are reported as the probability, P, of obtaining the observed distribution of data, or one even less likely, when the null hypothesis is true. Therefore, a P value of 0.01 indicates 99 percent confidence that the two data sets are different.

Specific conductance was measured in both the field and the laboratory for twenty-two samples, and there was no difference between the two data sets ($P = 0.19$). Both laboratory and field pH measurements were made for ten samples, and the two data sets were systematically different ($P = 0.006$). Field pH values were lower by a median of 0.3 pH units. The increase in pH between field and laboratory measurement may be explained by equilibration of the sample with

the atmosphere after collection. The partial pressure of CO_2 in ground water is often greater than the atmospheric partial pressure (Appelo and Postma, 2005), thus CO_2 degasses from the ground water when it is brought in contact with the atmosphere. CO_2 loss results in increased pH. Field and laboratory alkalinities were measured for seven samples, and the two data sets were not significantly different ($P = 0.035$). Field alkalinity values were lower by a median of 5 mg/L as CaCO_3 , but the differences between the field and laboratory values were less than 4 percent for all but one sample, which was within the error of the alkalinity measurement (Rounds, 2006).

For arsenic, chromium, and iron concentrations, the standard methods used by the NWQL are preferred over the research methods used by the USGS Trace Metal Laboratory. The concentrations measured by the Trace Metal Laboratory are used only to calculate ratios of redox species for each

element, $\frac{\text{As(V)}}{\text{As(III)}}$ for arsenic, $\frac{\text{Cr(VI)}}{\text{Cr(III)}}$ for chromium, and $\frac{\text{Fe(III)}}{\text{Fe(II)}}$ for iron. For example:

$$\frac{\text{Fe(III)}}{\text{Fe(II)}} = \frac{\text{Fe(T)} - \text{Fe(II)}}{\text{Fe(II)}}$$

where

- Fe(T) is the total iron concentration (measured)
- Fe(II) is the concentration of ferrous iron (measured)
- Fe(III) is the concentration of ferric iron (calculated).

Quality Assurance

Blanks

Blank samples (blanks) were collected using water (Nitrogen-Purged Universal blank water) certified by the NWQL to contain less than the LRL or MRL of the analytes investigated in the study. Two types of blanks were collected: source-solution and field blanks. Source-solution blanks were collected to verify that the blank water used for the field blanks was free of analytes. Field blanks were collected at 12 percent of the wells sampled and source solution blanks at 8 percent of the wells sampled to determine if equipment or procedures used in the field or laboratory introduced contamination. Field blanks were analyzed for VOCs; gasoline oxygenates and degradates; pesticides; pharmaceuticals; perchlorate; NDMA; 1,2,3-TCP; nutrients; dissolved organic carbon; major and minor ions; trace elements; iron, arsenic, and chromium speciation; and radioactive constituents (table A3). Universal blank water is not available for tritium or noble gases, thus field blanks were not collected for these constituents.

Source-solution blanks were collected at the sampling site by pouring blank water directly into sample containers that were preserved, stored, shipped, and analyzed in the same manner as the ground-water samples. For field blanks, blank water was either pumped or poured through the sampling equipment (fittings and tubing) used to collect ground water, then processed and transported using the same protocols for the ground-water samples. The equipment used to collect samples from wells on the slow schedule was different than the equipment used to collect samples from wells on the fast and intermediate schedules; therefore, detections in field blanks collected at slow wells were compared with detections in ground-water samples from slow wells, and detections in field blanks collected at fast and intermediate wells were compared with detections in ground-water samples from fast and intermediate wells.

If a constituent was detected in a field blank, the associated source-solution blank results were examined for similar constituent detections. If the field blank and the source-solution blank contained the constituent, then the source solution water was interpreted as the origin of the contamination in the blanks, and the field blank detections using the same blank water were disregarded. If the sample collected just prior to the contaminated field blank had high concentrations of the constituents in question, carry-over was considered to be the cause of the contamination.

If the presence of a constituent in a field blank could not be accounted for by contamination of the source-solution, carry-over, or a specific problem recorded in the field notes, then that field blank detection was used to censor detections in all ground-water samples collected with the same equipment. The censoring level was defined as the concentration of the constituent in the field blank plus one-half the LRL for that constituent. Detections in ground-water samples below the censoring level were censored. Censored values are indicated by a 'V' preceding the value in the tables, and are excluded from the summary statistics.

Replicates

Sequential replicate samples were collected to assess variability that may result from the processing and analyses of inorganic and organic constituents. Relative standard deviation (RSD) of the measured values was used in determining the variability between replicate pairs for each compound (tables A4A–D). The RSD is defined as 100 times the standard deviation divided by the mean concentration for each replicate pair of samples. If one value in a sample pair was reported as a non-detection and the other value was reported as an estimate below the LRL or MRL, the RSD was set to zero because the values are analytically identical. If one value in a sample pair was reported as a non-detection and the other value was

greater than the LRL or MRL, then the non-detection value was set equal to one-quarter of the LRL and the RSD was calculated (Hamlin and others, 2002). Values of RSD less than 20 percent are considered acceptable in this study. An RSD value of 20 percent corresponds to a relative percent difference (RPD) value of 29 percent. High RSD values for a compound may indicate analytical uncertainty at low concentrations, particularly for concentrations within an order of magnitude of LT-MDL or MDL. Sequential replicate samples were collected at 18 percent of the wells sampled.

Matrix Spikes

Addition of a known concentration of a constituent ('spike') to a replicate environmental sample enables the analyzing laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. The known compounds added in matrix spikes are the same as those being analyzed in the method. This enables an analysis of matrix interferences on a compound by compound basis. Matrix spikes were added at the laboratory performing the analysis. Compounds with low recoveries are of potential concern if environmental concentrations are close to the MCLs; a concentration below an MCL could be falsely indicated. Conversely, compounds with high recoveries are of potential concern if the environmental concentrations exceed MCLs: a high recovery could falsely indicate a concentration above the MCL.

Acceptable ranges for matrix-spike recoveries are based on the acceptable ranges established for laboratory "set" spike recoveries. Laboratory set spikes are aliquots of laboratory blank water to which the same spike solution used for the matrix spikes has been added. One set spike is analyzed with each set of samples. Acceptable ranges for set spike recoveries are 70 to 130 percent for NWQL schedules 2020, 4024, and 1433 (Connor and others, 1998; Rose and Sandstrom, 2003; Zaugg and others, 2002), 60 to 120 percent for NWQL schedule 2003 (Sandstrom and others, 2001), and 60 to 130 percent for schedule 2080 (Kolpin and others, 2002). Based on these ranges, we defined 70 to 130 percent as the acceptable range for matrix-spike recoveries for organic compounds in this study.

Matrix spikes were performed for VOCs, gasoline oxygenates and degradates, pesticides, pharmaceuticals, wastewater-indicators, NDMA, and 1,2,3-TCP because the analytical methods for these constituents are chromatographic methods that may be susceptible to matrix interferences. Replicate samples for matrix-spike additions were collected at 12 percent of the wells sampled, although not all analyte classes were tested at every well (tables A5A–E).

Surrogates

Surrogate compounds are added to environmental samples in the laboratory prior to analysis in order to evaluate the recovery of similar constituents. Surrogate compounds were added to all ground-water and quality-control samples that were analyzed for VOCs, gasoline oxygenates and degradates, pesticides, pharmaceuticals, wastewater-indicators, NDMA, and 1,2,3-TCP (table A6). Most of the surrogate compounds are deuterated analogs of compounds being analyzed. For example, the surrogate toluene-d8 used for the VOC analytical method has the same chemical structure as toluene, except that the eight hydrogen-1 atoms on the molecule have been replaced by deuterium (hydrogen-2). Toluene-d8 and toluene behave very similarly in the analytical procedure, but the small mass difference between the two results in slightly different chromatographic retention times, thus the use of a toluene-d8 surrogate does not interfere with the analysis of toluene (Grob, 1995). Only 0.015 percent of hydrogen atoms are deuterium (Firestone and others, 1996), thus deuterated compounds like toluene-d8 do not occur naturally and are not found in environmental samples. Surrogates are used to identify general problems that may arise during sample analysis that could affect the analysis results for all compounds in that sample. Potential problems include matrix interferences (such as high levels of dissolved organic carbon) that produce a positive bias, or incomplete laboratory recovery (possibly due to improper maintenance and calibration of analytical equipment) that produces a negative bias. A 70 to 130 percent recovery of surrogates is generally considered acceptable; values outside this range indicate possible problems with the processing and analysis of samples (Connor and others, 1998; Sandstrom and others, 2001).

Quality-Control Sample Results

Detections in Field and Source-Solution Blanks

Field blanks were collected at approximately 12 percent of the sites sampled in SOSA. Table A3 presents a summary of detections in field blanks. The only VOC observed in field blanks was toluene. Toluene was detected in one of the six field blanks at a concentration of E0.02 µg/L. The field blank with the detection was collected using the “fast” and “intermediate” schedule equipment. However, low levels of toluene have been detected in source-solution and field blanks collected using both the “slow” and “intermediate” and “fast” equipment sets in many of the earlier study units (Wright and others, 2005; Kulongoski and others, 2006; Bennett and others, 2006; Dawson and others, 2007; Kulongoski and Belitz, 2007). Thus, the detection in the field blank was used to censor data collected using both equipment sets. Toluene was detected at a concentration of E0.02 µg/L in two ground-water samples; both of these detections were censored (tables 5 and A3).

Field blanks were collected at three of the twenty-two sites sampled for analysis of trace elements. Chromium was detected in all three field blanks at concentrations of E0.02, E0.02, and E0.03 µg/L. The field blank with a chromium concentration of E0.03 µg/L was accompanied by a source-solution blank that also had a concentration of E0.03 µg/L. The lowest concentration detected in ground-water samples was 0.04 µg/L; thus, no chromium data were censored on the basis of detections in the field blanks. Zinc was detected in two of three field blanks at concentrations of E0.5 µg/L and 1.40 µg/L. Three detections of zinc in ground-water samples with concentrations less than 1.7 µg/L (1.4 µg/L plus one-half the LRL of 0.6 µg/L) were therefore censored (tables 11 and A3). Barium and lead were each detected in one field blank, but at concentrations lower than found in the environmental samples, thus no data were censored. Copper and nickel were detected in one field blank at concentrations of 0.94 µg/L and 0.29 µg/L, respectively. The field blank containing copper and nickel and was collected using the “intermediate” schedule equipment. Six detections of copper in ground-water samples collected using the “intermediate” schedule equipment with concentrations less than 1.1 µg/L (0.94 µg/L plus one-half the LRL of 0.4 µg/L), and three detections of nickel with concentrations less than 0.32 µg/L (0.29 µg/L plus one-half the LRL of 0.03 µg/L) were therefore censored (tables 11 and A3). This resulted in censoring of three detections of copper and one detection of nickel in ground-water samples (tables 11 and A3).

Field blanks were collected at five of the fifty sites sampled for chromium species analysis at the USGS Trace Metal Laboratory (TML) and two of the twenty-two sites sampled for arsenic and iron species at the TML. One source-solution blank was collected for chromium, iron, and arsenic species analysis. None of the field or source-solution blanks contained iron or chromium. One field blank contained 2.3 µg/L of arsenic. The source-solution blank contained 4.3 µg/L of arsenic, but arsenic was not detected in the source solution blank and field blank collected at the same time for analysis by the NWQL. Five detections of arsenic in ground-water samples analyzed by the TML at concentrations less than 2.55 µg/L (2.3 µg/L plus one-half the MDL of 0.5 µg/L) were censored (tables 12 and A3).

DOC was detected in one field blank at a concentration of E0.2 mg/L, and low concentrations of DOC were detected in field blanks collected in previous GAMA study units (Kulongoski and Belitz, 2007; Bennett and others, 2006). Thus, the data for all ground-water samples with concentrations of E0.2 mg/L and E0.3 mg/L were censored (tables 9 and A3).

One field blank was collected for analysis of radioactive constituents. Radium-226 was detected at an activity of E0.02 pCi/L in the field blank. The one detection of radium-226 at an activity less than the activity measured in the blank

was censored ([table 15](#) and [A3](#)). No other radioactive constituents were detected in the field blank.

No compounds were detected in field blanks for the following analyte groups: pesticides and pesticide degradates (five field blanks), pharmaceutical compounds (six field blanks), wastewater-indicator compounds (one field blank), perchlorate (three field blanks), NDMA and 1,2,3-TCP (two field blanks), major and minor ions (three field blanks), and nutrients (three field blanks).

Variability in Replicate Samples

[Tables A4A–D](#) summarize the results of replicate analyses for constituents detected in ground-water samples collected in the SOSA study. Nearly 300 replicate analyses were made for constituents detected in at least one ground-water sample. Replicate analyses that were non-detections are not reported in [tables A4A–D](#). Concentrations or activities in the environmental and replicate samples are reported for all replicate analyses with RSD values greater than zero. Most replicate analyses had RSD values less than 5 percent and only twelve had RSD values greater than the acceptable limit of 20 percent. Constituents with replicate analyses with RSD values greater than 20 percent include acetaminophen ([table A4A](#)), perchlorate ([table A4A](#)), DOC ([table A4B](#)), aluminum ([table A4C](#)), zinc ([table A4C](#)), tritium ([table A4D](#)), and iron, arsenic, and chromium analyzed by the USGS Trace Metal Laboratory ([table A4C](#)). However, with the exception of one zinc replicate analysis, the magnitudes of the concentrations of the replicate sample pairs with RSD values greater than 20 percent were all within a factor of five of the LRLs for the respective analytes. At these low concentrations, small deviations in measured values result in large RSDs. The tritium replicate analyses were within laboratory analytical uncertainty of one another. Only four replicate analyses included one detection and one non-detection (aluminum, acetaminophen, and iron and arsenic analyzed at the Trace Metal Laboratory) and the detected concentrations were less than twice the LRLs. No data were censored as a result of variability in replicate analyses.

Matrix-Spike Recoveries

[Tables A5A–E](#) present a summary of matrix-spike recoveries for the SOSA study. Addition of a spike or known concentration of a constituent to an environmental sample enables the analyzing laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. Six environmental samples were spiked with VOCs to calculate matrix-spike recoveries ([table A5A](#)). Sixty-eight of the eighty-eight VOC spike compounds had recoveries within the acceptable range of 70 and 130 percent. Fifteen VOC spike compounds had at least one matrix-spike recovery greater than 130 percent; however,

only two of these compounds were detected in ground-water samples. All six matrix-spike recoveries for carbon tetrachloride (tetrachloromethane) were greater than 130 percent (median 188 percent), suggesting that measured concentrations in environmental samples may be disproportionately high. An “E” code was given to the one detection of carbon tetrachloride to indicate that the magnitude of the concentration is uncertain ([table 5](#)). Of the six matrix spikes for trichlorofluoromethane (CFC-11) only two had recoveries greater than 130 percent and neither of the two environmental samples with trichlorofluoromethane detections was analyzed in the same batch as the matrix spike with high recoveries. Thus, the trichlorofluoromethane detections were not flagged. Dichlorodifluoromethane, dichloromethane, 1,2,3,4-tetramethylbenzene, 1,2,3,5-tetramethylbenzene, and 1,2,3-trichlorobenzene had median matrix-spike recoveries below 70 percent, but these compounds were not detected in ground-water samples ([table 12](#)). [NOTE – low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations].

Five ground-water samples were spiked with pesticide and pesticide degradate compounds in order to calculate matrix-spike recoveries. Twenty-eight of the sixty-three spike compounds had recoveries within the acceptable range of 70 and 130 percent ([table A5B](#)). All five of the compounds detected in ground-water samples had spike recoveries within the acceptable range. Three spike compounds had at least one recovery greater than 130 percent. Thirty-three spike compounds had at least one recovery below 70 percent, and the median recovery was below 70 percent for fifteen compounds. [NOTE – low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations].

Four ground-water samples were spiked with pharmaceutical compounds. Eight of the fourteen pharmaceutical compounds had recoveries within the acceptable range of 70 to 130 percent, and six compounds had recoveries less than 70 percent for at least one of the four tests ([table A5C](#)). Two compounds detected in ground-water samples, diphenhydramine and sulfamethoxazole, had low recoveries in all four spiked samples. [NOTE – low recoveries may indicate that the compound might not have been detected in some samples if it was present at very low concentrations].

One ground-water sample was spiked with wastewater-indicator compounds. Sixteen of the sixty-two compounds had recoveries less than 70 percent and one had recovery greater than 130 percent ([table A5D](#)). One of the compounds detected in ground-water samples, tetrachloroethene (PCE), had a recovery of only 15 percent, but the wastewater-indicator analytical method (NWQL schedule 1433) is not the preferred analytical method for tetrachloroethene ([table A2](#)).

Three ground-water samples were spiked with NDMA and 1,2,3-TCP. All spike recoveries were within the acceptable range of 70 to 130 percent ([table A5E](#)).

Surrogate Compound Recoveries

Surrogate compounds were added to environmental samples in the laboratory and analyzed to evaluate the recovery of similar constituents. [Table A6](#) lists the surrogate, analytical schedule on which it was applied, the number of analyses for blank and non-blank samples, the number of surrogate recoveries below 70 percent, and the number of surrogate recoveries above 130 percent for the blank and non-blank samples. Blank and non-blank samples were considered separately to assess whether the matrices present in non-blank samples affect surrogate recoveries. No systematic differences between surrogate recoveries in blank and non-blank samples were observed. All surrogate recoveries in analyses of pharmaceutical compounds were in the acceptable range of 70 to 130 percent recovery, as were 90 percent of the surrogate recoveries for VOC and gasoline oxygenate and degradate analyses, and 93 percent of the surrogate recoveries for pesticide, NDMA, and 1,2,3-TCP analyses. Two-thirds of the surrogate recoveries for wastewater-indicator constituent analyses were in the acceptable range.

Three environmental samples with detections of VOCs had recoveries of the surrogate 1,2-dichloroethane-d4 greater than 130 percent. The three VOCs detected in these three samples all elute near 1,2-dichloroethane-d4 in the chromatographic sequence. A high recovery for a surrogate suggests that the measured concentrations of analytes eluting near the surrogate may be biased to higher concentrations. All three detections already had 'E' codes, thus no additional flagging was needed.

Internal Laboratory Quality-Control Samples for Pharmaceutical Compounds

The protocols for analysis of pharmaceutical compounds (NWQL schedule 2080) has been used for routine sample analysis since October 2005, but due to the newness of the method compared with the other methods of analysis used in this study, an extra level of quality-control assessment was applied to the pharmaceutical data. In addition to the results for field blanks, matrix-spike recoveries, surrogates recoveries, and replicate variability, results for internal laboratory quality-control samples that were run with SOSA ground-water samples were compiled and examined. The fifty ground-water samples were analyzed in eleven different laboratory sets. Each set also included a set blank and a set spike. Purified water (de-ionized, carbon-filtered, and ultraviolet-radiation sterilized) was used for the set blanks and the matrix water for the set spikes (Kolpin and others, 2002).

Ten of the eleven set blanks had no detections of any pharmaceutical compounds. Diphenhydramine and carbamazepine were detected in one set blank at concentrations of E0.0005 µg/L and E0.0006 µg/L, respectively ([table A7A](#)). Detections in a set blank may indicate contamination of laboratory equipment that may affect other samples analyzed in the same set. Diphenhydramine and carbamazepine were each detected once in ground-water samples analyzed in the same set as the set blank containing those constituents. The concentrations in the ground-water samples were more than ten times the concentrations in the set blanks, thus the detections in the ground-water samples were not censored on this basis. However, examination of set blanks for laboratory sets containing GAMA ground-water samples collected between October 2005 and March 2007 showed that diphenhydramine was consistently detected in more than 20 percent of the set blanks. Due to this unacceptably high rate of low-level contamination, all detections of diphenhydramine were censored, even if the concentration in the ground-water sample was more than ten times greater than the concentration in the set blanks.

Recoveries of spike constituents in the set spike samples ([table A7B](#)) were similar to those in the ground-water matrix-spike samples ([table A5C](#)). Six of the fourteen pharmaceutical compounds had recoveries within the acceptable range of 70 to 130 percent in all eleven set spikes. Of the remaining eight

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories.

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule	Citation(s)
Water-quality indicators			
Field parameters		USGS field measurement	U.S. Geological Survey, variously dated
Organic constituents			
VOCs	Purge and trap capillary gas chromatography/mass spectrometry	NWQL, schedule 2020	Connor and others, 1998
Gasoline oxygenates	Heated purge and trap/gas chromatography/mass spectrometry	NWQL, schedule 4024	Rose and Sandstrom, 2003
Pesticides	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, schedule 2003	Zaugg and others, 1995; Lindley and others, 1996; Madsen and others, 2003; Sandstrom and others, 2001
Pharmaceuticals	Solid-phase extraction and HPLC/mass spectrometry	NWQL, schedule 2080	Kolpin and others, 2002
Wastewater-indicators	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, schedule 1433	Zaugg and others, 2002
Constituents of special interest			
Perchlorate	Chromatography and mass spectrometry	Montgomery Watson-Harza Laboratory	Hautman and others, 1999
<i>N</i> -nitrosodimethylamine (NDMA)	Chromatography and mass spectrometry	Montgomery Watson-Harza Laboratory	U.S. Environmental Protection Agency, 1996; U.S. Environmental Protection Agency, 1999
1,2,3-Trichloropropane	Gas chromatography/electron capture detector	Montgomery Watson-Harza Laboratory	U.S. Environmental Protection Agency, 1995
Inorganic constituents			
Nutrients	Alkaline persulfate digestion, Kjeldahl digestion	NWQL, schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Dissolved organic carbon	UV-promoted persulfate oxidation and infrared spectrometry	NWQL, schedule 2613	Brenton and Arnett, 1993
Major and minor ions, trace elements and nutrients	Atomic absorption spectrometry, colorimetry, ion-exchange chromatography, inductively-coupled plasma atomic emission spectrometry and mass spectrometry	NWQL, schedule 1948	Fishman and Friedman, 1989; Fishman, 1993; Faires, 1993; McLain, 1993; Garbarino, 1999; Garbarino and Damrau, 2001; American Public Health Association, 1998; Garbarino and others, 2006
Chromium, arsenic and iron speciation	Various techniques of ultraviolet visible (UV-VIS) spectrophotometry and atomic absorbance spectroscopy	USGS Trace Metal Laboratory, Boulder, Colorado	Stookey, 1970; To and others, 1998; Ball and McCleskey, 2003a and 2003b; McCleskey and others, 2003
Stable isotopes			
Stable isotopes of water	Gaseous hydrogen and carbon dioxide-water equilibration and stable-isotope mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia	Epstein and Mayeda, 1953; Coplen and others, 1991; Coplen, 1994
Carbon isotopes	Accelerator mass spectrometry	University of Waterloo, Environmental Isotope Lab; University of Arizona Accelerator Mass Spectrometry Lab	Donahue and others, 1990; Jull and others, 2004

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories—Continued.

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule	Citation(s)
Radioactivity and gases			
Tritium	Electrolytic enrichment-liquid scintillation	USGS Stable Isotope and Tritium Laboratory, Menlo Park, California	Thatcher and others, 1977
Tritium and noble gases	Helium-3 in-growth and mass spectrometry	Lawrence Livermore National Laboratory	Moran and others, 2002; Eaton and others, 2004
Radon-222	Liquid scintillation counting	NWQL, schedule 1369	American Society for Testing and Materials, 1998
Radium 226/228	Alpha activity counting	Eberline Analytical Services, NWQL schedule 1262	Krieger and Whittaker, 1980
Gross alpha and beta radioactivity	Alpha and beta activity counting	Eberline Analytical Services, NWQL schedule 1792	Krieger and Whittaker, 1980
Microbial constituents			
F-specific and somatic coliphage	Single-agar layer (SAL) and two-step enrichment methods	USGS Ohio Water Microbiology Laboratory	U.S. Environmental Protection Agency, 2001
Total and <i>Escherichia</i> coliform	Membrane filter technique with "MI agar"	USGS field measurement	U.S. Environmental Protection Agency, 2002b

Table A2. Preferred analytical schedules for constituents appearing on multiple schedules for samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006

[Preferred analytical schedules are the methods of analysis with the greatest accuracy and precision out of the ones used for the compound in question. LLNL, Lawrence Livermore National Laboratory; MWH, Montgomery Watson Harza Laboratory; SITL, U.S. Geological Survey Stable Isotope and Tritium Laboratory; TML, U.S. Geological Survey Trace Metal Laboratory; VOC, volatile organic compound]

Constituent	Primary constituent classification	Analytical schedules	Preferred analytical schedule
Results from preferred method reported			
Acetone	VOC, gasoline degradate	2020, 4024	2020
Bromoform	VOC	2020, 1433	2020
Caffeine	Wastewater indicator	2080, 1433	2080
Carbaryl	Pesticide	2003, 1433	2003
Chlorpyrifos	Pesticide	2003, 1433	2003
Cotinine	Wastewater indicator	1433, 2080	2080
Diazinon	Pesticide	2003, 1433	2003
1,4-Dichlorobenzene	VOC, pesticide	2020, 1433	2020
Dichlorvos	Pesticide	1433, 2003	2003
Diisopropyl ether	VOC, gasoline oxygenate	2020, 4024	2020
Ethyl <i>tert</i> -Butyl ether (ETBE)	VOC, gasoline oxygenate	2020, 4024	2020
Isopropylbenzene	VOC	2020, 1433	2020
Metalaxyl	Pesticide	2003, 1433	2003
Methyl <i>tert</i> -butyl ether (MTBE)	VOC, gasoline oxygenate	2020, 4024	2020
Methyl <i>tert</i> -pentyl ether	VOC, gasoline oxygenate	2020, 4024	2020
Metolachlor	Pesticide	2003, 1433	2003
Naphthalene	VOC	2020, 1433	2020
Prometon	Pesticide	2003, 1433	2003
Tetrachloroethene (PCE)	VOC	2020, 1433	2020
Results from both methods reported			
Alkalinity	Water-quality indicator	1948, field	field
Arsenic, total	Trace element	1948, TML	1948
Chromium, total	Trace element	1948, TML	1948
Iron, total	Trace element	1948, TML	1948
pH	Water-quality indicator	1948, field	field
Specific conductance	Water-quality indicator	1948, field	field
1,2,3-Trichloropropane (1,2,3-TCP)	VOC	2020, MWH	MWH
Tritium	Radioactive	LLNL, SITL	both

Table A3. Constituents detected in field blanks collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Censored data are reported but not used in summary statistics; E, estimated value; pCi/L, picocuries per liter; mg/L, milligrams per liter; µg/L, micrograms per liter, — not detected]

Constituent	Slow Schedule			Fast and Intermediate Schedule		
	Number of field blank detections/analyses	Concentration detected in field blanks	Number of ground-water samples censored	Number of field blank detections/analyses	Concentration detected in field blanks	Number of ground-water samples censored
Organic constituents (µg/L)						
Toluene	0/1	—	1	1/5	E0.02	1
Nutrients (mg/L)						
Dissolved organic carbon	0/1	—	3	1/2	E0.2	6
Inorganic constituents (µg/L)						
Barium	0/1	—	0	1/2	E0.12	2
Chromium	1/1	E0.03	0	2/2	E0.02, E0.02	0
Copper	0/1	—	0	1/2	0.94	6
Lead	0/1	—	0	1/2	0.1	0
Nickel	0/1	—	0	1/2	0.29	3
Zinc	1/1	E0.5	0	1/2	1.4	3
Arsenic (TML) ¹	0/0	—	2	1/2	2.3	3
Radioactive constituents (pCi/L)						
Radium-226	1/1	E0.02	1	0/0	—	0

¹Arsenic analyses made by U.S. Geological Survey Trace Metal Laboratory (80093).

Table A4A. Quality-control summary for replicate analyses of organic constituents detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[RSD, relative standard deviation in percent; nd, not detected; µg/L, micrograms per liter]

Constituent	Number of RSDs greater than zero/ number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSD greater than zero (environmental/replicate) (µg/L)
Volatile organic compounds and gasoline oxygenates (Schedules 2020 and 4204)				
Chloroform	0/5	0	0	
1,2-Dichlorobenzene	0/5	0	0	
<i>cis</i> -1,2-Dichloroethene	0/5	0	0	
1,2-Dichloropropane	0/5	0	0	
Methyl <i>tert</i> -butyl ether (MTBE)	0/5	0	0	
Tetrachloroethene (PCE)	1/5	3	0	(0.23, 0.24)
Tetrachloromethane	0/5	0	0	
Toluene	0/5	0	0	
Trichloroethene (TCE)	0/5	0	0	
Trichlorofluoromethane	0/5	0	0	
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	0/5	0	0	
Pesticides and pesticide degradates (Schedule 2003)				
Atrazine	0/8	0	0	
Deethylatrazine	0/8	0	0	
Fipronil sulfide	0/8	0	0	
Prometon	0/8	0	0	
Simazine	0/8	0	0	
Pharmaceuticals (Schedule 2080)				
Acetaminophen	1/8	99	0	(nd, 0.034)
Caffeine	0/8	0	0	
Carbamazapine	0/8	0	0	
Sulfamethoxazole	0/8	0	0	
Constituents of Special Interest				
Perchlorate	2/5	23	0.0	(0.92, 0.66), (0.69, 0.77)
1,2,3 - Trichloropropane	0/3	0.0	0.0	
<i>N</i> -Nitrosodimethylamine	0/3	0.0	0.0	

Table A4B. Quality-control summary for replicate analyses of major and minor ions and nutrients detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[RSD, relative standard deviation in percent; mg/L, milligrams per liter]

Constituent	Number of RSDs greater than zero/ number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSD greater than zero (environmental/ replicate) (mg/L)
Major and minor ions				
Calcium	3/3	2.2	0.1	(42.5, 41.2), (56.3, 56.2), (66.5, 66.6)
Magnesium	3/3	2.1	1.4	(6.95, 6.75), (15.2, 15.5), (9.06, 9.08)
Potassium	3/3	1.6	1.5	(1.36, 1.39), (3.40, 3.48), (0.78, 0.77)
Sodium	3/3	1.8	0.4	(35.4, 34.5), (24.1, 24.0), (33.1, 33.3)
Bromide	0/0	0	0	
Chloride	2/3	0.5	0.4	(14.7, 14.8), (17.7, 17.8)
Fluoride	1/3	20	0	(0.4, 0.3)
Iodide	0/1	0	0	
Sulfate	1/3	0.2	0	(45.4, 45.5)
Silica	2/3	0.3	0.2	(46.7, 46.6), (23.9, 24.0)
Total dissolved solids	1/3	0.3	0	(256, 257)
Residue on evaporation	2/3	0.5	0.4	(266, 264), (341, 343)
Nutrients and dissolved organic carbon				
Dissolved organic carbon	2/3	28	20	(0.3, 0.2), (0.4, 0.3)
Phosphorus	1/3	3.4	0	(0.21, 0.20)
Total nitrogen	3/3	3.8	1.3	(1.89, 1.90), (3.42, 3.36), (5.31, 5.60)
Nitrate plus nitrite	2/3	0.5	0.4	(1.75, 1.76), (5.44, 5.40)
Ammonia	0/3	0	0	
Nitrite	0/3	0	0	

Table A4C. Quality-control summary for replicate analyses of trace elements detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[RSD, relative standard deviation in percent; nd, not detected; µg/L, micrograms per liter]

Constituent	Number of RSDs greater than zero/ number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSD greater than zero (environmental/ replicate) (µg/L)
USGS National Water Quality Laboratory (Schedule 1948)				
Aluminum	1/3	101	0	(nd, 3)
Antimony	0/3	0	0	
Arsenic	1/3	4	0	(0.63, 0.67)
Barium	2/3	1.4	0.7	(49, 50), (109, 108)
Beryllium	0/3	0	0	
Boron	2/3	3.1	1.8	(22, 23), (40, 39)
Cadmium	0/3	0	0	
Chromium	0/3	0	0	
Cobalt	3/3	3.5	1.5	(0.062, 0.059), (0.140, 0.137), (0.144, 0.147)
Copper	1/3	3.8	0	(1.9, 1.8)
Iron	1/3	8	0	(9, 8)
Lead	1/3	7	0	(2.03, 2.23)
Lithium	2/3	4.9	4.3	(1.7, 1.6), (1.5, 1.4)
Manganese	1/3	2	0	(3.2, 3.3)
Molybdenum	2/3	2	1.5	(4.9, 4.8), (27.1, 26.2)
Nickel	3/3	19	14	(0.36, 0.47), (2.74, 2.75), (1.94, 2.06)
Selenium	1/3	2	0	(0.37, 0.36)
Silver	0/3	0.0	0	
Strontium	2/3	0	0.3	(220, 221), (158, 159)
Thallium	0/3	0	0	
Tungsten	1/3	0.3	0	(22.0, 22.1)
Uranium	2/3	1.1	0.2	(1.31, 1.29), (4.47, 4.46)
Vanadium	3/3	1.0	0.6	(11.5, 11.4), (18.8, 18.7), (6.8, 6.7)
Zinc	3/3	23	8.3	(3.4, 4.7), (0.9, 0.8), (2.6, 2.8)
USGS Trace Metals Laboratory				
Iron, total	1/2	101	51	(nd, 3)
Iron (II)	1/2	101	51	(nd, 3)
Arsenic, total	2/2	113	73	(2.6, 1.6), (nd, 1.1)
Arsenic (III)	0/2	0	0	
Chromium, total	1/6	47	0	(2,1)
Chromium (VI)	0/6	0	0	

Table A4D. Quality-control summary of replicate analyses of constituents of special interest and radioactive constituents detected in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[RSD, percent relative standard deviation; µg/L, microgram per liter; pCi/L, picocuries per liter]

Constituent	Number of RSDs greater than zero/ number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSD greater than zero (environmental/ replicate)
Constituents of special interest (µg/L)				
Perchlorate	2/5	19	0	(0.70, 0.92), (0.77,0.69)
1,2,3-Trichloropropane (1,2,3-TCP)	0/3	0	0	
Radioactive constituents (pCi/L)				
Radon-222	1/1	6.8	6.8	(286, 315)
Tritium	1/2	22	11	(1.9, 2.6)

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and degradates in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetone ¹	6	78	98	82
Acrylonitrile	6	97	115	106
<i>tert</i> -Amyl alcohol	2	95	113	104
Benzene	6	96	106	97
Bromobenzene	6	98	113	102
Bromochloromethane	6	82	96	88
Bromodichloromethane	6	104	132	109
Bromoethene	6	106	122	112
Bromoform (tribromomethane)	6	101	127	107
Bromomethane	6	86	147	124
2-Butanone (ethyl methyl ketone)	6	95	112	97
<i>tert</i> -Butyl alcohol (TBA)	2	88	110	99
Butylbenzene (<i>n</i> -Butylbenzene)	6	88	99	94
<i>sec</i> -Butylbenzene	6	94	106	100
<i>tert</i> -Butylbenzene	6	97	120	104
Carbon disulfide	6	87	101	95
Chlorobenzene	6	100	110	103
Chloroethane	6	80	97	88
Chloroform (trichloromethane) ²	6	104	130	109
Chloromethane	6	81	113	94
3-Chloropropene	6	139	168	144
2-Chlorotoluene	6	96	109	99
4-Chlorotoluene	6	79	88	85
Dibromochloromethane	6	113	137	113
1,2-Dibromo-3-chloropropane (DBCP)	6	98	110	100
1,2-Dibromoethane (EDB)	6	100	115	104
Dibromomethane	6	96	121	102
1,2-Dichlorobenzene ²	6	94	111	100
1,3-Dichlorobenzene	6	98	109	100
1,4-Dichlorobenzene	6	94	106	98
<i>trans</i> -1,4-Dichloro-2-butene	6	99	123	104
Dichlorodifluoromethane (CFC-12)	6	52	73	67
1,1-Dichloroethane	6	145	179	152
1,2-Dichloroethane	6	115	156	123
1,1-Dichloroethylene (DCE)	6	88	110	97
<i>cis</i> -1,2-Dichloroethylene ²	6	100	115	103
<i>trans</i> -1,2-Dichloroethylene	6	96	111	99
Dichloromethane (methylene chloride)	6	24	30	30
1,1-Dichloropropene	6	131	155	138
1,2-Dichloropropane ²	6	100	117	105
1,3-Dichloropropane	6	125	152	134
<i>cis</i> -1,3-Dichloropropane	6	97	110	102
<i>trans</i> -1,3-Dichloropropane	6	102	119	107
2,2-Dichloropropane	6	92	124	111
Diethyl ether	6	113	131	119
Diisopropyl ether ¹	6	96	115	102
Ethylbenzene	6	96	113	100
Ethyl <i>tert</i> -butyl ether (ETBE, <i>tert</i> -butyl ethyl ether) ¹	6	98	121	102
Ethyl methacrylate	6	102	117	102
<i>o</i> -Ethyl toluene (2-Ethyltoluene)	6	74	82	80
Hexachlorobutadiene	6	84	107	92
Hexachloroethane	6	101	117	103

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and degradates in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006—Continued.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
2-Hexanone (<i>n</i> -Butyl methyl ketone)	6	97	111	101
Isopropylbenzene	6	102	117	106
4-Isopropyl-1-methylbenzene	6	83	94	87
Methyl acetate	2	114	116	115
Methyl acrylate	6	105	120	108
Methyl acrylonitrile	6	84	99	90
Methyl <i>tert</i> -butyl ether (MTBE) ^{1,2}	6	94	120	99
Methyl iodide (iodomethane)	6	81	141	104
Methyl methacrylate	6	93	105	96
4-Methyl-2-pentanone (MIBK, isobutyl methyl ketone)	6	94	113	100
Methyl <i>tert</i> -pentyl ether ¹	6	119	144	122
Naphthalene	6	77	94	83
<i>n</i> -Propylbenzene	6	91	106	96
Styrene	6	94	102	100
1,1,1,2-Tetrachloroethane	6	100	119	102
1,1,2,2-Tetrachloroethane	6	114	127	116
Tetrachloroethene (PCE) ²	6	96	108	99
Tetrachloromethane (carbon tetrachloride) ²	6	164	221	188
Tetrahydrofuran	6	96	112	107
1,2,3,4-Tetramethylbenzene	6	63	77	68
1,2,3,5-Tetramethylbenzene (isodurene)	6	62	75	66
Toluene ¹	6	98	113	104
1,2,3-Trichlorobenzene	6	55	63	55
1,2,4-Trichlorobenzene	6	115	133	115
1,1,1-Trichloroethane (TCA)	6	104	136	111
1,1,2-Trichloroethane	6	84	102	87
Trichloroethene (TCE) ²	6	94	115	100
Trichlorofluoromethane (CFC-11) ²	6	106	149	119
1,2,3-Trichloropropane (1,2,3-TCP)	6	90	118	96
1,1,2-Trichlorotrifluoroethane (CFC-113) ²	6	81	102	95
1,2,3-Trimethylbenzene	6	80	97	84
1,2,4-Trimethylbenzene	6	82	93	86
1,3,5-Trimethylbenzene	6	94	109	100
Vinyl chloride	6	87	106	87
<i>m</i> - and <i>p</i> -Xylene	6	166	189	172
<i>o</i> -Xylene	6	77	91	82

¹Constituents on schedules 2020 and 4024; only values from schedule 2020 are reported because it is the preferred analytical schedule.²Constituents detected in ground-water samples.

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetochlor	5	82	108	100
Alachlor	5	89	110	102
Atrazine ¹	5	88	104	97
Azinphos-methyl	5	71	126	102
Azinphos-methyl-oxon	5	39	109	88
Benfluralin	5	47	77	69
Carbaryl	5	79	120	103
2-Chloro-2,6-diethylacetanilide	5	79	110	106
4-Chloro-2-methylphenol	5	55	71	58
Chlorpyrifos	5	87	97	89
Chlorpyrifos, oxygen analog	5	20	39	30
Cyfluthrin	5	49	75	51
Cypermethrin	5	47	70	53
Dacthal (DCPA)	5	87	108	102
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-s-triazine) ¹	5	38	53	51
Desulfinylfipronil	5	80	93	84
Desulfinylfipronil amide	5	53	112	78
Diazinon	5	86	102	90
Diazinon, oxon	5	49	99	90
3,4-Dichloroaniline	5	70	83	75
Dichlorvos	5	19	30	30
Dicrotophos	5	20	49	39
Dieldrin	5	71	121	96
2,6-Diethylaniline	5	88	97	94
Dimethoate	5	25	43	35
Ethion	5	65	119	90
Ethion monoxon	5	59	129	100
2-Ethyl-6-methylaniline	5	82	93	87
Fenamiphos	5	69	140	129
Fenamiphos sulfone	5	60	121	106
Fenamiphos sulfoxide	5	39	80	78
Fipronil	5	69	101	92
Fipronil sulfide ¹	5	75	93	87
Fipronil sulfone	5	57	94	64
Fonofos	5	82	96	88
Hexazinone	5	57	111	81
Isofenphos	5	85	108	103
Malaoxon	5	48	107	103
Malathion	5	80	107	104
Metalaxyl	5	85	106	97
Methidathion	5	83	133	105
Metolachlor	5	99	120	105
Metribuzin	5	65	89	86
Myclobutanil	5	77	112	94
1-Naphthol	5	19	59	20
Paraoxon-methyl	5	49	60	49
Parathion-methyl	5	60	92	84
Pendimethalin	5	76	112	108
<i>cis</i> -Permethrin	5	49	79	55
Phorate	5	69	101	73
Phorate oxon	5	69	120	117
Phosmet	2	8	8	8
Phosmet oxon	2	49	50	49

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006—Continued.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Prometon ¹	5	79	108	97
Prometryn	5	81	108	102
Propyzamide	5	77	104	98
Simazine ¹	5	81	103	99
Tebuthiuron	5	69	120	118
Terbufos	5	79	130	118
Terbufos oxon sulfone	5	49	119	98
Terbutylazine	5	89	108	97
Trifluralin	5	55	85	78

¹Constituents detected in ground-water samples.

Table A5C. Quality-control summary for matrix-spike recoveries of pharmaceutical compounds in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetaminophen	4	90	104	101
Caffeine	4	96	104	98
Carbamazepine ¹	4	70	96	93
Codeine	4	89	96	93
Cotinine	4	96	100	98
Dehydronifedipine	4	100	113	107
Diltiazem	4	44	59	50
1,7-Dimethylxanthine	4	89	98	93
Diphenhydramine ¹	4	55	74	69
Salbutamol (albuterol)	4	64	90	81
Sulfamethoxazole ¹	4	53	70	62
Thiabendazole	4	50	83	79
Trimethoprim	4	79	99	96
Warfarin	4	63	76	71

¹Constituents detected in ground-water samples.

Table A5D. Quality-control summary for matrix-spike recoveries of wastewater-indicator compounds in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Recovery (percent)	Constituent	Recovery (percent)
Acetophenone	94	Menthol	98
Acetyl hexamethyl tetrahydro naphthalene	70	Metalaxyl	93
Anthracene, water	72	1-Methylnaphthalene	65
9,10-Anthraquinone	85	2-Methylnaphthalene	57
Benzo[a]pyrene	68	3-Methyl-1H-indole	83
Benzophenone	90	5-Methyl-1H-benzotriazole	51
Bisphenol A	19	Methyl salicylate	86
Bromacil	94	Metolachlor	84
3- <i>tert</i> -Butyl-4-hydroxyanisole	38	Naphthalene	73
Caffeine	87	4-Nonylphenol	65
Camphor	90	4-Nonylphenol diethoxylates	139
Carbaryl	80	4-Octylphenol	57
Carbazole	78	4- <i>tert</i> -Octylphenol	72
Chlorpyrifos	73	4-Octylphenol diethoxylates	89
Cholesterol	70	4-Octylphenol monoethoxylates	118
3- <i>beta</i> -Coprostanol	64	Pentachlorophenol	22
Cotinine	81	Phenanthrene	80
<i>p</i> -Cresol	80	Phenol	95
4-Cumylphenol, water	72	Prometon	83
DEET (<i>N,N</i> -diethyl- <i>meta</i> -toluamide)	89	Pyrene	76
Diazinon	80	<i>beta</i> -Sitosterol	53
1,4-Dichlorobenzene	60	<i>beta</i> -Stigmastanol	61
2,6-Dimethylnaphthalene	49	Tetrachloroethylene	15
Fluoranthene	77	Tribromomethane	69
Hexahydrohexamethyl cyclopentabenzopyran	75	Tributyl phosphate	86
Indole	76	Triclosan	74
Isoborneol	97	Triethyl citrate	90
Isophorone	92	Triphenyl phosphate	86
Isopropylbenzene	49	Tris(2-butoxyethyl) phosphate	92
Isoquinoline	86	Tris(2-chloroethyl) phosphate	83
D-Limonene	32	Tris(dichloroisopropyl) phosphate	89

Table A5E. Quality-control summary for matrix-spike recoveries of *N*-Nitrosodimethylamine (NDMA) and 1,2,3-Trichloropropane (1,2,3-TCP) in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
1,2,3-Trichloropropane ¹	3	95	114	113
<i>N</i> -Nitrosodimethylamine (NDMA)	3	101	106	104

¹Constituent detected in ground-water samples

Table A6. Quality-control summary for surrogate recoveries of volatile organic compounds, gasoline oxygenates and degradates, pesticides and pesticide degradates, pharmaceutical compounds, wastewater-indicator compounds, and constituents of special interest in samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.[MWH, Montgomery Watson-Harza Laboratory; VOC, volatile organic compound; 1,2,3-TCP, 1,2,3-trichloropropane; NDMA, *N*-nitrosodimethylamine; na, not analyzed]

Surrogate	Analytical schedule	Constituent or constituent class analyzed	Number of blanks analyses	Median recovery in blanks (percent)	Number of surrogate recoveries below 70 percent in blanks
1-Bromo-4-fluorobenzene	2020, 4024	VOC, gas oxygenate	9	73	2
1,2-Dichloroethane-d4	2020, 4024	VOC, gas oxygenate	9	117	0
Isobutyl alcohol-d6	4024	Gas oxygenate	3	112	0
Toluene-d8	2020, 4024	VOC, gas oxygenate	9	99	0
Diazinon-d10	2003	Pesticide	5	98	0
alpha-HCH-d6	2003	Pesticide	5	87	0
Toluene-d8	MWH	1,2,3-TCP	3	100	0
NDMA-d6	MWH	NDMA	3	64	0
Ethyl nicotinate-d4	2080	Pharmaceutical	10	107	0
Carbamazapine-d10	2080	Pharmaceutical	10	107	0
Caffeine- ¹³ C	1433	Wastewater-indicator	na	na	na
Decafluorobiphenyl	1433	Wastewater-indicator	na	na	na
Fluoranthene-d10	1433	Wastewater-indicator	na	na	na
Surrogate	Number of surrogate recoveries above 130 percent in blanks	Number of sample analyses	Median recovery in samples (percent)	Number of surrogate recoveries below 70 percent in samples	Number of surrogate recoveries above 130 percent in samples
1-Bromo-4-fluorobenzene	0	71	99	14	0
1,2-Dichloroethane-d4	1	71	115	0	10
Isobutyl alcohol-d6	0	30	109	0	1
Toluene-d8	0	71	100	0	0
Diazinon-d10	0	68	94	3	0
alpha-HCH-d6	0	68	94	7	0
Toluene-d8	0	27	99	0	0
NDMA-d6	0	27	91	4	0
Ethyl nicotinate-d4	0	62	102	0	0
Carbamazapine-d10	0	62	103	0	0
Caffeine- ¹³ C	na	8	91	0	0
Decafluorobiphenyl	na	8	45	8	0
Fluoranthene-d10	na	8	95	0	0

Table A7A. Quality-control summary for laboratory “set blanks” for pharmaceutical compounds corresponding to analyses of samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[µg/L, micrograms per liter; E, estimated value]

Constituent	Number of set blank detections/analyses	Maximum concentration detected in set blank samples	Minimum concentration detected in ground-water samples in set	Number of ground-water samples censored
Acetaminophen	0/11			
Albuterol	0/11			
Caffeine	0/11			
Carbamazepine	1/11	E0.0006	E0.004	0
Codeine	0/11			
Cotinine	0/11			
Dehydronifedipine	0/11			
Diltiazem	0/11			
1,7-Dimethylxanthine	0/11			
Diphenhydramine	1/11	E0.0005	E0.004	0
Sulfamethoxazole	0/11			
Thiabendazole	0/11			
Trimethoprim	0/11			
Warfarin	0/11			

Table A7B. Quality-control summary for laboratory “set spikes” for pharmaceutical compounds corresponding to analyses of samples collected for the Southern Sierra Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of set spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetaminophen	11	60	92	69
Albuterol	11	69	98	82
Caffeine	11	90	104	94
Carbamazapine ¹	11	84	93	88
Codeine	11	76	84	81
Cotinine	11	94	102	97
Dehydronifedipine	11	69	93	86
Diltiazem	11	4	47	21
1,7-dimethylxanthine	11	56	88	78
Diphenhydramine ¹	11	57	70	60
Sulfamethoxazole ¹	11	58	78	70
Thiabendazole	11	70	89	87
Trimethoprim	11	88	96	92
Warfarin	11	18	65	35

¹Constituents detected in ground-water samples.

