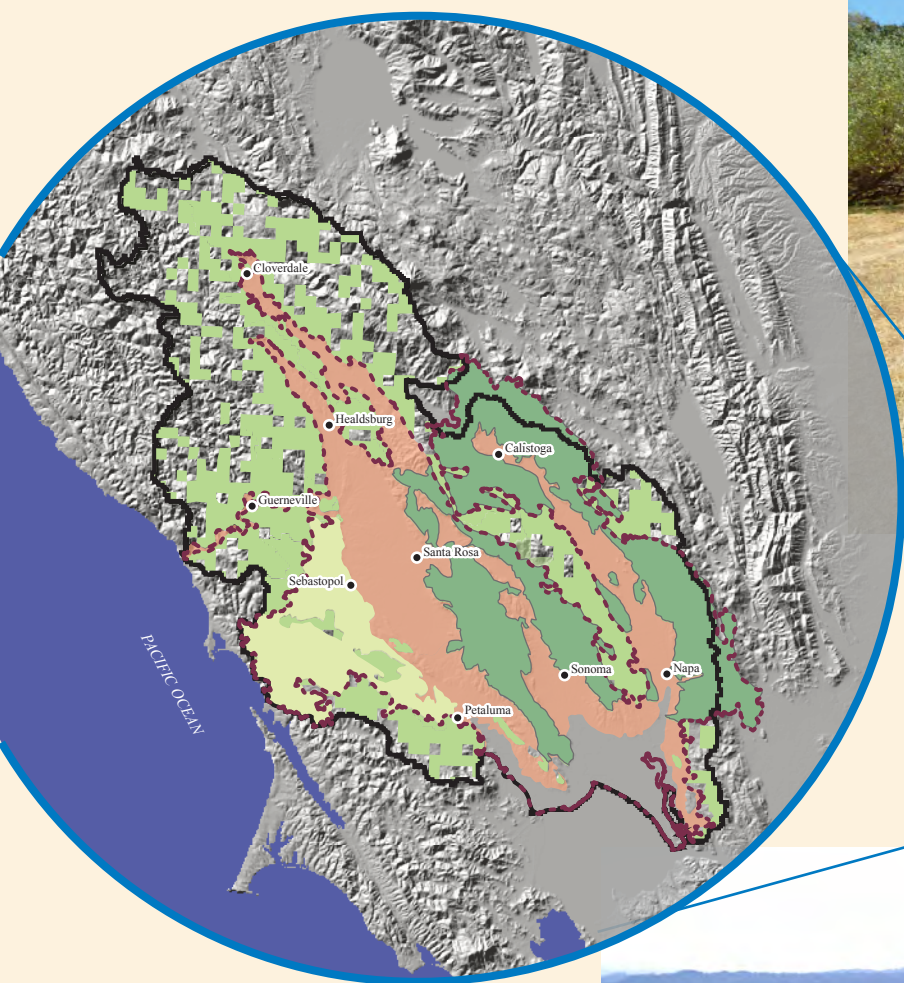


Prepared in cooperation with the California State Water Resources Control Board  
*A product of the California Groundwater Ambient Monitoring and Assessment (GAMA) Program*

# Groundwater-Quality Data in the North San Francisco Bay Shallow Aquifer Study Unit, 2012: Results from the California GAMA Program



Data Series 865

U.S. Department of the Interior  
U.S. Geological Survey



**Cover photographs:**

**Top photo:** Well pump in field near Petaluma, California. (Photograph by Sarmad Al-Kayssi, U.S. Geological Survey)

**Bottom photo:** Scenic photograph near Petaluma, California. (Photograph by George Bennett, U.S. Geological Survey)

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By George L. Bennett V and Miranda S. Fram

A product of the California Groundwater Ambient Monitoring and Assessment (GAMA) Program

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**U.S. Department of the Interior  
U.S. Geological Survey**

**U.S. Department of the Interior**

SALLY JEWELL, Secretary

**U.S. Geological Survey**

Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

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## Conversion Factors and Datums

Inch/foot/mile to International System of Units (SI)

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
quart (qt)	0.95	liter (L)
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

SI to Inch/foot/mile

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.28	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
liter (L)	1.0567	quart (qt)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound, avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:  
 $^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$ .

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ( $\mu\text{S}/\text{cm}$  at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter  $\mu\text{g}/\text{L}$ .

Milligrams per liter is equivalent to parts per million (ppm), and micrograms per liter is equivalent to parts per billion (ppb).

Concentrations of radioactive constituents in water are given in picocuries per liter (pCi/L).

## Datums

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

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above or below the vertical datum and is reported as feet above mean sea level (ft above msl) and feet below mean sea level (ft below msl).



## Selected Terms and Symbols

$\alpha$	significance level
$\delta$	delta value, the ratio of a heavier isotope of an element ( $\delta$ ) to the more common lighter isotope of that element, relative to a standard reference material, expressed as per mil
=	equal to
>	greater than
$\geq$	greater than or equal to
<	less than
$\leq$	less than or equal to
meq/L	milliequivalents per liter
N	Normal (1-gram-equivalent per liter of solution)
—	not detected
pH	a measure of the acidity or basicity of a solution
$\text{pK}_{1,2}$	negative logarithms of the acid dissociation constants for carbonic acid
$\text{pK}_w$	negative logarithm of the acid dissociation constant of water, $K_w$
R	result
$\pm$	plus or minus
*	value is at a concentration greater than benchmark level
**	value is at a concentration greater than upper benchmark level

## Abbreviations and Acronyms

AL-US	action level (USEPA)
APE	Alternate Place Entry program designed for USGS sampling
CASRN	Chemical Abstracts Service (American Chemical Society) Registry Number®
CSU	combined standard uncertainty
E	estimated or having a higher degree of uncertainty
GPS	Global Positioning System
HAL-US	lifetime health advisory level (USEPA)
HBSL	Health-Based Screening Level
HPLC	high-performance liquid chromatography
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL-CA	maximum contaminant level (CDPH)
MCL-US	maximum contaminant level (USEPA)
MDL	method detection limit
MRL	minimum reporting level
MU	method uncertainty
na	not available
NAD	normalized absolute difference
nc	not collected
NFM	National Field Manual (USGS)

## Abbreviations and Acronyms—Continued

NL-CA	notification level (CDPH)
np	no preference
NSF-SA	North San Francisco Bay Shallow Aquifer study unit
nv	no measured value or no value in category
NWIS	National Water Information System (USGS)
PBP	Priority Basin Project
PCFF	Personal Computer Field Form program designed for USGS sampling
QA	quality assurance
QC	quality control
RL	reporting level
RSD	relative standard deviation
RSD5-US	risk-specific dose at a risk factor of $10^{-5}$ (USEPA)
SD	standard deviation
SMCL-CA	secondary maximum contaminant level (CDPH)
SMCL-US	secondary maximum contaminant level (USEPA)
S-NSF-H	North San Francisco Bay Shallow Aquifer study unit Highlands study area grid well
S-NSF-HU	North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well
S-NSF-VP	North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area grid well
SRL	study reporting level (concentration cutoff for applying the $\leq$ symbol in reporting results)
ssL <sub>c</sub>	sample-specific critical level
VPDB	Vienna Pee Dee Belemnite (the international reference standard for carbon isotopes)
VSMOW	Vienna Standard Mean Ocean Water (an isotopic water standard defined in 1968 by the International Atomic Energy Agency)

## Organizations

BBP	Blind Blank Program
BQS	Branch of Quality Systems (USGS)
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CDWR	California Department of Water Resources
GAMA	Groundwater Ambient Monitoring and Assessment Program
IBSP	Inorganic Blind Sample Program (USGS)
LLNL	Lawrence Livermore National Laboratory, Livermore, California
NAWQA	National Water-Quality Assessment Program (USGS)
NELAP	National Environmental Laboratory Accreditation Program
NJDEP	New Jersey Department of Environmental Protection

## Organizations—Continued

NFQA	National Field Quality Assurance Program (USGS)
NWQL	National Water Quality Laboratory (USGS)
OSSU	Oregon Health & Science University
SITL	Stable Isotope and Tritium Laboratory, Menlo Park, California (USGS)
SWRCB	California State Water Resources Control Board
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

## Selected Chemical Names

$\text{CaCO}_3$	calcium carbonate
$\text{CO}_3^{2-}$	carbonate
$\text{H}_2\text{O}$	water
HCl	hydrochloric acid
$\text{HCO}_3^-$	bicarbonate
NDMA	<i>N</i> -nitrosodimethylamine
PVC	polyvinyl chloride
1,2,3-TCP	1,2,3-trichloropropane
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound



# Groundwater-Quality Data in the North San Francisco Bay Shallow Aquifer Study Unit, 2012: Results from the California GAMA Program

By George L. Bennett V and Miranda S. Fram

## Abstract

Groundwater quality in the 1,850-square-mile North San Francisco Bay Shallow Aquifer (NSF-SA) study unit was investigated by the U.S. Geological Survey (USGS) from April to August 2012, as part of the California State Water Resources Control Board (SWRCB) Groundwater Ambient Monitoring and Assessment (GAMA) Program's Priority Basin Project (PBP). The GAMA-PBP was developed in response to the California Groundwater Quality Monitoring Act of 2001 and is being conducted in collaboration with the SWRCB and Lawrence Livermore National Laboratory (LLNL). The NSF-SA study unit was the first study unit to be sampled as part of the second phase of the GAMA-PBP, which focuses on the shallow aquifer system.

The GAMA NSF-SA study was designed to provide a spatially unbiased assessment of untreated-groundwater quality in the shallow aquifer systems and to facilitate statistically consistent comparisons of untreated-groundwater quality throughout California. The shallow aquifer system in the NSF-SA study unit was defined as the part of the aquifer system that is used by many private domestic wells and is shallower than the primary aquifer system used by many public-supply wells.

In the NSF-SA study unit located in Marin, Mendocino, Napa, Solano, and Sonoma Counties, groundwater samples were collected from 71 wells. Seventy of the wells were selected by using a spatially distributed, randomized grid-based method to provide statistical representation of the study unit (grid wells), and one well was selected to aid in evaluation of water-quality issues (understanding well).

The groundwater samples were analyzed for organic constituents (volatile organic compounds [VOCs], pesticides, and pesticide degradates); constituents of special interest (perchlorate and 1,2,3-trichloropropane [1,2,3-TCP]); naturally occurring inorganic constituents (trace elements, nutrients, major and minor ions, silica, and total dissolved solids [TDS]); and radioactive constituents (radon-222 and gross alpha and gross beta radioactivity). Naturally occurring isotopes (stable isotopes of hydrogen, oxygen, boron,

strontium, and inorganic carbon in water, tritium activities, and carbon-14 abundances) were measured to help identify the sources and ages of the sampled groundwater. In total, 207 constituents and water-quality indicators were measured.

Three types of quality-control samples (blanks, replicates, and matrix spikes) were collected at up to 13 percent of the wells in the NSF-SA study unit, and the results for these samples were used to evaluate the quality of the data for the groundwater samples. Blanks rarely contained detectable concentrations of any constituent, suggesting that contamination from sample-collection procedures was not a significant source of bias in the data for the groundwater samples. Replicate samples generally were within the limits of acceptable analytical reproducibility. Matrix-spike recoveries were within the acceptable range (70 to 130 percent) for approximately 91 percent of the compounds.

Most of the wells sampled for this study were private domestic wells. Private domestic wells are not regulated in California, and groundwater from these wells is rarely analyzed for water-quality constituents. Although regulatory benchmarks for drinking-water quality do not apply to private domestic wells, to provide some context for the results, concentrations of constituents measured in the untreated groundwater were compared with regulatory and non-regulatory health-based benchmarks established by the U.S. Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH), to non-regulatory health-based benchmarks established by the USGS in cooperation with the USEPA, and to non-regulatory benchmarks established for aesthetic concerns by the CDPH. Comparisons between data collected for this study and benchmarks for drinking water are for illustrative purposes only and are not indicative of compliance or non-compliance with those benchmarks. Most of the organic and inorganic constituents that were detected in groundwater samples from the 70 grid wells in the NSF-SA study unit were detected at concentrations less than drinking-water benchmarks.

Of the 149 organic and special-interest constituents analyzed for in groundwater samples, 31 were detected; concentrations of most detected constituents were less than regulatory and non-regulatory health-based benchmarks.

One VOC, benzene, and one insecticide, dieldrin, were detected at concentrations above their respective health-based benchmarks. In total, VOCs were detected in 40 percent of the grid wells sampled, pesticides and pesticide degradates were detected in 13 percent, and perchlorate was detected in 27 percent of the 70 grid wells sampled.

Groundwater samples from 70 grid wells were analyzed for trace elements, major and minor ions, nutrients, and radioactive constituents; most detected concentrations were less than health-based benchmarks. Exceptions are 12 detections of manganese greater than the USGS Health-Based Screening Level (HBSL), 7 detections of arsenic greater than the USEPA maximum contaminant level (MCL-US) of 10 micrograms per liter ( $\mu\text{g/L}$ ), 2 detections of boron greater than the HBSL of 6,000  $\mu\text{g/L}$ , 2 detections of fluoride greater than the CDPH maximum contaminant level (MCL-CA) of 2 milligrams per liter ( $\text{mg/L}$ ), 2 detections of nitrate greater than the MCL-US of 10  $\text{mg/L}$ , and two detections of radon-222 greater than the proposed MCL-US of 4,000 picocuries per liter.

Results for constituents with non-regulatory benchmarks set for aesthetic concerns from the grid wells showed that iron concentrations greater than the CDPH secondary maximum contaminant level (SMCL-CA) of 300  $\mu\text{g/L}$  were detected in 13 grid wells. Chloride was detected at a concentration greater than the SMCL-CA recommended benchmark of 250  $\text{mg/L}$  in two grid wells. Sulfate concentrations greater than the SMCL-CA recommended benchmark of 250  $\text{mg/L}$  were measured in two grid wells, and the concentration in one of these wells was also greater than the SMCL-CA upper benchmark of 500  $\text{mg/L}$ . TDS concentrations greater than the SMCL-CA recommended benchmark of 500  $\text{mg/L}$  were measured in 15 grid wells, and concentrations in 4 of these wells were also greater than the SMCL-CA upper benchmark of 1,000  $\text{mg/L}$ .

## Introduction

About one-half of the water used for public and domestic drinking-water supply in California is groundwater (Kenny and others, 2009). To assess the quality of ambient groundwater in shallow aquifers used for drinking-water supply and to establish a baseline groundwater-quality monitoring program, the California State Water Resources Control Board (SWRCB), in cooperation with the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory (LLNL), implemented the Groundwater Ambient Monitoring and Assessment (GAMA) Program (California State Water Resources Control Board, 2013). The main goals of the GAMA Program are to improve groundwater monitoring and to increase the availability of groundwater-quality data to the public.

The GAMA Program currently consists of four projects: (1) the GAMA Priority Basin Project (PBP) conducted by the USGS (U.S. Geological Survey, 2013a); (2) the GAMA

Domestic Well Project conducted by the SWRCB; (3) the GAMA Special Studies Project conducted by LLNL; and (4) GeoTracker GAMA conducted by the SWRCB. The first phase of the GAMA-PBP (2004–2012) primarily focused on the deeper aquifer system, which is typically used for public drinking-water supply. The second phase of the GAMA-PBP focuses on the shallow aquifer system, typically used by domestic and small-system wells (2012–present). The GAMA Domestic Well Project samples domestic wells in selected counties, and the GAMA Special Studies Project focuses on using research methods to help explain the source, fate, transport, and occurrence of chemicals that can affect groundwater quality. GeoTracker GAMA is an online groundwater information system that serves groundwater-quality data and other groundwater information collected for programs operated by many agencies including the SWRCB, the Regional Water Quality Control Boards, and the California Departments of Public Health (CDPH), Water Resources (CDWR), Toxic Substances Control (CDTSC), and Pesticide Regulation (CDPR).

The SWRCB initiated the GAMA Program in 2000 in response to a legislative mandate (State of California, 2001a, b). The GAMA-PBP was initiated in response to the Groundwater Quality Monitoring Act of 2001 to assess and monitor the quality of groundwater in California (State of California, 2001b). The GAMA-PBP is a comprehensive assessment of statewide groundwater quality designed to help better understand and identify risks to groundwater resources and to increase the availability of information about groundwater quality to the public. For the first phase of the GAMA-PBP, the USGS, in collaboration with the SWRCB, developed a monitoring plan to assess groundwater basins through direct sampling of groundwater and other statistically reliable sampling approaches (Belitz and others, 2003; California State Water Resources Control Board, 2003). Building on the first phase, the second phase expands the monitoring plan to include shallow aquifer systems. Additional partners in the GAMA-PBP include the CDPH, CDWR, CDPR, and local water agencies and well owners (Kulongoski and Belitz, 2004; U.S. Geological Survey, 2013b).

Hydrologic and geologic conditions and land-use patterns in California were considered in this statewide assessment of groundwater quality. Belitz and others (2003) partitioned the State into 10 hydrogeologic provinces, each with distinctive hydrologic, geologic, and land-use characteristics: Cascades and Modoc Plateau, Klamath Mountains, Northern Coast Ranges, Central Valley, Sierra Nevada, Basin and Range, Southern Coast Ranges, Transverse Ranges and selected Peninsular Ranges, Desert, and San Diego Drainages ([fig. 1](#)). These 10 hydrogeologic provinces include groundwater basins designated by the CDWR (California Department of Water Resources, 2003). Groundwater basins generally consist of relatively permeable, unconsolidated deposits of alluvial origin. Areas outside of basins generally consist of fractured hard-rock aquifers and are an important source of drinking water in some of the hydrogeologic provinces.





**Figure 1.** Hydrogeologic provinces of California and the location of the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project.



The first phase of the GAMA-PBP assessed approximately 95 percent of the groundwater resource used for public supply. Basins were prioritized for sampling on the basis of number of public-supply wells listed in the CDPH database, with secondary consideration given to municipal groundwater use, agricultural pumping, the number of historically leaking underground fuel tanks, and the number of square-mile sections having registered pesticide applications (Belitz and others, 2003). The 35 study units sampled in this first phase (2004–2012) included all of the priority basins, a subset of low-use basins, and selected areas outside of basins.

For the second phase of the GAMA-PBP, a different method of prioritization was required because shallow aquifer systems typically are used by private domestic wells, and no statewide database of these wells was available. The State was divided into 938 groundwater units, corresponding to the 463 alluvial groundwater basins defined by the CDWR and 475 areas outside of basins (hereinafter referred to as highland areas) (Johnson and Belitz, 2014). The estimated number of households relying on domestic wells in each groundwater unit was calculated from U.S. Census data (U.S. Census Bureau, 1990), and water-use information was compiled from drillers' logs submitted to CDWR (Johnson and Belitz, in press). The groundwater units were prioritized for sampling on the basis of the number and density of households relying on domestic wells. Groundwater units are grouped into study units designed to facilitate comparison of groundwater quality between the shallow aquifer systems being assessed in this second phase of the GAMA-PBP and the deeper aquifer systems assessed in the first phase.

The North San Francisco Bay Shallow Aquifer (NSF-SA) study unit is the first study unit to be sampled in the second phase of the GAMA-PBP and is located in the Northern Coast Ranges hydrogeologic province ([fig. 1](#)).

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 groundwater resource; (2) *Understanding*: identification of the natural and human factors affecting groundwater quality; and (3) *Trends*: detection of changes in groundwater quality over time (Kulongoski and Belitz, 2004). The assessments include comparison between the shallow aquifer system and the deeper primary aquifer system assessed in the first phase. These assessments are intended to characterize the quality of groundwater in the aquifer systems of the study units, not the quality of drinking water used by consumers. Groundwater may be treated prior to use as drinking water.

In groundwater basins, domestic and small-system wells typically are shallower than public-supply wells listed in the CDPH database. In the first phase of the GAMA-PBP, the primary aquifer system in a study unit was defined by the depths of the screened or open intervals of public-supply wells listed in the CDPH database for the study unit. The shallow aquifer system assessed in this second phase of the GAMA-PBP is defined as shallower than the primary aquifer system. In highland areas, the differences in depth zones used by public-supply wells and domestic and small-system wells may be less distinct.

The GAMA-PBP is unique in California because it includes many chemical analyses that are not otherwise available in statewide water-quality monitoring datasets. Groundwater samples collected for the GAMA-PBP are typically analyzed for approximately 200 chemical constituents, and the analytical methods used have lower detection limits than required by the CDPH for regulatory monitoring of public-supply wells. These analyses are useful for providing an early indication of changes in groundwater quality. In addition, the GAMA-PBP analyzes samples for a suite of chemical and isotope tracers for exploring hydrologic and geochemical processes. A broader understanding of groundwater composition is useful for identifying the natural and human factors affecting water quality. Understanding the occurrence and distribution of chemical constituents of significance to water quality is important for the long-term management and protection of groundwater resources.

All published and quality-assured data collected for the GAMA Program are available through the USGS National Water Information System (NWIS) web interface (U.S. Geological Survey, 2013c) and the SWRCB GeoTracker groundwater information system (California State Water Resources Control Board, 2009).

This USGS Data Series Report is similar to other USGS Data Series Reports written for the GAMA-PBP study units sampled to date and is the first in a series of reports presenting the water-quality data collected in the NSF-SA study unit. Data Series Reports and additional reports addressing the *status*, *understanding*, and *trends* aspects of the water-quality assessments of each study unit are available from the U.S. Geological Survey (2013d) at [http://ca.water.usgs.gov/gama/includes/GAMA\\_publications.html](http://ca.water.usgs.gov/gama/includes/GAMA_publications.html).

## Purpose and Scope

The purposes of this report are to describe (1) the hydrogeologic setting of the NSF-SA study unit, the study design, and the study methods; (2) the analytical results for groundwater samples collected in the NSF-SA study unit, and (3) the results of QC analyses. Groundwater samples were collected and analyzed for field water-quality indicators; organic, special-interest, inorganic, and radioactive constituents; and geochemical and age-dating tracers. The chemical data presented in this report were compared to California State and Federal drinking-water regulatory benchmarks that are applied to treated drinking water, and to non-regulatory benchmarks established for constituents without regulatory benchmarks. Regulatory and non-regulatory benchmarks considered for this report are those established by the USEPA, the CDPH, and the USGS. Discussion of the factors that influence the distribution and occurrence of the constituents detected in groundwater samples will be the subject of subsequent publications.

## Hydrogeologic Setting

The NSF-SA study unit lies within the Northern Coast Ranges hydrogeologic province described by Belitz and others (2003). The study unit covers 1,850 square miles (mi<sup>2</sup>) in Napa, Sonoma, Mendocino, Marin, and Solano Counties. The NSF-SA study unit is larger than the North San Francisco Bay Primary Aquifer study unit defined by Kulongoski and others (2006) for the GAMA-PBP assessment of public-supply aquifers ([fig. 2](#)). The NSF-SA study unit is divided into two study areas, the Valley and Plains study area and the Highlands study area.

The climate in the NSF-SA study unit is characterized by warm, dry summers and cool, moist winters. The average annual temperature in Sonoma is 59 degrees Fahrenheit (°F), and the average annual precipitation is 30 inches, occurring as rain during the winter and early spring (Western Regional Climate Center, 2013).

The study unit is drained by several rivers and their principal tributaries, including the Napa River, Sonoma Creek, and Petaluma River, which flow into San Pablo Bay, and the Laguna de Santa Rosa and Russian Rivers, which flow out to the Pacific Ocean. The highland areas are drained primarily by tributaries of the larger rivers and creeks listed here ([fig. 2](#)).

### Valley and Plains Study Area

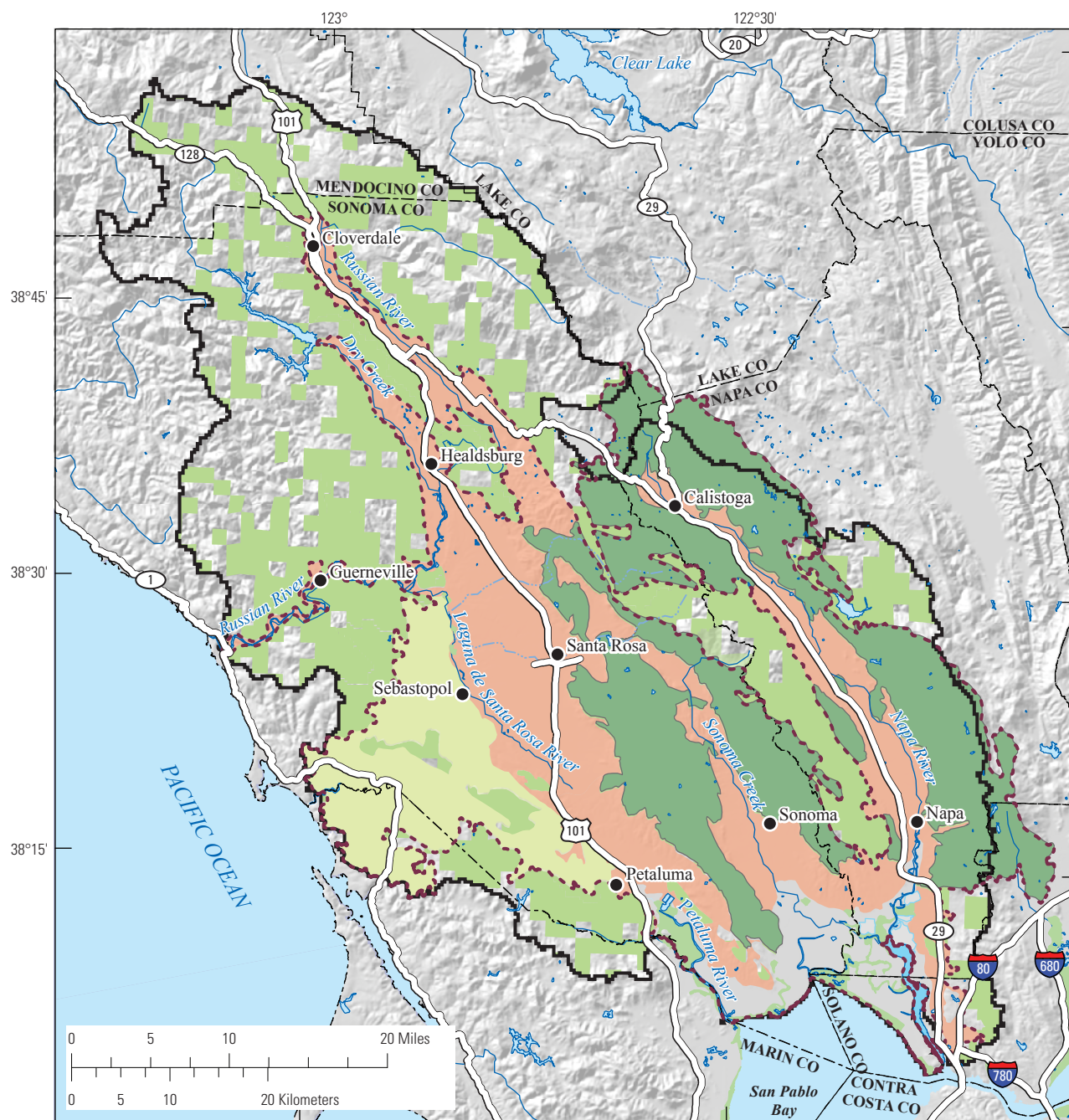
The Valley and Plains study area covers the same area as the Valley and Plains study area of Kulongoski and others (2006) and was defined by the extent of six CDWR groundwater basins: the Alexander, Kenwood, Napa-Sonoma,

Petaluma, Santa Rosa, and Sonoma Valleys (California Department of Water Resources, 2003) ([fig. 2](#)). These basins result from a series of northwest-southeast-trending structural depressions in the southern part of the Northern Coast Ranges (Cardwell, 1958; Farrar and others, 2006; Metzger and others, 2006). The main water-bearing units in the basins are the alluvial sediments that range in age from Tertiary to Quaternary (California Department of Water Resources, 2003, 2004a–f). The thickness of the sediments progressively increases from north to south and from the valley margins towards the rivers in the centers of the valleys. Sediment thickness within the valleys ranges from 10 feet (ft) to more than 300 ft. Groundwater recharge to the alluvial aquifers occurs primarily by stream-channel infiltration beneath major rivers and their tributaries and by direct infiltration of precipitation, with only minor recharge resulting from irrigation or other sources (Farrar and others, 2006; Metzger and others, 2006).

### Highlands Study Area

The Highlands study area consists of the CDWR Wilson Grove Formation Highlands groundwater basin and the areas surrounding the Valley and Plains study area ([fig. 2](#)). Johnson and Belitz (in press) divided the State into 938 groundwater units: the 463 alluvial groundwater basins defined by the CDWR, and 475 areas outside of these groundwater basins, hereinafter identified as highland areas. The highland areas associated with groundwater basins were delineated based upon the surficial contributing area (watershed) immediately adjacent to and upslope of each groundwater basin (Johnson and Belitz, in press). The Highlands study area includes the highland groundwater units associated with the CDWR groundwater basins located in the Valley and Plains study area. Although it is defined as a groundwater basin by CDWR, the Wilson Grove Formation Highlands groundwater basin was defined by Johnson and Belitz (in press) as an associated highland groundwater unit and is included in the Highlands study area. The Highlands study area is larger than the Wilson Grove Formation and Volcanic Highlands study areas of Kulongoski and others (2006).

The Highlands study area covers about 940 mi<sup>2</sup> with topography ranging from rolling hills and rounded hill tops to mountainous; mountain elevations are from 1,000 to more than 4,000 ft. The study area is composed of a variety of geologic units, with Tertiary volcanic (primarily the Sonoma Volcanics) and Cretaceous marine rocks (primarily the Franciscan Complex) predominating. Important water-bearing units within these rocks are often those with the highest porosities and transmissivities, which for the volcanic rocks are the tuffs (consolidated volcanic ash) and breccias (angular broken rock fragments), and for marine rocks are the conglomerates and sandstones.



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

#### EXPLANATION

- |  |                                                                                           |  |                                                                           |
|--|-------------------------------------------------------------------------------------------|--|---------------------------------------------------------------------------|
|  | North San Francisco Bay Shallow Aquifer study unit                                        |  | Volcanic Highlands study area (Kulongoski and others, 2006)               |
|  | North San Francisco Bay Primary Aquifer study unit boundary (Kulongoski and others, 2006) |  | Wilson Grove Formation Highlands study area (Kulongoski and others, 2006) |
|  | Highlands study area                                                                      |  |                                                                           |
|  | Valley and Plains study area                                                              |  |                                                                           |

**Figure 2.** Location and boundaries of the North San Francisco Bay Shallow Aquifer study unit, the Primary Aquifer study unit (Kulongoski and others, 2006), and the Highlands and Valley and Plains study areas, and the location of major cities, topographic features, and hydrologic features, California GAMA Priority Basin Project.



## Methods

Methods used for the GAMA-PBP were selected to achieve the following objectives: (1) design a sampling plan for suitable statistical representation; (2) collect samples in a consistent manner; (3) analyze samples by using proven and reliable laboratory methods; (4) assure the quality of the groundwater data; and (5) maintain data securely and with relevant documentation. [Appendix A](#) contains detailed descriptions of the sample-collection protocols, analytical methods, the QA methods, and the results of analyses of QC samples.

## Study Design

Seventy wells were selected to provide a statistically unbiased, spatially distributed assessment of the quality of groundwater resources within the shallow aquifer system. Wells sampled as part of the spatially distributed, randomized grid-cell network, hereinafter, are referred to as “grid wells.” One additional, non-randomized well (hereinafter referred to as the “understanding well”) was selected to aid in the understanding of specific issues associated with vertical changes in groundwater quality and age.

The grid wells were selected by using a randomized grid-based method (Scott, 1990). The study unit was divided into equal-area grid cells as part of the randomized grid-based method; however, geographic features may force a grid cell to be divided into multiple pieces to obtain the designated coverage area for each cell. For example, parts of a grid cell may be located on either side of a mountain range, but the grid cell is still considered one grid cell. The Valley and Plains study area was divided into thirty 12-mi<sup>2</sup> grid cells, and the Highlands study area was divided into forty 23-mi<sup>2</sup> grid cells. To avoid having grid cells in the Highlands study area that did not contain any wells suitable for this study, only sections of land with at least one drillers’ log for a domestic or public-supply well were included in the area divided into grid cells. The population of wells in each section statewide was estimated from a statistical evaluation of the CDWR’s library of 750,000 scanned images of drillers’ logs (Johnson and Belitz, in press). Sections without drillers logs lack the green color of the Highlands study area and are most often in the northern portions of the study unit.

The objective was to sample one shallow well in each grid cell ([fig. 3](#)). Shallow wells were targeted by using drillers’ log information obtained from the CDWR. Drillers’ logs of shallow wells (generally private domestic and small-system wells) that contained location information were compiled for each cell. To ensure that wells were randomly selected, a random latitude/longitude point was defined in each cell, and wells located closest to the random point were given highest priority. Locations were visited in descending order of priority while waiting for permission from the well owner to sample

an appropriate well. Basic sampling criteria (for example, a sampling point located prior to any treatment, such as chlorination, or the capability to pump for an extended period of time) were considered prior to sampling.

The 70 grid wells sampled in the NSF-SA study unit were named by using the prefix “S-NSF-H” for wells in the Highlands study area or “S-NSF-VP” for wells in the Valley and Plains study area ([fig. 3](#)). A sequence number defined by the number of the grid cell in which the samples were collected in each study area was then added, creating a unique alphanumeric GAMA identification number.

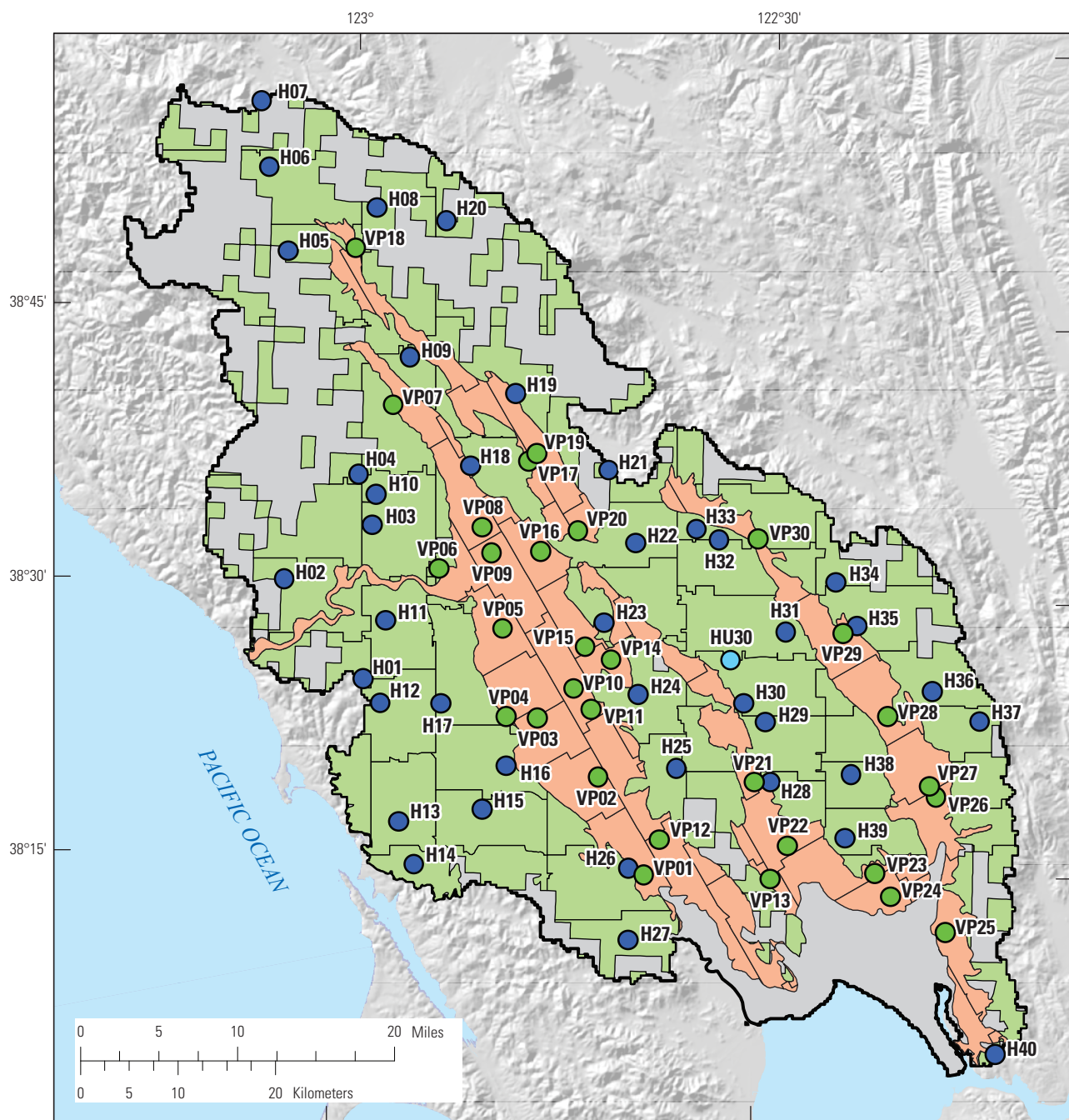
The one understanding well sampled as part of the study was not included in the statistical characterization of water quality in the NSF-SA study unit because inclusion of this well would lead to the overrepresentation of one cell. The additional well was named by using the prefix “S-NSF-HU” (“U” indicating “understanding”).

The GAMA identification number for each well, the date sampled, well type, well altitude, available well-construction information, and depth to water level are listed in [table 1](#). Groundwater samples were collected during the time period from April to August 2012. Well types in [table 1](#) are identified as production, spring, or unused. Any site with a pump that brought groundwater to the land surface was considered a production well, whereas any site where groundwater intersected the land surface was considered a spring. Grid wells included 64 production wells, 4 springs, and 2 unused wells. The understanding well was a production well. Unless the distinction is important, for the remainder of the report, all sampled sites will be referred to as wells even though some are springs.

Well locations were verified by using a global positioning system (GPS), 1:24,000-scale USGS topographic maps, existing well information in USGS and CDPH databases, and information provided by well owners, drillers’ logs, or other sources of site information. Well locations and information were recorded by hand on field sheets and electronically on field laptop computers using the Alternate Place Entry (APE) program designed by the USGS. All information was verified and then uploaded into the USGS NWIS. Well owner and well use information is confidential.

## Sample Collection and Analysis

Samples were collected in accordance with the USGS National Field Manual (NFM) (U.S. Geological Survey, variously dated) and modified USGS National Water Quality Assessment (NAWQA) Program sampling protocols (Koterba and others, 1995). These sampling protocols were followed so that representative samples of groundwater were collected at each well and to ensure that the samples were collected and handled in a manner that minimized the potential for contamination.



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

#### EXPLANATION

- Highlands study area understanding well
- Highlands study area grid well
- Valley and Plains study area grid well
- Highlands study area
- Valley and Plains study area
- Study unit boundary

**Figure 3.** Distribution of the Highlands and Valley and Plains study area grid cells, the location of sampled grid and understanding wells, and topographic features, North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project.

All 71 wells in the NSF-SA study unit were sampled for a standard set of constituents ([table 2](#)). [Tables 3A–G](#) list the compounds analyzed in each constituent class. Groundwater samples were analyzed for 85 volatile organic compounds (VOCs; [table 3A](#)); 63 pesticides and pesticide degradates ([table 3B](#)); 2 constituents of special interest ([table 3C](#)); 23 trace elements ([table 3D](#)); 5 nutrients ([table 3E](#)); 9 major and minor ions, silica, total dissolved solids (TDS), and laboratory alkalinity ([table 3F](#)); and 5 isotopic tracers and 5 radioactive constituents, including tritium and carbon-14 abundance ([table 3G](#)). The methods used for sample collection and analysis are described in the section in [appendix A](#) titled “Sample Collection and Analysis.”

## Data Reporting

The methods and conventions used for reporting the data are described in the section in [appendix A](#) titled “Data Reporting.” Five constituents analyzed in this study were measured by more than one method at the USGS National Water Quality Laboratory (NWQL), four of which only have results reported from the preferred method (see the section in [appendix A](#) titled “Constituents on Multiple Analytical Schedules” for the preferred method selection procedure). Three field water-quality indicators—alkalinity, pH, and specific conductance—were measured in the field and at the NWQL. The VOC 1,2,3-trichloropropane (1,2,3-TCP) was measured at the NWQL and Weck Laboratories, Inc.

## Quality-Assurance Methods

The QA/QC procedures used for this study followed the protocols used by the NAWQA Program (Koterba and others, 1995) and are described in the NFM (U.S. Geological Survey, variously dated). The QA plan followed by the NWQL, the primary laboratory used to analyze samples for this study, is described in Pirkey and Glodt (1998) and Maloney (2005). QC samples collected in the NSF-SA study unit were blanks, replicates, and matrix and surrogate spikes. QC samples were collected to evaluate potential contamination, as well as bias and variability of the data that may have resulted from sample collection, processing, storage, transportation, and laboratory analysis. QA/QC procedures and results are described in the section in [appendix A](#) titled “Quality-Assurance Methods and Results.”

# Water-Quality Results

## Quality-Control Results

Results of QC analyses (blanks, replicates, and matrix and surrogate spikes) were used to evaluate the quality of the data for the groundwater samples. On the basis of detections in field blanks collected for this and for previous GAMA-PBP study units, the study reporting levels (SRLs) for ten volatile organic compounds and eight trace elements were raised (see [table A3](#) and additional discussion in the section in [appendix A](#) titled “Detections in Field Blanks and Application of SRLs”). Detections of these constituents with concentrations less than their SRLs were reported as a non-detection (VOCs) or flagged with a less than or equal to symbol ( $\leq$ ) (trace elements) in this report and in the NWIS database ([tables 5](#) and [8](#)).

Results from the replicates confirm that the procedures used to collect and analyze the samples were consistent. Variability for nearly 100 percent of the replicate pairs for constituents detected in samples was within the acceptable limits ([tables A4A–C](#)). The criteria for acceptable replication is described in the section in [appendix A](#) titled “Quality Assurance Methods and Results.” Median matrix-spike recoveries for 28 of the 148 organic constituents analyzed were lower than the acceptable limit of 70 percent, and 11 were greater than the acceptable limit of 130 percent ([tables 3B](#) and [A5A–B](#)). The constituents for which low recoveries occurred might not have been detected in some samples if they were present in the samples at concentrations near the laboratory reporting levels (LRLs). High recoveries of constituents may indicate that reported values could be greater than what is in the sample. The QC results are described in the section in [appendix A](#) titled “Quality-Control Methods and Results.”

## Comparison Benchmarks

The chemical data presented in this report are meant to characterize the quality of the untreated groundwater within the shallow aquifers of the NSF-SA study unit and are not intended to represent the drinking water used by consumers. The chemical composition of treated drinking water may differ from untreated groundwater because treated drinking water may be subjected to disinfection, filtration, mixing with other waters, and (or) exposure to the atmosphere prior to its use. To place the results in a human-health context, however, concentrations of constituents measured in the untreated groundwater were compared to regulatory and non-regulatory benchmarks that are used to assess drinking-water quality.



In the first phase of the GAMA-PBP (primary aquifer system), concentrations of constituents detected in groundwater samples were compared with CDPH and U.S. Environmental Protection Agency (USEPA) regulatory and non-regulatory drinking-water health-based benchmarks and benchmarks established for aesthetic purposes (California Department of Public Health, 2010, 2013a; U.S. Environmental Protection Agency, 2012). For the second phase (shallow aquifer system) of the GAMA-PBP, an additional non-regulatory health-based drinking-water benchmark was included: the Health-Based Screening Level (HBSL) (Toccalino and others, 2012). A constituent may have values for more than one type of benchmark, and the different benchmarks must be prioritized in order to develop a consistent set of comparison benchmarks. In both phases of the GAMA-PBP, highest priority was given to regulatory, health-based benchmarks (fig. 4). The prioritization of benchmarks used for constituents without regulatory health-based benchmarks was changed between the first and second phases of the GAMA-PBP. In the first phase, non-regulatory aesthetic-based and health-based benchmarks established by the CDPH were given priority over non-regulatory health-based benchmarks established by the USEPA; whereas, in the second phase, non-regulatory health-based benchmarks were given priority over non-regulatory aesthetic-based benchmarks (fig. 4). The comparison benchmarks used in this study are described in order of priority. The effects of the change in prioritization are described in appendix B. Boron and manganese are the only constituents detected in the NSF-SA study unit for which the change in the prioritization of the benchmarks and addition of the HBSLs changed the presentation of the results.

**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 benchmark concentrations for a number of constituents with MCLs established by the USEPA. In this report, a benchmark 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.” Well owners are notified when constituents are detected at concentrations greater than an MCL-US or an MCL-CA benchmark in samples collected for the GAMA-PBP, but these detections do not constitute violations of CDPH regulations.

**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 greater than the action-level benchmarks 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, these benchmarks are labeled “AL-US” in this report.

Hierarchies used by GAMA-PBP to select benchmarks for comparison with groundwater-quality data

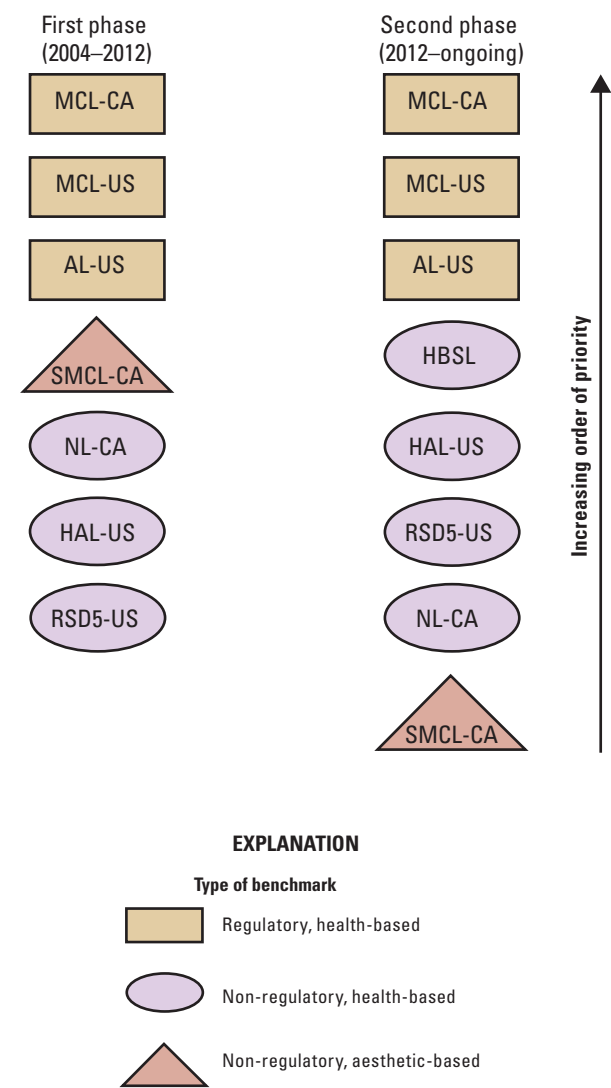


Figure 4. Hierarchies showing the California GAMA Priority Basin Project select benchmarks used for comparison with groundwater-quality data.



**HBSL—Health-Based Screening Level.** Non-enforceable water-quality benchmarks developed by the USGS in collaboration with the USEPA, New Jersey Department of Environmental Protection (NJDEP), and Oregon Health & Science University (OHSU). HBSLs are established by using the same methodologies implemented by the USEPA when establishing drinking-water guidelines and are based on the most recent human-health toxicity information available (Toccalino and others, 2012). HBSLs are not established for constituents that have MCL-US benchmarks. HBSLs have been established for many constituents that also have USEPA non-regulatory health-based benchmarks and for a large number of organic constituents for which USEPA has not yet established benchmarks. For carcinogenic constituents, the HBSL range represents the constituent concentration in drinking water that represents an excess estimated lifetime cancer risk of 1 chance in 1 million to 1 chance in 10 thousand. For noncarcinogens, the HBSL concentration is the maximum concentration in drinking water that a lifetime of exposure is not expected to cause any adverse effect. HBSLs follow USEPA assumptions about lifetime ingestion and are calculated assuming consumption of 2 liters (L) (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.

**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 L (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. Because the methods used to calculate HAL-US and HBSL benchmarks are the same, for constituents having a HAL-US, the HBSL and the HAL-US generally have the same value.

**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 the  $10^{-5}$  risk level ( $10^{-5}$  equals 1/100,000). RSD5s are calculated by dividing the  $10^{-4}$  cancer risk concentration established by the USEPA by 10 (RSD5-US).

**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 in drinking water at concentrations greater than its NL-CA, California State law requires timely notification of local governing bodies and recommends consumer notification.

**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 the 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. For chloride, sulfate, specific conductance, and TDS, CDPH defines a “recommended” and an “upper” SMCL-CA; detections of these constituents in groundwater samples were compared with both levels. The SMCL-US levels for these constituents correspond to their recommended SMCL-CAs. 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.

Note that using this hierarchy to select the comparative benchmark for a constituent with more than one type of established benchmark will not necessarily result in selection of the benchmark with the lowest concentration. For example, the HBSL for boron is 6,000 micrograms per liter ( $\mu\text{g/L}$ ), and the NL-CA is 1,000  $\mu\text{g/L}$ , but the comparative benchmark selected by this hierarchy is the HBSL. The comparative benchmarks used in this report are listed in [tables 3A–G](#) for all constituents and in [tables 4–12](#) for constituents detected in groundwater samples from the NSF-SA study unit. Established benchmarks are not available for all constituents analyzed for this study. Detections of constituents at concentrations greater than the selected comparative benchmarks are marked with an asterisk (\*) in tables.

## Groundwater-Quality Data

Results from analyses of untreated-groundwater samples from the NSF-SA study unit are presented in [tables 4–12](#). Groundwater samples collected in the NSF-SA study unit were analyzed for 207 constituents and water-quality indicators; 118 of those constituents were not detected in any of the samples, and 89 constituents or water-quality indicators were detected.

For organic and special-interest constituents, the results tables include only those constituents that were detected. For the organic constituents, the following summary statistics are presented for all of the grid wells: 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 in the study unit), and the total number of constituents detected at each well. For the inorganic, isotopic, and radioactive constituents, the tables include all of the constituents and wells that were analyzed.

Water-quality indicators measured in the field and at the NWQL are included in [table 4](#). The results of groundwater analyses, organized by constituent class, are presented in [tables 5–12](#):

- Organic constituents
  - Volatile organic compounds ([table 5](#))
  - Pesticides and pesticide degradates ([table 6](#))
- Constituents of special interest ([table 7](#))
- Inorganic constituents
  - Trace elements ([table 8](#))
  - Nutrients ([table 9](#))
  - Major and minor ions, silica, and total dissolved solids ([table 10](#))
  - Isotope tracers ([table 11](#))
  - Radioactive constituents ([table 12](#))

## Water-Quality Indicators

Field measurements of dissolved oxygen and water temperature and field and laboratory measurements of pH, specific conductance, and alkalinity are presented in [table 4](#). Bicarbonate and carbonate concentrations were calculated from the pH and alkalinity results. Dissolved oxygen and alkalinity are used as indicators of natural processes that affect water chemistry. The pH value indicates the acidity or basicity of the water. Specific conductance is the measure of electrical conductivity of the water and is proportional to amount of TDS in the water.

Field pH values were outside of the SMCL-US range for 14 percent of the NSF-SA study unit grid wells: eight well samples had field pH values less than 6.5, and two well samples had field pH values greater than 8.5 ([table 4](#)). Low pH in water may contribute to corrosion of pipes, and high pH in water may contribute to scaling. Laboratory pH values may differ from field pH values because the pH of groundwater may change upon removal from the ambient environment and exposure to the atmosphere.

Field specific-conductance values were greater than the recommended SMCL-CA of 900 microsiemens per centimeter at 25 degrees Celsius ( $\mu\text{S}/\text{cm}$  at 25 °C) for 9 of the 70 grid-well samples, 2 of which were also greater than the upper benchmark of 1,600  $\mu\text{S}/\text{cm}$  at 25 °C ([table 4](#)).

## Organic Constituents

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 groundwater than in surface water because groundwater is isolated from the atmosphere.

Of the 85 VOCs analyzed for the NSF-SA study unit, 22 were detected in groundwater samples, and all but 1 of the concentrations detected were less than health-based benchmarks ([table 5](#)). The VOC benzene was detected in one well at a concentration of 4.41  $\mu\text{g}/\text{L}$ , which is greater than the MCL-CA of 1  $\mu\text{g}/\text{L}$ . One or more VOCs were detected in 28 of the 70 grid-well samples (about 40 percent detection frequency). One VOC had a detection frequency above 10 percent. The trihalomethane chloroform (trichloromethane) was the most frequently detected VOC in the study unit (about 19 percent detection frequency). Chloroform is among the most commonly detected VOCs in groundwater nationally, and its source is attributed, in part, to the recycling of chlorinated waters to aquifers (Zogorski and others, 2006).

Pesticides include herbicides, insecticides, and fungicides and are used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. Of the 63 pesticides and pesticide degradates analyzed at 70 grid wells in the NSF-SA study unit, 8 were detected in groundwater samples, and all but 1 of the concentrations detected were less than health-based benchmarks ([table 6](#)). The insecticide dieldrin was detected in one well at a concentration of 0.065  $\mu\text{g}/\text{L}$  which is greater than the HBSL of 0.02  $\mu\text{g}/\text{L}$ . One or more pesticides or pesticide degradates were detected in 9 of the 70 NSF-SA study unit grid well samples (about 13 percent detection frequency). The herbicide simazine was detected in more than 10 percent of the samples from the Valley and Plains study area. Simazine is among the nation's most commonly detected pesticide compounds in groundwater (Gilliom and others, 2006).

## Constituents of Special Interest

Perchlorate and 1,2,3-TCP were classified as constituents of special interest at the inception of the GAMA-PBP in 2003 because they had recently been detected in some drinking-water supplies in California and the CDPH was considering whether or not to pursue future regulation of these constituents. The CDPH promulgated an MCL-CA for perchlorate in 2007 and is currently (as of 2013) developing an MCL-CA for 1,2,3-TCP (California Department of Public Health, 2013b). Perchlorate was detected in 19 of 70 grid-well samples (about 27 percent detection frequency), and all detections had concentrations less than the MCL-CA of 6  $\mu\text{g}/\text{L}$  ([table 7](#)). 1,2,3-TCP was not detected.

## Inorganic Constituents

Unlike the organic constituents, most of the inorganic constituents generally are naturally present in groundwater, although their concentrations may be influenced by human activities.

Nineteen of the 23 trace elements and 1 of the major and minor ions analyzed and detected in the NSF-SA study unit have regulatory or non-regulatory health-based benchmarks (tables 3D, F). Of these 19 constituents with health-based benchmarks, 4 constituents were detected at concentrations greater than benchmarks; all detections of 15 constituents had concentrations less than their respective benchmarks. Manganese concentrations greater than the HBSL of 300 µg/L were detected in samples from 13 grid wells, arsenic concentrations greater than the MCL-US of 10 µg/L were detected in samples from 7 grid wells, boron concentrations greater than the HBSL of 6,000 µg/L were detected in samples from 2 grid wells, and fluoride concentrations greater than the MCL-CA of 2 milligrams per liter (mg/L) were detected in samples from 2 grid wells (tables 8 and 10).

Nutrients (nitrogen and phosphorus) present in groundwater can affect biological activity in aquifers and in surface-water bodies that receive groundwater discharge. Inorganic nitrogen may be present in the form of ammonia, nitrite, or nitrate, depending on the oxidation-reduction state of the groundwater. High concentrations of nitrate can adversely affect human health, particularly the health of infants. Groundwater samples from two grid wells (S-NSF-VP11 and S-NSF-VP25) had nitrate concentrations equal to or greater than the MCL-US of 10 mg/L (table 9). All other nutrient concentrations in NSF-SA were less than health-based benchmarks.

The levels of certain trace elements, major-ion composition, and TDS content in groundwater affect the aesthetic properties of water, such as taste, color, and odor, and the technical properties of water, such as scaling and staining. Although there are no adverse health effects directly associated with these properties, they may reduce consumer satisfaction with the water or may have economic effects. The CDPH has established non-enforceable benchmarks (SMCL-CAs) that are based on aesthetic properties rather than on human-health concerns for iron, manganese, silver, zinc, chloride, sulfate, and TDS. Manganese, silver, and zinc also have HBSLs, which are used as the comparison benchmarks in this study (table 3D). Iron and manganese are trace elements whose concentrations are affected by the oxidation-reduction state of the groundwater. Precipitation of minerals containing iron or manganese may cause orange, brown, or black staining of surfaces.

Iron concentrations greater than the SMCL-CA of 300 µg/L were detected in 13 grid-well samples (table 8). Chloride concentrations were greater than the recommended SMCL-CA of 250 mg/L in two grid-well samples (table 10).

Chloride was not detected at a concentration greater than the upper SMCL-CA of 500 mg/L. Sulfate concentrations were greater than the recommended SMCL-CA of 250 mg/L in two grid-well samples, one of which was also greater than the upper SMCL-CA of 500 mg/L (table 10). TDS concentrations were greater than the recommended SMCL-CA of 500 mg/L for 15 grid-well samples, 4 of which were also greater than the upper SMCL-CA of 1,000 mg/L (table 10).

## Geochemical and Age-Dating Tracers

Geochemical and age-dating tracers may be used to help interpret hydrologic processes affecting groundwater quality (Clark and Fritz, 1997).

The stable isotopic ratios of hydrogen and oxygen in water (table 11) aid in the interpretation of the sources of groundwater recharge (see section in appendix A titled “Notation” for description of how stable isotopic ratios are reported). These stable isotopic ratios reflect the altitude, latitude, and temperature of precipitation and also the extent of evaporation of the water in surface-water bodies or soils prior to infiltration into the aquifer. The stable isotopic ratio of boron in water may be useful in distinguishing the sources of boron in aquifers. In regions that have diverse geology, strontium isotope ratios may aid in estimating groundwater-flow paths.

Tritium activities (table 12) and helium isotope ratios provide information about the age (time since recharge) of groundwater. Tritium is a short-lived radioactive isotope of hydrogen that is incorporated into the water molecule. Low levels of tritium are produced continuously by interaction of cosmic radiation with the Earth’s atmosphere, and a large amount of tritium was produced as a result of atmospheric testing of nuclear weapons between 1952 and 1963. Thus, concentrations of tritium greater than background generally indicate the presence of water recharged after the early 1950s. Helium isotope ratios are used in conjunction with tritium concentrations to estimate ages for young groundwater. Of the isotope-tracer constituents analyzed for this study, tritium is the only one with a health-based benchmark. All of the measured tritium activities in samples from the NSF-SA study unit were less than 1/100 of the MCL-CA benchmark (table 12).

Carbon-14 (table 11), a radioactive isotope of carbon, is also an age-dating tracer. Low levels of carbon-14 are produced continuously by interaction of cosmic radiation with the Earth’s atmosphere and incorporated into atmospheric carbon dioxide. Carbon dioxide dissolves in precipitation, surface water, and groundwater exposed to the atmosphere, thereby entering the hydrologic cycle. Because carbon-14 decays with a half-life of approximately 5,700 years, low activities of carbon-14, relative to modern values, generally indicate a presence of groundwater that is several thousand years old or more.



## Radioactive Constituents

Radioactivity is the release of energy or energetic particles during changes in the structure of the nucleus of an atom. Most radioactivity in groundwater 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. Uranium and thorium decay in a series of steps eventually forming stable isotopes of lead (Soddy, 1913; Faure and Mensing, 2005). 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. The alpha and beta particles emitted during radioactive decay may be hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA may increase the risk of getting cancer.

Activity often is used instead of concentration for reporting the presence of radioactive constituents. Activity of radioactive constituents in groundwater is measured in units of picocuries per liter (pCi/L), and 1 pCi/L 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.

Radon-222 was collected and analyzed in samples from 68 of the 70 grid wells. Radon-222 activity was greater than the proposed MCL-US of 4,000 pCi/L in two of the grid wells ([table 12](#)). The proposed 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, 1999). Gross alpha and gross beta particle activities were less than established health-based benchmarks in all samples ([table 12](#)).

## Future Work

Subsequent reports for the NSF-SA study unit will be focused on assessment of the data presented in this report by using a variety of statistical, qualitative, and quantitative approaches to evaluate the natural and human factors affecting groundwater quality in the NSF-SA study unit. If available, additional water-quality data will be compiled, evaluated, and used in combination with the data that are presented in this report.

## Summary

Groundwater quality in the 1,850-square-mile North San Francisco Bay Shallow Aquifer (NSF-SA) study unit was investigated by the U.S. Geological Survey (USGS) from April to August 2012, as part of the California State Water Resources Control Board (SWRCB) Groundwater Ambient Monitoring and Assessment (GAMA) Program's Priority Basin Project (PBP). The GAMA Program was

created to provide a comprehensive baseline of groundwater quality in the State. The GAMA-PBP was created as a result of the Groundwater Quality Monitoring Act of 2001 (Sections 10780–10782.3 of the California Water Code, Assembly Bill 599) to assess and monitor the quality of groundwater. The GAMA-PBP is being conducted by the USGS in cooperation with the SWRCB and Lawrence Livermore National Laboratory (LLNL).

The GAMA NSF-SA study was designed to provide a spatially unbiased assessment of untreated-groundwater quality within the shallow aquifer system and to facilitate statistically consistent comparisons of untreated-groundwater quality throughout California. The shallow aquifer system is defined as the part of the aquifer system that is used by many private domestic wells and is shallower than the primary aquifer system used by many public-supply wells.

This assessment characterized the quality of groundwater in the NSF-SA study. Most of the wells sampled for this study were private domestic wells. Private domestic wells are not regulated in California and groundwater from these wells is rarely analyzed for water-quality constituents. Although regulatory benchmarks for drinking water quality do not apply to private domestic wells, to provide some context for the results, concentrations of constituents measured in the untreated groundwater were compared with regulatory and non-regulatory health-based benchmarks established by the U.S. Environmental Protection Agency (USEPA), CDPH, and USGS and non-regulatory benchmarks established for aesthetic concerns by CDPH.

The NSF-SA study unit is located within the Northern Coast Ranges hydrogeologic province and includes 12 groundwater basins or subbasins defined by the California Department of Water Resources and surrounding highland areas outside of the groundwater basins. The NSF-SA study included assessment of the groundwater quality from 71 wells in Marin, Mendocino, Napa, Solano, and Sonoma Counties. Seventy wells were selected by using a randomized grid approach to achieve a statistically unbiased representation of groundwater in shallow aquifer systems used for private, domestic drinking-water supplies (grid wells), and one additional well was selected to aid in the evaluation of water-quality issues (understanding well).

Groundwater samples were analyzed for field water-quality indicators, organic constituents, special-interest constituents, inorganic constituents, and radioactive constituents. Naturally occurring isotopes were measured to provide a dataset that will be used to interpret the sources and ages of the sampled groundwater. In total, 207 constituents and water-quality indicators were measured for this study. This report describes the sampling, analytical, and quality-assurance methods used in the study and presents the results of the chemical analyses made of the groundwater samples.

Three types of quality-control samples (blanks, replicates, and matrix spikes) were collected at up to 13 percent of the wells in the NSF-SA study unit, and the results for these samples were used to evaluate the quality of the

data for the groundwater samples. Blanks rarely contained detectable concentrations of any constituent, suggesting that contamination from sample collection procedures was not a significant source of bias in the data for the groundwater samples. Replicate samples generally were within the limits of acceptable analytical reproducibility. Matrix-spike recoveries were within the acceptable range (70 to 130 percent) for approximately 91 percent of the compounds.

In the grid-well samples, 1 detection of benzene was greater than the CDPH maximum contaminant level (MCL-CA), 1 detection of dieldrin was greater than the USGS Health-Based Screening Level (HBSL), 13 detections of manganese were greater than the HBSL, 7 detections of arsenic were greater than the USEPA maximum contaminant level (MCL-US), 2 detections of boron were greater than the HBSL, 2 detections of fluoride were greater than the MCL-CA, 2 detections of nitrate were greater than the MCL-US, and 2 detections of radon-222 were greater than the proposed MCL-US. The following constituents had concentrations greater than the CDPH secondary maximum contaminant level (SMCL-CA): 13 detections of iron, 2 detections of chloride, 2 detections of sulfate (1 of which was also greater than the SMCL-CA upper benchmark), and 15 detections of total dissolved solids (4 of which were also greater than the SMCL-CA upper benchmark).

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## References Cited

- American Public Health Association, 1998, Standard methods for the examination of water and wastewater (20<sup>th</sup> ed.): Washington, D.C., American Public Health Association, American Water Works Association, and Water Environment Federation, p. 3-37-3-43.
- American Society for Testing and Materials, 1998, Water and environmental technology, *in* Annual Book of ASTM Standards: Philadelphia, Pa., American Society for Testing and Materials, section 11.02 (Water II), p. 664-666.
- Anderson, R.L., 1987, Practical statistics for analytical chemists: New York, Van Nostrand Reinhold Company, Inc., 315 p.
- Belitz, Kenneth, Dubrovsky, N.M., Burow, K.R., Jurgens, Bryant, and Johnson, Tyler, 2003, Framework for a groundwater quality monitoring and assessment program for California: U.S. Geological Survey Water-Resources Investigations Report 03-4166, 78 p.
- Bullen, T.D., Krabbenhoft, D.P., and Kendall, Carol, 1996, Kinetic and mineralogic controls on the evolution of groundwater chemistry and <sup>87</sup>Sr/<sup>86</sup>Sr in a sandy silicate aquifer, northern Wisconsin, USA: *Geochimica et Cosmochimica Acta*, v. 60, no. 10, p. 1807-1821.
- California Department of Public Health, 2010, Drinking water notification levels and response levels—An overview: California Department of Public Health, accessed February 18, 2014, at <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Notificationlevels/notificationlevels.pdf>.
- California Department of Public Health, 2011, Certificates and licenses—Drinking water systems—1,4-Dioxane, accessed February 18, 2014, at <http://www.cdph.ca.gov/certlic/drinkingwater/Pages/1,4-dioxane.aspx>.
- California Department of Public Health, 2013a, California regulations related to drinking water—Title 22: California Department of Public Health, accessed February 18, 2014, at <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/dwregulations-2013-07-01.pdf>.
- California Department of Public Health, 2013b, Certificates and licenses—Drinking water systems—1,2,3-Trichloropropane, accessed February 18, 2014, at <http://www.cdph.ca.gov/certlic/drinkingwater/Pages/123TCP.aspx>.
- California Department of Public Health, 2014, Chromium-6 drinking water MCL, accessed August 29, 2014, at <http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chromium6.aspx>.
- California Department of Water Resources, 2003, California's groundwater update 2003: California Department of Water Resources Bulletin 118, 246 p., accessed October 27, 2011, at <http://www.water.ca.gov/groundwater/bulletin118/update2003.cfm>.
- California Department of Water Resources, 2004a, California's groundwater—Individual basin descriptions, Alexander Valley, Alexander subbasin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-54.01.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-54.01.pdf).
- California Department of Water Resources, 2004b, California's groundwater—Individual basin descriptions, Alexander Valley groundwater basin, Cloverdale subbasin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-54.02.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-54.02.pdf).

- California Department of Water Resources, 2004c, California's groundwater—Individual basin descriptions, Lower Russian River Valley groundwater basin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-60.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-60.pdf).
- California Department of Water Resources, 2004d, California's groundwater—Individual basin descriptions, Santa Rosa Valley, Santa Rosa Plain subbasin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-55.01.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-55.01.pdf).
- California Department of Water Resources, 2004e, California's groundwater—Individual basin descriptions, Santa Rosa Valley, Healdsburg Area subbasin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-55.02.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-55.02.pdf).
- California Department of Water Resources, 2004f, California's groundwater—Individual basin descriptions, Santa Rosa Valley, Rincon Valley subbasin: California Department of Water Resources Bulletin 118, accessed August 6, 2013, at [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/basindescriptions/1-55.03.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/1-55.03.pdf).
- California State Water Resources Control Board, 2003, Report to the Governor and Legislature, A comprehensive groundwater quality monitoring program for California: Assembly Bill 599, March 2003, 121 p., accessed October 27, 2011, at [http://www.waterboards.ca.gov/gama/docs/final\\_ab\\_599\\_rpt\\_to\\_legis\\_7\\_31\\_03.pdf](http://www.waterboards.ca.gov/gama/docs/final_ab_599_rpt_to_legis_7_31_03.pdf).
- California State Water Resources Control Board, 2009, Geotracker GAMA: State Water Resources Control Board database, accessed June 11, 2013, at <https://geotracker.waterboards.ca.gov/gama/>.
- California State Water Resources Control Board, 2013, GAMA—Groundwater Ambient Monitoring and Assessment Program, accessed June 6, 2013, at [http://www.waterboards.ca.gov/water\\_issues/programs/gama/](http://www.waterboards.ca.gov/water_issues/programs/gama/).
- Cardwell, G.T., 1958, Geology and ground water in the Santa Rosa and Petaluma Valley areas, Sonoma County, California: U.S. Geological Survey Water-Supply Paper 1427, 273 p., 5 pls.
- Childress, C.J.O., Foreman, W.T., Connor, B.F., and Maloney, T.J., 1999, New reporting procedures based on long-term method-detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p.
- Clark, I.D., and Fritz, P., 1997, Environmental isotopes in hydrogeology: Boca Raton, Fla., CRC Press LLC, 328 p.
- Connor, B.F., Rose, D.L., Noriega, M.C., Murtagh, L.K., and Abney, S.R., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of 86 volatile organic compounds in water by gas chromatography/mass spectrometry, including detections less than reporting limits: U.S. Geological Survey Open-File Report 97–829, 78 p.
- Coplen, T.B., 1994, Reporting of stable hydrogen, carbon, and oxygen isotopic abundances: Pure and Applied Chemistry, v. 66, p. 273–276.
- Coplen, T.B., Hopple, J.A., Böhlke, J.K., Peiser, H.S., Rieder, S.E., Krouse, H.R., Rosman, K.J.R., Ding, T., Vocke, R.D., Jr., Revesz, K.M., Lamberty, A., Taylor, P., and DeBierve, P., 2002, Compilation of minimum and maximum isotope ratios of selected elements in naturally occurring terrestrial materials and reagents: U.S. Geological Survey Water-Resources Investigations Report 01–4222, 98 p.
- Coplen, T.B., Wildman, J.D., and Chen, J., 1991, Improvements in the gaseous hydrogen-water equilibrium technique for hydrogen isotope analysis: Analytical Chemistry, v. 63, p. 910–912.
- Donahue, D.J., Linick, T.W., and Jull, A.J.T., 1990, Isotope-ratio and background corrections for accelerator mass spectrometry radiocarbon measurements: Radiocarbon, v. 32, book 2, p. 135–142.
- Dwyer, G.S., and Vengosh, A., 2008, Alternative filament loading solution for accurate analysis of boron isotopes by negative thermal ionization mass spectrometry: Eos, Transactions, American Geophysical Union, v. 89, no. 53, abstract H51C-0824.
- Epstein, Samuel, and Mayeda, T.K., 1953, Variation of  $O^{18}$  content of water from natural sources: Geochimica et Cosmochimica Acta, v. 4, p. 213–224.
- Faires, L.M., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of metals in water by inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 92–634, 28 p.
- Farrar, C.D., Metzger, L.F., Nishikawa, Tracy, Koczot, K.M., and Reichard, E.G., 2006, Geohydrological characterization, water-chemistry, and ground-water flow simulation model of the Sonoma Valley area, Sonoma County, California, *with a section on* Basement rock configuration interpreted from gravity data by Victoria E. Langenheim: U.S. Geological Survey Scientific Investigations Report 2006–5092, 167 p.



- Farrar, J.W., and Long, H.K., 1997, Report on the U.S. Geological Survey's evaluation program for standard reference samples distributed in September 1996—T-143 (trace constituents), T-145 (trace constituents), M-140 (major constituents), N-51 (nutrient constituents), P-27 (low ionic strength constituents), and Hg-23 (mercury): U.S. Geological Survey Open-File Report 97-20, 145 p.
- Faure, Gunter, and Mensing, T.M., 2005, *Isotopes—Principles and applications* (3d ed.): Hoboken, New Jersey, John Wiley & Sons, Inc., 897 p.
- Fishman, M.J., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93-125, 217 p.
- Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.
- Fram, M.S., Munday, Cathy, and Belitz, Kenneth, 2009, Groundwater quality data for the Tahoe–Martis study unit, 2007—Results from the California GAMA Program: U.S. Geological Survey Data Series 432, 88 p. (Also available at <http://pubs.usgs.gov/ds/432/>.)
- Fram, M.S., Olsen, L.D., and Belitz, Kenneth, 2012, Evaluation of volatile organic compound (VOC) blank data and application of study reporting levels to groundwater data collected for the California GAMA Priority Basin Project, May 2004 through September 2010: U.S. Geological Survey Scientific Investigations Report 2012-5139, 94 p.
- Gagnon, A.R., and Jones, G.A., 1993, AMS-graphite target production methods at the Woods Hole Oceanographic Institution during 1986–1991: *Radiocarbon*, v. 35, book 2, p. 301–310, <https://journals.uair.arizona.edu/index.php/radiocarbon/article/viewFile/18070/17800#page=65>.
- Garbarino, J.R., 1999, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved arsenic, boron, lithium, selenium, strontium, thallium, and vanadium using inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 99-093, 31 p.
- Garbarino, J.R., Kanagy, J.R., and Cree, M.E., 2006, Determination of elements in natural-water, biota, sediment, and soil samples using collision/reaction cell inductively coupled plasma-mass spectrometry: U.S. Geological Survey Techniques and Methods, book 5, chap. B1, 88 p.
- Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, N., Nowell, L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P., and Wolock, D.M., 2006, The quality of our Nation's waters—Pesticides in the Nation's streams and ground water, 1992–2001: U.S. Geological Survey Circular 1291, 172 p.
- Gran, G., 1952, Determination of the equivalence point in potentiometric titration, Part II: *Analyst*, v. 77, p. 661–671.
- Hahn, G.J., and Meeker W.Q., 1991, *Statistical intervals—A guide for practitioners*: New York, John Wiley & Sons, 392 p.
- Hawaii Department of Health, 2005, Rules relating to public water systems: Hawaii Administrative Rules, Title 11, Chapter 20, 346 p., accessed April 30, 2014, at <http://oeqc.doh.hawaii.gov/sites/har/AdmRules1/11-20.pdf>.
- Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 510 p. (Also available at <http://water.usgs.gov/pubs/twri/twri4a3/>.)
- Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p., 3 pls.
- Hoaglin, D.C., 1983, Letter values—A set of selected order statistics, in Hoaglin, D.C., Mosteller, F., and Tukey, J.W., eds., *Understanding robust and exploratory data analysis*: New York, John Wiley & Sons, p. 33–54.
- Hooker, E.P., Fulcher, K.G., and Gibb, H.J., 2012, Report to the Hawaii Department of Health, Safe Drinking Water Branch, regarding the human health risks of 1,2,3-trichloropropane in tap water: Tetra Tech Services, 101 p., accessed June 12, 2013, at <http://eha-web.doh.hawaii.gov/eha-cma/documents/fd65a6d2-73d1-4d5c-88c6-97a47ba36650>.
- Johnson, T.D., and Belitz, Kenneth, 2014, California Groundwater Units: U.S. Geological Survey Data Series 796, 34 p. (Also available at <http://dx.doi.org/10.3133/ds796>.)
- Johnson, T.D., and Belitz, Kenneth, in press, Domestic wells in California—Mapping their location and population served: *Journal of Hydrology: Regional Studies*.
- Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.



- Koterba, M.T., Wilde, F.D., and Lapham, W.W., 1995, Groundwater data-collection protocols and procedures for the National Water-Quality Assessment Program—Collection and documentation of water-quality samples and related data: U.S. Geological Survey Open-File Report 95–399, 113 p.
- Krieger, H.L., and Whittaker, E.L., 1980, Prescribed procedures for measurement of radioactivity in drinking water: U.S. Environmental Protection Agency EPA-600-4-80-032, 142 p. (Also available as PB80-224744 at <http://www.ntis.gov>.)
- Kulongoski, J.T., and Belitz, K., 2004, Groundwater Ambient Monitoring and Assessment Program: U.S. Geological Survey Fact Sheet 2004–3088, 2 p.
- Kulongoski, J.T., Belitz, Kenneth, and Dawson, B.J., 2006, Ground-water quality data in the North San Francisco Bay hydrologic provinces, California, 2004—Results from the California Ground-Water Ambient Monitoring and Assessment (GAMA) Program: U.S. Geological Survey Data Series Report 167, 100 p.
- Landon, M.K., Belitz, Kenneth, Jurgens, B.C., Kulongoski, J.T., and Johnson, T.D., 2010, Status and understanding of groundwater quality in the Central–Eastside San Joaquin Basin, 2006—California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2009–5266, 97 p.
- Lane, S.L., Flanagan, Sarah, and Wilde, F.D., 2003, Selection of equipment for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A2, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A2/>.
- Lewis, M.E., 2006, Dissolved oxygen (ver. 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.2, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A6.2/>.
- Lindley, C.E., Stewart, J.T., and Sandstrom, M.W., 1996, Determination of low concentrations of acetochlor in water by automated solid-phase extraction and gas chromatography with mass selective detection: *Journal of AOAC International*, v. 79, no. 4, p. 962–966.
- Madsen, J.E., Sandstrom, M.W., and Zaugg, S.D., 2003, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—A method supplement for the determination of fipronil and degradates in water by gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 02–462, 11 p.
- Maloney, T.J., ed., 2005, Quality management system, U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 2005–1263, accessed October 27, 2011, at <http://pubs.usgs.gov/of/2005/1263/>.
- McCurdy, D.E., Garbarino, J.R., and Mullin, A.H., 2008, Interpreting and reporting radiological water-quality data: U.S. Geological Survey Techniques and Methods, book 5, chap. B6, 33 p.
- McLain, B., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of chromium in water by graphite furnace atomic absorption spectrophotometry: U.S. Geological Survey Open-File Report 93–449, 16 p.
- McNichol, A.P., Gagnon, A.R., Jones, G.A., and Osborne, E.A., 1992, Illumination of a black box—Analysis of gas composition during graphite target preparation, *in* Long, A., and Kra, R.S., eds., *Proceedings of the 14th International <sup>14</sup>C Conference: Radiocarbon*, v. 34, book 3, p. 321–329.
- McNichol, A.P., Jones, G.A., Hutton, D.L., and Gagnon, A.R., 1994, The rapid preparation of seawater  $\Sigma\text{CO}_2$  for radiocarbon analysis at the National Ocean Sciences AMS Facility: *Radiocarbon*, v. 36, book 2, p. 237–246.
- Metzger, L.F., Farrar, C.D., Koczot, K.M., and Reichard, E.G., 2006, Geohydrology and water chemistry of the Alexander Valley, Sonoma County, California: U.S. Geological Survey Scientific Investigations Report 2006–5115, 83 p.
- Mueller, D.K., and Titus, C.J., 2005, Quality of nutrient data from streams and ground water sampled during water years 1992–2001: U.S. Geological Survey Scientific Investigations Report 2005–5106, 27 p.
- Okamoto, H.S., Steeber, W.R., Remoy, R., Hill, P., and Perera, S.K., eds., 2002, Determination of 1,2,3-trichloropropane in drinking water by purge and trap gas chromatography/mass spectrometry (February 2002): California Department of Health Services, Division of Drinking Water and Environmental Management, Sanitation and Radiation Laboratories Branch, accessed June 6, 2013, at <http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Drinkingwaterlabs/TCPbyPT-GCMS.pdf>.
- Olsen, L.D., Fram, M.S., and Belitz, Kenneth, 2010, Review of trace-element field-blank data collected for the California Groundwater Ambient Monitoring and Assessment (GAMA) Program, May 2004–January 2008: U.S. Geological Survey Scientific Investigations Report 2009–5220, 47 p.

- Patton, C.J., and Kryskalla, J.R., 2003, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Evaluation of alkaline persulfate digestion as an alternative to Kjeldahl digestion for determination of total and dissolved nitrogen and phosphorous in water: U.S. Geological Survey Water-Resources Investigations Report 03–4174, 33 p.
- Pirkey, K.D., and Glodt, S.R., 1998, Quality control at the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Fact Sheet 026–98, 4 p., accessed October 27, 2011, at <http://pubs.er.usgs.gov/usgspubs/fs/fs02698>.
- Radtke, D.B., Davis, J.V., and Wilde, F.D., 2005, Specific electrical conductance (ver. 1.2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.3, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A6.3/>.
- Sandstrom, M.W., Stoppel, M.E., Foreman, W.T., and Schroeder, M.P., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of moderate-use pesticides and selected degradates in water by C-18 solid-phase extraction and gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4098, 70 p.
- Schneider, R.J., Jones, G.A., McNichol, A.P., von Reden, K.F., Elder, K.A., Huang, K., and Kessel, E.D., 1994, Methods for data screening, flagging, and error analysis at the National Ocean Sciences AMS Facility: Nuclear Instruments and Methods in Physics Research, book 92, p. 172–175.
- Scott, J.C., 1990, Computerized stratified random site selection approaches for design of a ground-water-quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90–4101, 109 p.
- Shelton, J.L., Burow, K.R., Belitz, Kenneth, Dubrovsky, N.M., Land, M.T., and Gronberg, J.M., 2001, Low-level volatile organic compounds in active public supply wells as groundwater tracers in the Los Angeles physiographic basin, California, 2000: U.S. Geological Survey Water-Resources Investigations Report 01–4188, 29 p.
- Soddy, F., 1913, Radioactivity: Annual Reports on the Progress of Chemistry, v. 10, p. 262–288.
- State of California, 2001a, Assembly Bill No. 599, Chapter 522, accessed October 27, 2011, at [http://www.swrcb.ca.gov/gama/docs/ab\\_599\\_bill\\_20011005\\_chaptered.pdf](http://www.swrcb.ca.gov/gama/docs/ab_599_bill_20011005_chaptered.pdf).
- State of California, 2001b, Groundwater Monitoring Act of 2001: California Water Code, part 2.76, Sections 10780–10782.3, accessed October 27, 2011, at <http://www.leginfo.ca.gov/cgi-bin/displaycode?section=wat&group=10001-11000&file=10780-10782.3>.
- Stumm, W., and Morgan, J.J., 1996, Aquatic chemistry—Chemical equilibria and rates in natural waters (3d ed.): New York, John Wiley & Sons, 1022 p.
- Thatcher, L.L., Janzer, V.J., and Edwards, K.W., 1977, Methods for the determination of radioactive substances in water: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A5, 95 p.
- Timme, P.J., 1995, National Water Quality Laboratory 1995 services catalog: U.S. Geological Survey Open-File Report 95–352, 120 p.
- Toccalino, P.L., Norman, J.E., Booth, N.L., Thompson, J.L., and Zogorski, J.S., 2012, Health-Based Screening Levels—Benchmarks for evaluating water-quality data: U.S. Geological Survey, accessed February 19, 2014, at <http://water.usgs.gov/nawqa/HBSL/>.
- U.S. Census Bureau, 1990, Census of population and housing, summary tape file 3A, accessed June 6, 2013, at [ftp://ftp2.census.gov/census\\_1990/](ftp://ftp2.census.gov/census_1990/).
- U.S. Environmental Protection Agency, 1989, 1,2,3-Trichloropropane—Drinking water health advisory: Office of Water, 15 p., accessed February 18, 2014, at <http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=60001XkV.txt>.
- U.S. Environmental Protection Agency, 1999, National primary drinking water regulations, Radon-222: Federal Register, v. 64, no. 211, p. 59, 245–259, and 294.
- U.S. Environmental Protection Agency, 2002, Guidelines for establishing procedures for the analysis of pollutants: U.S. Code of Federal Regulations, Title 40, 136 p.
- U.S. Environmental Protection Agency, 2005, Method 331.0—Determination of perchlorate in drinking water by liquid chromatography electrospray ionization mass spectrometry (Revision 1.0, January 2005): Office of Groundwater and Drinking Water, EPA Document #815-R-05-007, 34 p., accessed October 27, 2011, at [http://www.epa.gov/safewater/methods/pdfs/methods/met331\\_0.pdf](http://www.epa.gov/safewater/methods/pdfs/methods/met331_0.pdf).
- U.S. Environmental Protection Agency, 2012, 2012 Edition of the drinking water standards and health advisories, accessed February 18, 2014, at <http://water.epa.gov/action/advisories/drinking/upload/dwstandards2012.pdf>.

- U.S. Environmental Protection Agency, 2013, Technical fact sheet—1,2,3-Trichloropropane: Office of Solid Waste and Emergency Response, EPA 505-F-11-008, accessed February 18, 2014, at [http://www2.epa.gov/sites/production/files/2014-03/documents/ffrofactsheet\\_contaminant\\_tcp\\_january2014\\_final.pdf](http://www2.epa.gov/sites/production/files/2014-03/documents/ffrofactsheet_contaminant_tcp_january2014_final.pdf).
- U.S. Geological Survey [variously dated], National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A1–A9, accessed October 27, 2011, at <http://water.usgs.gov/owq/FieldManual/>.
- U.S. Geological Survey, 2006, National Elevation Dataset (NED): U.S. Geological Survey database, accessed October 27, 2011, at <http://ned.usgs.gov/>.
- U.S. Geological Survey, 2009, Preferred method selection procedure, National Water Quality Laboratory website, accessed October 27, 2011, at [http://www.nwql.cr.usgs.gov/dyn.shtml?Preferred\\_method\\_selection\\_procedure](http://www.nwql.cr.usgs.gov/dyn.shtml?Preferred_method_selection_procedure).
- U.S. Geological Survey, 2013a, What is the Priority Basin Project?: California Water Science Center website, accessed June 6, 2013, at <http://ca.water.usgs.gov/gama/>.
- U.S. Geological Survey, 2013b, California Groundwater Ambient Monitoring and Assessment (GAMA) Program Priority Basin Project—Shallow aquifer assessment: U.S. Geological Survey Fact Sheet 2012–3136, 2 p.
- U.S. Geological Survey, 2013c, National Water Information System—Web interface, USGS water data for California, accessed June 6, 2013, at <http://waterdata.usgs.gov/ca/nwis/>.
- U.S. Geological Survey, 2013d, Publications: California Water Science Center website, accessed June 6, 2013, at [http://ca.water.usgs.gov/gama/includes/GAMA\\_publications.html](http://ca.water.usgs.gov/gama/includes/GAMA_publications.html).
- U.S. Geological Survey, 2013e, Branch of Quality Systems, Inorganic Blind Sample Project (IBSP) QADATA summaries, accessed June 6, 2013, at <http://bqs.usgs.gov/ibsp/qadata.shtml>.
- U.S. Geological Survey, 2013f, Branch of Quality Systems, Inorganic Blind Sample Project (IBSP) NWQL control charts for fiscal year 2011 analytes, accessed June 6, 2013, at <http://bqs.usgs.gov/ibsp/FY11charts.shtml>.
- Vengosh, A., Chivas, A.R., and McCulloch, M.T., 1989, Direct determination of boron and chlorine isotopes in geological materials by negative thermal ionization mass spectrometry: *Chemical Geology*, v. 79, p. 333–343.
- Vogel, J.S., Nelson, D.E., and Southon, J.R., 1987,  $^{14}\text{C}$  background levels in an accelerator mass spectrometry system: *Radiocarbon*, v. 29, book 3, p. 323–333.
- Weiss, R.F., 1968, Piggyback sampler for dissolved gas studies on sealed water samples: *Deep Sea Research*, v. 15, p. 721–735.
- Western Regional Climate Center, 2013, Western Regional Climate Center, Summary climate data for Northern California, average monthly precipitation data, accessed October 24, 2013, at <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca8351>.
- Wetzel, R.G., and Likens, G.E., 2000, *Limnological analyses* (3d ed.): New York, Springer, 429 p.
- Wilde, F.D., ed., 2004, Cleaning of equipment for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A3, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A3/>.
- Wilde, F.D., 2006, Temperature (ver. 2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.1, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A6.1/>.
- Wilde, F.D., Busenberg, E., and Radtke, D.B., 2006, pH (ver. 1.3): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.4, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A6.4/>.
- Wilde, F.D., and Radtke, D.B., 2005, General information and guidelines (ver. 1.2): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.0, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A6.0/>.
- Wilde, F.D., Radtke, D.B., Gibbs, J., and Iwatsubo, R.T., 1999, Collection of water samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A4/>.
- Wilde, F.D., Radtke, D.B., Gibbs, J., and Iwatsubo, R.T., 2004, Processing of water samples: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A5, accessed October 27, 2011, at <http://pubs.water.usgs.gov/twri9A5/>.
- Wright, M.T., Belitz, Kenneth, and Burton, C.A., 2005, California GAMA Program—Ground-water quality in the San Diego Drainages hydrogeologic province, California, 2004: U.S. Geological Survey Data Series 129, 91 p. (Also available at <http://pubs.usgs.gov/ds/2005/129/>.)
- Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 95–181, 60 p.
- Zogorski, J.S., Carter, J.M., Ivahnenko, T., Lapham, W.W., Moran, M.J., Rowe, B.L., Squillace, P.J., and Toccalino, P.L., 2006, Volatile organic compounds in the Nation's ground water and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.

**Table 1.** Identification, sampling, construction, and water-level information for wells sampled for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The altitude of the LSD is described in feet above the North American Vertical Datum 1988 (NAVD 88). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Other abbreviations:** ft, feet; na, not available]

Sampling information				Construction information <sup>1</sup>			Depth to water level (ft below LSD)
GAMA well identification number	Date sampled (mm/dd/ yyyy)	Well type	Altitude of LSD (ft above NAVD 88)	Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)							
Highlands study area wells (40 wells sampled)							
S-NSF-H01	7/23/2012	Production	1,073	80	na	na	17.16
S-NSF-H02	7/23/2012	Production	65	30	11	30	16.88
S-NSF-H03	7/16/2012	Spring	1,175	at LSD	at LSD	at LSD	na
S-NSF-H04	7/17/2012	Production	801	240	80	240	na
S-NSF-H05	7/25/2012	Production	1,150	160	60	160	41.45
S-NSF-H06	7/30/2012	Production	1,254	na	na	na	127.80
S-NSF-H07	7/30/2012	Production	1,144	200	60	200	36.30
S-NSF-H08	8/2/2012	Production	1,781	300	201	299	na
S-NSF-H09	8/2/2012	Production	387	141	61	141	70.37
S-NSF-H10	8/1/2012	Production	1,366	168	80	168	122.51
S-NSF-H11	6/19/2012	Production	226	22	11	22	11.81
S-NSF-H12	7/16/2012	Spring	710	at LSD	at LSD	at LSD	na
S-NSF-H13	7/24/2012	Production	77	na	na	na	12.22
S-NSF-H14	7/24/2012	Production	90	104	60	104	12.21
S-NSF-H15	6/18/2012	Production	99	116	na	na	8.05
S-NSF-H16	4/25/2012	Production	231	315	115	315	na
S-NSF-H17	4/23/2012	Production	232	180	60	180	31.97
S-NSF-H18	7/18/2012	Production	111	98	58	98	17.81
S-NSF-H19	8/23/2012	Spring	315	at LSD	at LSD	at LSD	na
S-NSF-H20	8/21/2012	Production	1,872	170	30	170	57.53
S-NSF-H21	7/31/2012	Production	490	270	110	270	na
S-NSF-H22	7/11/2012	Production	1,071	240	160	240	na
S-NSF-H23	6/13/2012	Production	482	92	70	92	34.20
S-NSF-H24	7/31/2012	Unused	461	382	112	382	71.18
S-NSF-H25	7/12/2012	Spring	1,571	at LSD	at LSD	at LSD	na
S-NSF-H26	4/18/2012	Production	89	189	na	na	79.25
S-NSF-H27	8/30/2012	Production	103	26	na	na	na
S-NSF-H28	6/20/2012	Production	263	102	na	na	64.55
S-NSF-H29	7/10/2012	Production	1,022	480	80	480	na
S-NSF-H30	8/20/2012	Production	672	345	na	na	<sup>2</sup> 229.24
S-NSF-H31	8/22/2012	Production	1,099	74	34	74	na
S-NSF-H32	7/2/2012	Production	1,125	550	210	550	na
S-NSF-H33	7/11/2012	Production	803	529	389	529	na
S-NSF-H34	4/11/2012	Production	371	155	40	155	7.30
S-NSF-H35	4/10/2012	Production	175	190	40	190	56.54



**Table 1.** Identification, sampling, construction, and water-level information for wells sampled for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The altitude of the LSD is described in feet above the North American Vertical Datum 1988 (NAVD 88). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Other abbreviations:** ft, feet; na, not available]

Sampling information				Construction information <sup>1</sup>			Depth to water level (ft below LSD)
GAMA well identification number	Date sampled (mm/dd/ yyyy)	Well type	Altitude of LSD (ft above NAVD 88)	Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued							
Highlands study area wells (40 wells sampled)—Continued							
S-NSF-H36	4/17/2012	Production	1,264	400	180	400	103.73
S-NSF-H37	8/23/2012	Production	1,230	345	20	345	na
S-NSF-H38	6/14/2012	Production	648	275	200	275	132.31
S-NSF-H39	6/20/2012	Production	582	620	420	620	183.26
S-NSF-H40	7/19/2012	Production	185	175	40	175	na
Valley and Plains study area wells (30 wells sampled)							
S-NSF-VP01	6/18/2012	Production	38	64	24	64	na
S-NSF-VP02	4/24/2012	Production	117	80	40	80	na
S-NSF-VP03	4/25/2012	Production	85	87	27	87	11.76
S-NSF-VP04	4/23/2012	Production	79	217	204	214	60.48
S-NSF-VP05	6/11/2012	Production	104	160	140	160	29.07
S-NSF-VP06	8/22/2012	Production	63	90	30	90	16.12
S-NSF-VP07	8/1/2012	Production	267	360	100	360	87.72
S-NSF-VP08	6/11/2012	Production	161	147	107	147	72.55
S-NSF-VP09	8/22/2012	Production	95	200	40	200	20.14
S-NSF-VP10	6/19/2012	Production	123	134	74	134	15.69
S-NSF-VP11	4/24/2012	Production	142	183	83	183	na
S-NSF-VP12	4/18/2012	Production	159	280	100	280	na
S-NSF-VP13	4/26/2012	Production	60	620	440	620	73.57
S-NSF-VP14	6/13/2012	Production	210	68	60	68	21.81
S-NSF-VP15	7/13/2012	Unused	173	80	38	44	17.02
S-NSF-VP16	7/25/2012	Production	236	107	87	107	37.62
S-NSF-VP17	6/12/2012	Production	150	50	20	50	21.70
S-NSF-VP18	7/26/2012	Production	308	28	8	28	17.53
S-NSF-VP19	8/23/2012	Production	213	200	60	200	82.30
S-NSF-VP20	7/17/2012	Production	543	157	57	157	56.15
S-NSF-VP21	8/22/2012	Production	201	755	395	755	255.24
S-NSF-VP22	7/10/2012	Production	53	250	90	250	27.70
S-NSF-VP23	7/9/2012	Production	107	500	80	500	na
S-NSF-VP24	7/26/2012	Production	94	201	95	205	na
S-NSF-VP25	4/19/2012	Production	36	80	na	na	24.57
S-NSF-VP26	4/9/2012	Production	41	150	40	150	24.45
S-NSF-VP27	4/9/2012	Production	44	190	30	190	9.64
S-NSF-VP28	4/11/2012	Production	83	255	77	255	10.93
S-NSF-VP29	4/12/2012	Production	161	455	180	455	49.71

**Table 1.** Identification, sampling, construction, and water-level information for wells sampled for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The altitude of the LSD is described in feet above the North American Vertical Datum 1988 (NAVD 88). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Other abbreviations:** ft, feet; na, not available]

Sampling information				Construction information <sup>1</sup>			Depth to water level (ft below LSD)
GAMA well identification number	Date sampled (mm/dd/ yyyy)	Well type	Altitude of LSD (ft above NAVD 88)	Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued							
Valley and Plains study area wells (30 wells sampled)—Continued							
S-NSF-VP30	8/21/2012	Production	273	410	60	410	42.83
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)							
S-NSF-HU30	8/20/2012	Production	592	47	na	na	na

<sup>1</sup> Some wells may have multiple perforation intervals; only the shallowest and deepest perforations are listed for those wells.

<sup>2</sup> Water-level measurement for this well was taken on 6/20/2012 and may not be representative of the water level in the well at the time of sampling.

**Table 2.** Classes of chemical constituents and field water-quality indicators collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[na, not applicable]

Constituent classes	Constituent list table	Results table
Field water-quality indicators		
Dissolved oxygen, temperature, pH, and specific conductance	na	<a href="#">4</a>
Field alkalinity, bicarbonate, and carbonate	na	<a href="#">4</a>
Organic constituents		
Volatile organic compounds (VOCs)	<a href="#">3A</a>	<a href="#">5</a>
Pesticides and pesticide degradates	<a href="#">3B</a>	<a href="#">6</a>
Constituents of special interest		
Perchlorate	<a href="#">3C</a>	<a href="#">7</a>
1,2,3-Trichloropropane	<a href="#">3C</a>	<a href="#">7</a>
Inorganic constituents		
Trace elements	<a href="#">3D</a>	<a href="#">8</a>
Nutrients	<a href="#">3E</a>	<a href="#">9</a>
Major and minor ions, silica, and total dissolved solids (TDS)	<a href="#">3F</a>	<a href="#">10</a>
Laboratory alkalinity, bicarbonate, and carbonate	<a href="#">3F</a>	<a href="#">4</a>
Isotopic tracers		
Stable isotopes of hydrogen and oxygen in water	<a href="#">3G</a>	<a href="#">11</a>
Stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance	<a href="#">3G</a>	<a href="#">11</a>
Stable isotopes of boron in water	<a href="#">3G</a>	<a href="#">11</a>
Stable isotopes of strontium in water	<a href="#">3G</a>	<a href="#">11</a>
Radioactive constituents		
Radon-222	<a href="#">3G</a>	<a href="#">12</a>
Gross alpha and gross beta radioactivity (72-hour and 30-day counts)	<a href="#">3G</a>	<a href="#">12</a>
Tritium	<a href="#">3G</a>	<a href="#">12</a>

**Table 3A.** Volatile organic compounds (VOCs), primary uses or sources, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2020.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; MCL-HI, Hawaii Department of Health maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of  $10^{-5}$ . **Other abbreviations:** CAS, Chemical Abstracts Service; CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; SRL, study reporting level; THM, trihalomethane; D, detected in groundwater samples ([table 5](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN® <sup>1</sup>	LRL (µg/L)	Benchmark type <sup>2</sup>	Benchmark level (µg/L) <sup>2</sup>	Detection
Acetone	Solvent	81552	67-64-1	3.4	HBSL (na)	6,000 (na)	—
Acrylonitrile	Organic synthesis	34215	107-13-1	0.48	HBSL (RSD5-US)	0.6 (0.6)	—
<i>tert</i> -Amyl methyl ether (TAME)	Gasoline oxygenate	50005	994-05-8	0.06	na	na	—
Benzene	Gasoline hydrocarbon	34030	71-43-2	0.026	MCL-CA	1	D <sup>3</sup>
Bromobenzene	Solvent	81555	108-86-1	0.022	HBSL (HAL-US)	60 (60)	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.06	HBSL (HAL-US)	90 (90)	D
Bromodichloromethane	Disinfection byproduct (THM)	32101	75-27-4	0.034	MCL-US	<sup>4</sup> 80	D
Bromoform (Tribromomethane)	Disinfection byproduct (THM)	32104	75-25-2	0.1	MCL-US	<sup>4</sup> 80	D
Bromomethane (Methyl bromide)	Fumigant	34413	74-83-9	0.2	HBSL (HAL-US)	100 (10)	—
<i>n</i> -Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.08	NL-CA	260	—
<i>sec</i> -Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.034	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	0.1	HBSL (NL-CA)	700 (160)	D
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.06	MCL-CA	0.5	D
Chlorobenzene	Solvent	34301	108-90-7	0.026	MCL-CA	70	D
Chloroethane	Solvent	34311	75-00-3	0.06	na	na	—
Chloroform (Trichloromethane)	Disinfection byproduct (THM)	32106	67-66-3	0.03	MCL-US	<sup>4</sup> 80	D
Chloromethane	Solvent	34418	74-87-3	0.1	na	na	—
3-Chloropropene	Organic synthesis	78109	107-05-1	0.08	na	na	—
2-Chlorotoluene	Solvent	77275	95-49-8	0.028	HBSL (NL-CA)	100 (140)	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.042	HBSL (NL-CA)	100 (140)	—
Dibromochloromethane	Disinfection byproduct (THM)	32105	124-48-1	0.12	MCL-US	<sup>4</sup> 80	D
1,2-Dibromo-3-chloropropane (DBCP)	Fumigant	82625	96-12-8	0.4	MCL-US	0.2	—
1,2-Dibromoethane (EDB)	Fumigant	77651	106-93-4	0.028	MCL-US	0.05	—
Dibromomethane	Solvent	30217	74-95-3	0.05	na	na	D
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.028	MCL-US	600	—



**Table 3A.** Volatile organic compounds (VOCs), primary uses or sources, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; MCL-HI, Hawaii Department of Health maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of 10<sup>-5</sup>. **Other abbreviations:** CAS, Chemical Abstracts Service; CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; SRL, study reporting level; THM, trihalomethane; D, detected in groundwater samples ([table 5](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN® <sup>1</sup>	LRL (µg/L)	Benchmark type <sup>2</sup>	Benchmark level (µg/L) <sup>2</sup>	Detection
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.024	HBSL (HAL-US)	600 (600)	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.026	MCL-CA	5	—
<i>trans</i> -1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	2	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.1	HBSL (NL-CA)	1,000 (1,000)	—
1,1-Dichloroethane (1,1-DCA)	Solvent	34496	75-34-3	0.044	MCL-CA	5	D
1,2-Dichloroethane (1,2-DCA)	Solvent	32103	107-06-2	0.08	MCL-CA	0.5	—
1,1-Dichloroethene (1,1-DCE)	Organic synthesis	34501	75-35-4	0.022	MCL-CA	6	—
<i>cis</i> -1,2-Dichloroethene ( <i>cis</i> -1,2-DCE)	Solvent	77093	156-59-2	0.022	MCL-CA	6	—
<i>trans</i> -1,2-Dichloroethene ( <i>trans</i> -1,2-DCE)	Solvent	34546	156-60-5	0.018	MCL-CA	10	—
1,2-Dichloropropane	Fumigant	34541	78-87-5	0.026	MCL-US	5	—
1,3-Dichloropropane	Fumigant	77173	142-28-9	0.06	na	na	—
2,2-Dichloropropane	Fumigant	77170	594-20-7	0.06	na	na	—
1,1-Dichloropropene	Organic synthesis	77168	563-58-6	0.04	na	na	—
<i>cis</i> -1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.1	MCL-CA	0.5	—
<i>trans</i> -1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.14	MCL-CA	0.5	—
Diethyl ether	Solvent	81576	60-29-7	0.1	HBSL (na)	1,000 (na)	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.06	na	na	D
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.036	MCL-CA	300	—
Ethyl <i>tert</i> -butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.032	na	na	—
Ethyl methacrylate	Organic synthesis	73570	97-63-2	0.2	na	na	—
<i>o</i> -Ethyl toluene (1-Ethyl-2-methyl benzene)	Gasoline hydrocarbon	77220	611-14-3	0.032	na	na	D
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.08	HBSL (RSD5-US)	90 (9)	—
Hexachloroethane	Solvent	34396	67-72-1	0.1	HBSL (HAL-US)	0.7 (1)	—
2-Hexanone ( <i>n</i> -Butyl methyl ketone)	Solvent	77103	591-78-6	0.4	HBSL (na)	40 (na)	—
Iodomethane (Methyl iodide)	Organic synthesis	77424	74-88-4	0.26	na	na	—
Isopropylbenzene	Gasoline hydrocarbon	77223	98-82-8	0.042	HBSL (NL-CA)	700 (770)	D

**Table 3A.** Volatile organic compounds (VOCs), primary uses or sources, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; MCL-HI, Hawaii Department of Health maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of  $10^{-5}$ . **Other abbreviations:** CAS, Chemical Abstracts Service; CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; SRL, study reporting level; THM, trihalomethane; D, detected in groundwater samples ([table 5](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN® <sup>1</sup>	LRL (µg/L)	Benchmark type <sup>2</sup>	Benchmark level (µg/L) <sup>2</sup>	Detection
4-Isopropyl-1-methyl benzene	Gasoline hydrocarbon	77356	99-87-6	0.06	na	na	—
Methyl acrylate	Organic synthesis	49991	96-33-3	0.8	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.26	HBSL (na)	0.7 (na)	—
Methyl <i>tert</i> -butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.1	MCL-CA	13	D
Methyl <i>iso</i> -butyl ketone (MIBK)	Solvent	78133	108-10-1	0.32	NL-CA	120	—
Methylene chloride (Dichloromethane)	Solvent	34423	75-09-2	0.04	MCL-US	5	—
Methyl ethyl ketone (2-butanone, MEK)	Solvent	81595	78-93-3	1.6	HBSL (HAL-US)	4,000 (4,000)	—
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.22	HBSL (na)	10,000 (na)	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.18	HBSL (NL-CA)	100 (17)	D
Perchloroethene (PCE, Tetrachloroethene)	Solvent	34475	127-18-4	0.026	MCL-US	5	D
<i>n</i> -Propylbenzene	Solvent	77224	103-65-1	0.036	NL-CA	260	—
Styrene	Gasoline hydrocarbon	77128	100-42-5	0.042	MCL-US	100	D
1,1,1,2-Tetrachloroethane	Solvent	77562	630-20-6	0.04	HBSL (HAL-US)	70 (70)	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.14	MCL-CA	1	—
Tetrahydrofuran	Solvent	81607	109-99-9	1.4	na	na	—
1,2,3,4-Tetramethylbenzene	Gasoline hydrocarbon	49999	488-23-3	0.1	na	na	—
1,2,3,5-Tetramethylbenzene	Gasoline hydrocarbon	50000	527-53-7	0.08	na	na	—
Toluene	Gasoline hydrocarbon	34010	108-88-3	0.018	MCL-CA	150	D
1,2,3-Trichlorobenzene	Organic synthesis	77613	87-61-6	0.06	na	na	—
1,2,4-Trichlorobenzene	Solvent	34551	120-82-1	0.08	MCL-CA	5	—
1,1,1-Trichloroethane (1,1,1-TCA)	Solvent	34506	71-55-6	0.03	MCL-US	200	—
1,1,2-Trichloroethane (1,1,2-TCA)	Solvent	34511	79-00-5	0.046	MCL-US	5	—
Trichloroethene (TCE)	Solvent	39180	79-01-6	0.022	MCL-US	5	D
Trichlorofluoromethane (CFC-11)	Refrigerant	34488	75-69-4	0.06	MCL-CA	150	D
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.12	MCL-HI <sup>5</sup> (NL-CA)	0.6 (0.005)	—
Trichlorotrifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.022	MCL-CA	1,200	D

**Table 3A.** Volatile organic compounds (VOCs), primary uses or sources, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; MCL-HI, Hawaii Department of Health maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of  $10^{-5}$ . **Other abbreviations:** CAS, Chemical Abstracts Service; CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; SRL, study reporting level; THM, trihalomethane; D, detected in groundwater samples ([table 5](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN® <sup>1</sup>	LRL (µg/L)	Benchmark type <sup>2</sup>	Benchmark level (µg/L) <sup>2</sup>	Detection
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.06	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	0.032	NL-CA	330	—
1,3,5-Trimethylbenzene	Organic synthesis	77226	108-67-8	0.032	NL-CA	330	—
Vinyl bromide (Bromoethene)	Fire retardant	50002	593-60-2	0.12	na	na	—
Vinyl chloride (Chloroethene)	Organic synthesis	39175	75-01-4	0.06	MCL-CA	0.5	—
<i>m</i> - plus <i>p</i> -Xylene	Gasoline hydrocarbon	85795	108-38-3 / 106-42-3	0.08	MCL-CA	<sup>6</sup> 1,750	—
<i>o</i> -Xylene	Gasoline hydrocarbon	77135	95-47-6	0.032	MCL-CA	<sup>6</sup> 1,750	—

<sup>1</sup> This report contains CASRNs®, which is a Registered Trademark of the American Chemical Society. CAS recommends the verification of the CASRNs® through CAS Client Services<sup>SM</sup>.

<sup>2</sup> Constituents with HBSLs also can have other non-regulatory, health-based benchmarks. The type and value of these other benchmarks are shown in parentheses.

<sup>3</sup> Detected above MCL-CA.

<sup>4</sup> The MCL-US benchmark for trihalomethanes is the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

<sup>5</sup> Currently (2014) Hawaii is the only jurisdiction that has an enforceable maximum contaminant level for 1,2,3-TCP (Hooker and others, 2012).

<sup>6</sup> The MCL-CA benchmark for *m*- plus *p*-xylene and *o*-xylene is the sum of all three xylene compounds.

**Table 3B.** Pesticides and pesticide degradates, primary uses or sources, comparison benchmarks, 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. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of  $10^{-5}$ . **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; D, detected in groundwater samples ([table 6](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN®	LRL (µg/L)	Benchmark type <sup>1</sup>	Benchmark level (µg/L) <sup>1</sup>	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.01	HBSL (na)	10 (na)	—
Alachlor	Herbicide	46342	15972-60-8	0.008	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.008	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.12	HBSL (na)	10 (na)	— <sup>(2)</sup>
Azinphos-methyl oxon	Insecticide degradate	61635	961-22-8	0.042	na	na	— <sup>(2)</sup>
Benfluralin	Herbicide	82673	1861-40-1	0.014	HBSL (na)	4 (na)	— <sup>(2)</sup>
Carbaryl	Insecticide	82680	63-25-2	0.06	HBSL <sup>3</sup> (RSD5-US)	400 (400)	—
2-Chloro-2,6-diethylacetanilide	Herbicide degradate	61618	6967-29-9	0.01	na	na	—
4-Chloro-2-methylphenol	Herbicide degradate	61633	1570-64-5	0.008	na	na	— <sup>(2)</sup>
Chlorpyrifos	Insecticide	38933	2921-88-2	0.0036	HBSL (HAL-US)	2 (2)	—
Chlorpyrifos oxon	Insecticide degradate	61636	5598-15-2	0.08	HBSL (na)	0.8 (na)	— <sup>(2)</sup>
Cyfluthrin	Insecticide	61585	68359-37-5	0.016	HBSL (na)	200 (na)	— <sup>(2)</sup>
Cypermethrin	Insecticide	61586	52315-07-8	0.02	HBSL (na)	40 (na)	— <sup>(2)</sup>
Dacthal (DCPA)	Herbicide	82682	1861-32-1	0.0076	HBSL (HAL-US)	70 (70)	—
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino- <i>s</i> -triazine)	Herbicide degradate	04040	6190-65-4	0.006	na	na	D <sup>(2)</sup>
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	0.006	HBSL (NL-CA)	1 (1.2)	—
3,4-Dichloroaniline	Herbicide degradate	61625	95-76-1	0.006	na	na	D
Dichlorvos	Insecticide	38775	62-73-7	0.04	na	na	— <sup>(2)</sup>
Dicrotophos	Insecticide	38454	141-66-2	0.08	HBSL (na)	0.05 (na)	— <sup>(2)</sup>
Dieldrin	Insecticide	39381	60-57-1	0.008	HBSL (RSD5-US)	0.02 (0.02)	D
2,6-Diethylaniline	Herbicide degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.006	HBSL (na)	2 (na)	— <sup>(2)</sup>
Ethion	Insecticide	82346	563-12-2	0.01	HBSL (na)	4 (na)	— <sup>(2)</sup>
Ethion monoxon	Insecticide degradate	61644	17356-42-2	0.021	na	na	—
2-Ethyl-6-methylaniline	Herbicide degradate	61620	24549-06-2	0.01	na	na	—
Fenamiphos	Insecticide	61591	22224-92-6	0.03	HBSL (HAL-US)	0.7 (0.7)	—
Fenamiphos sulfone	Insecticide degradate	61645	31972-44-8	0.054	na	na	—
Fenamiphos sulfoxide	Insecticide degradate	61646	31972-43-7	0.08	na	na	— <sup>(2)</sup>
Fipronil	Insecticide	62166	120068-37-3	0.018	HBSL (na)	0.1 (na)	—
Fipronil sulfide	Insecticide degradate	62167	120067-83-6	0.012	na	na	D
Fipronil sulfone	Insecticide degradate	62168	120068-36-2	0.024	na	na	—
Fonofos	Insecticide	04095	944-22-9	0.0048	HBSL (HAL-US)	10 (10)	—
Hexazinone	Herbicide	04025	51235-04-2	0.012	HBSL (HAL-US)	400 (400)	— <sup>(2)</sup>

**Table 3B.** Pesticides and pesticide degradates, primary uses or sources, comparison benchmarks, 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. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; RSD5-US, USEPA risk-specific dose at a risk factor of  $10^{-5}$ . **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; LRL, laboratory reporting level; D, detected in groundwater samples ([table 6](#)); na, not available; µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN®	LRL (µg/L)	Benchmark type <sup>1</sup>	Benchmark level (µg/L) <sup>1</sup>	Detection
Iprodione	Fungicide	61593	36734-19-7	0.014	HBSL (na)	80 (na)	— <sup>(2)</sup>
Isofenphos	Insecticide	61594	25311-71-1	0.008	HBSL (na)	6 (na)	—
Malaoxon	Insecticide degradate	61652	1634-78-2	0.022	na	na	—
Malathion	Insecticide	39532	121-75-5	0.016	HBSL (HAL-US)	500 (500)	—
Metalaxyl	Fungicide	61596	57837-19-1	0.014	HBSL (na)	500 (na)	—
Methidathion	Insecticide	61598	950-37-8	0.012	HBSL (na)	1 (na)	—
Metolachlor	Herbicide	39415	51218-45-2	0.02	HBSL (HAL-US)	700 (700)	—
Metribuzin	Herbicide	82630	21087-64-9	0.012	HBSL (HAL-US)	90 (70)	—
Myclobutanil	Fungicide	61599	88671-89-0	0.01	HBSL (na)	200 (na)	—
1-Naphthol	Insecticide degradate	49295	90-15-3	0.036	na	na	— <sup>(2)</sup>
Paraoxon-methyl	Insecticide degradate	61664	950-35-6	0.014	na	na	— <sup>(2)</sup>
Parathion-methyl	Insecticide	82667	298-00-0	0.008	HBSL (HAL-US)	1 (1)	—
Pendimethalin	Herbicide	82683	40487-42-1	0.012	HBSL (na)	20 (na)	—
cis-Permethrin	Insecticide	82687	54774-45-7	0.01	HBSL (na)	400 (na)	— <sup>(2)</sup>
Phorate	Insecticide	82664	298-02-2	0.02	HBSL (na)	4 (na)	— <sup>(2)</sup>
Phorate oxon	Insecticide degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.08	HBSL (na)	4 (na)	— <sup>(2)</sup>
Phosmet oxon	Insecticide degradate	61668	3735-33-9	0.0511	na	na	— <sup>(2)</sup>
Prometon	Herbicide	04037	1610-18-0	0.012	HBSL (HAL-US)	400 (400)	D <sup>(2)</sup>
Prometryn	Herbicide	04036	7287-19-6	0.01	HBSL (na)	300 (na)	—
Pronamide (Propyzamide)	Herbicide	82676	23950-58-5	0.0036	HBSL (RSD5-US)	10 (10)	—
Simazine	Herbicide	04035	122-34-9	0.006	MCL-US	4	D
Tebuthiuron	Herbicide	82670	34014-18-1	0.028	HBSL (HAL-US)	1,000 (500)	D
Terbufos	Insecticide	82675	13071-79-9	0.018	HBSL (HAL-US)	0.4 (0.4)	— <sup>(2)</sup>
Terbufos oxon sulfone	Insecticide degradate	61674	56070-15-6	0.045	na	na	— <sup>(2)</sup>
Terbutylazine	Herbicide	04022	5915-41-3	0.008	HBSL (na)	2 (na)	—
Tribufos	Defoliant	61610	78-48-8	0.018	HBSL (na)	7 (na)	— <sup>(2)</sup>
Trifluralin	Herbicide	82661	1582-09-8	0.018	HBSL (HAL-US)	20 (10)	—

<sup>1</sup> Constituents with HBSLs also can have other non-regulatory, health-based benchmarks. The type and value of these other benchmarks are shown in parentheses.

<sup>2</sup> One or more median matrix-spike recoveries were 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.

<sup>3</sup> An HBSL range of 40 to 4,000 µg/L is defined; 400 µg/L is selected as the comparison benchmark in this report.



**Table 3C.** Constituents of special interest, primary uses or source, comparison benchmarks, and reporting information for analyses performed by Weck Laboratories, Inc. (Weck), City of Industry, California.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. MRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health maximum contaminant level. MCL-HI, Hawaii Department of Health maximum contaminant level. **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; MRL, minimum reporting level; D, detected in groundwater samples (table 7); µg/L, micrograms per liter; —, not detected]

Constituent (synonym or abbreviation)	Primary use or source	USGS parameter code	CASRN®	MRL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
Perchlorate	Rocket fuel, fireworks, flares, natural	63790	14797-73-0	0.10	MCL-CA	6	D
1,2,3-Trichloropropane	Fumigant, solvent	77443	96-18-4	0.005	MCL-HI <sup>1</sup>	0.6	—

<sup>1</sup> Currently (2014) Hawaii is the only jurisdiction that has an enforceable maximum contaminant level for 1,2,3-TCP (Hooker and others, 2012). Previous GAMA-PBP reports used the NL-CA of 0.005 µg/L or the HAL-US of 40 µg/L (no longer in existence as of 2006) as the comparison benchmark.

**Table 3D.** Trace elements, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LRL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS Health-Based Screening Level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; LT-MDL, long-term method detection limit; D, detected in groundwater samples (table 8); na, not available; µg/L, micrograms per liter]

Constituent	USGS parameter code	CASRN®	LT-MDL (µg/L)	Benchmark type <sup>1</sup>	Benchmark level (µg/L) <sup>1</sup>	Detection
Aluminum	01106	7429-90-5	2.2	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.027	MCL-US	6	D
Arsenic	01000	7440-38-2	0.03	MCL-US	10	D
Barium	01005	7440-39-3	0.07	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.006	MCL-US	4	D
Boron	01020	7440-42-8	3	HBSL (NL-CA)	6,000 (1,000)	D
Cadmium	01025	7440-43-9	0.016	MCL-US	5	D
Chromium	01030	7440-47-3	0.07	MCL-CA	50	D
Cobalt	01035	7440-48-4	0.021	na	na	D
Copper	01040	7440-50-8	0.08	AL-US	1,300	D
Iron	01046	7439-89-6	3.2	SMCL-CA	300	D
Lead	01049	7439-92-1	0.025	AL-US	15	D
Lithium	01130	7439-93-2	0.22	na	na	D
Manganese	01056	7439-96-5	0.13	HBSL (SMCL-CA)	300 (50)	D
Molybdenum	01060	7439-98-7	0.014	HBSL (HAL-US)	40 (40)	D
Nickel	01065	7440-02-0	0.09	MCL-CA	100	D
Selenium	01145	7782-49-2	0.03	MCL-US	50	D
Silver	01075	7440-22-4	0.005	HBSL (SMCL-CA)	100 (100)	D
Strontium	01080	7440-24-6	0.2	HBSL (HAL-US)	4,000 (4,000)	D
Thallium	01057	7440-28-0	0.01	MCL-US	2	D
Uranium	22703	7440-61-1	0.003	MCL-US	30	D
Vanadium	01085	7440-62-2	0.08	NL-CA	50	D
Zinc	01090	7440-66-6	1.4	HBSL (SMCL-CA)	2,000 (5,000)	D

<sup>1</sup> Constituents with HBSLs also can have other non-regulatory, health-based benchmarks. The type and value of these other benchmarks are shown in parentheses.

**Table 3E.** Nutrients, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2755.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LT-MDL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level. **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; LT-MDL, long-term method detection limit; D, detected in groundwater samples ([table 9](#)); na, not available; mg/L, milligrams per liter]

Constituent	USGS parameter code	CASRN®	LT-MDL (mg/L)	Benchmark type	Benchmark level (mg/L)	Detection
Ammonia (as nitrogen)	00608	7664-41-7	0.01	HAL-US	<sup>1</sup> 24.7	D
Nitrite (as nitrogen)	00613	14797-65-0	0.001	MCL-US	1	D
Nitrate plus nitrite (as nitrogen) <sup>2</sup>	00631	na	0.04	MCL-US	10	D
Total nitrogen (ammonia + nitrite + nitrate + organic nitrogen)	62854	17778-88-0	0.05	na	na	D
Phosphate, orthophosphate (as phosphorus)	00671	14265-44-2	0.004	na	na	D

<sup>1</sup> The HAL-US is 30 mg/L “as ammonia.” To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L “as nitrogen.”

<sup>2</sup> Nitrite plus nitrate (as nitrogen) is referred to as nitrate in the text for clarity.

**Table 3F.** Major and minor ions, silica, total dissolved solids (TDS), and alkalinity, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. LT-MDL, benchmark type, and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; LT-MDL, long-term method detection limit; D, detected in groundwater samples ([table 10](#)); na, not available; mg/L, milligrams per liter; SiO<sub>2</sub>, silicon dioxide; CaCO<sub>3</sub>, calcium carbonate]

Constituent (synonym or abbreviation)	USGS parameter code	CASRN®	LT-MDL (mg/L)	Benchmark type	Benchmark level (mg/L)	Detection
Bromide	71870	24959-67-9	0.01	na	na	D
Calcium	00915	7440-70-2	0.022	na	na	D
Chloride	00940	16887-00-6	0.06	SMCL-CA	<sup>1</sup> 250 (500)	D
Fluoride	00950	16984-48-8	0.04	MCL-CA	2	D
Iodide	71865	7553-56-2	0.001	na	na	D
Magnesium	00925	7439-95-4	0.011	na	na	D
Potassium	00935	7440-09-7	0.03	na	na	D
Sodium	00930	7440-23-5	0.06	na	na	D
Sulfate	00945	14808-79-8	0.09	SMCL-CA	<sup>1</sup> 250 (500)	D
Silica (as SiO <sub>2</sub> )	00955	7631-86-9	0.018	na	na	D
Total dissolved solids (TDS)	70300	na	10	SMCL-CA	<sup>1</sup> 500 (1,000)	D
Laboratory alkalinity (as CaCO <sub>3</sub> ) <sup>2</sup>	29801	na	4.6	na	na	D

<sup>1</sup> The SMCL-CA for chloride, sulfate, and TDS have recommended and upper benchmark values. The upper benchmark value is shown in parentheses.

<sup>2</sup> Laboratory alkalinity results are presented in [table 4](#).

**Table 3G.** Isotopic tracers, radioactive constituents, comparison benchmarks, and reporting information for laboratory analyses.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation ( $\delta$ ), the ratio of a heavier isotope to the more common lighter isotope of that element, relative to a standard reference material. Laboratory entity codes in the USGS National Water Information System (NWIS) for laboratories other than the USGS National Water Quality Laboratory (NWQL) are given in parentheses after the laboratory names in table footnotes. Benchmark type and benchmark value as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Elements:** H, hydrogen; O, oxygen; B, boron; Sr, strontium; C, carbon. **Reporting units:** pCi/L, picocuries per liter. **Other abbreviations:** CASRN®, Chemical Abstracts Service Registry Number®; CSU, 1-sigma combined standard uncertainty; D, detected in groundwater samples (tables 11 and 12); na, not available; NRP, National Research Program; pmc, percent modern carbon; ssL<sub>C</sub>, sample-specific critical level; USGS, U.S. Geological Survey]

Constituent	USGS parameter code	CASRN®	Reporting level	Reporting uncertainty	Reporting units	Benchmark type	Benchmark level	Detection
Isotopic tracers								
<sup>11</sup> B/ <sup>10</sup> B of dissolved boron <sup>1</sup>	62648	na	na	2	per mil	na	na	D
$\delta^2\text{H}$ in water <sup>2</sup>	82082	na	na	2	per mil	na	na	D
$\delta^{18}\text{O}$ in water <sup>2</sup>	82085	na	na	0.20	per mil	na	na	D
$\delta^{13}\text{C}$ in dissolved inorganic carbon <sup>3</sup>	82081	na	na	0.05	per mil	na	na	D
<sup>87</sup> Sr/ <sup>86</sup> Sr of dissolved strontium <sup>1</sup>	75978	na	na	0.00005	atom ratio	na	na	D
Radioactive constituents								
Carbon-14 <sup>3</sup>	49933	14762-75-5	na	0.0015	pmc	na	na	D
Tritium <sup>5</sup>	07000	10028-17-8	ssL <sub>C</sub>	CSU	pCi/L	MCL-CA	20,000	D
Radon-222 <sup>4</sup>	82303	14859-67-7	ssL <sub>C</sub>	CSU	pCi/L	MCL-US (Proposed)	4,000	D
Gross alpha radioactivity, 72-hour and 30-day counts <sup>6</sup>	62636, 62639	12587-46-1	ssL <sub>C</sub>	CSU	pCi/L	MCL-US	<sup>7</sup> 15	D
Gross beta radioactivity, 72-hour and 30-day counts <sup>6</sup>	62642, 62645	12587-47-2	ssL <sub>C</sub>	CSU	pCi/L	MCL-CA	50	D

<sup>1</sup> USGS-NRP Metals Isotope Research Laboratory, Menlo Park, California (USGSMICA).

<sup>2</sup> USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

<sup>3</sup> Woods Hole Oceanographic Institution, National Ocean Sciences Accelerator Mass Spectrometry Facility [NOMAS], Woods Hole, Massachusetts (MA-WHAMS).

<sup>4</sup> USGS National Water Quality Laboratory (USGSNWQL).

<sup>5</sup> USGS Stable Isotope and Tritium Laboratory [SITL], Menlo Park, California (USGSH3CA).

<sup>6</sup> Eberline Analytical Services, Richmond, California (CA-EBERL).

<sup>7</sup> The MCL-US benchmark for gross alpha activity applies to adjusted gross alpha, which is equal to measured gross alpha activity minus uranium activity.

**Table 4.** Water-quality indicators in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and RL as of August 30, 2012. **Benchmark type:** SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; nc, not collected; na, not available; RL, reporting level or range; µS/cm, microsiemens per centimeter; <, less than; >, greater than; CaCO<sub>3</sub>, calcium carbonate; \*, concentration greater than (or outside of range of) the benchmark level; \*\*, concentration greater than the upper benchmark level; —, not detected]

<b>GAMA well identification number</b>	<b>Dissolved oxygen, field (mg/L) (00300)</b>	<b>Water temperature, field (°C) (00010)</b>	<b>pH, field (standard units) (00400)</b>	<b>pH, laboratory (standard units) (00403)</b>	<b>Specific conductance, field (µS/cm at 25 °C) (00095)</b>	<b>Specific conductance, laboratory (µS/cm at 25 °C) (90095)</b>	<b>Alkalinity, field (mg/L as CaCO<sub>3</sub>) (29802)</b>	<b>Alkalinity, laboratory (mg/L as CaCO<sub>3</sub>) (29801)</b>	<b>Bicarbonate, field (mg/L) (63786)</b>	<b>Bicarbonate, laboratory<sup>2</sup> (mg/L)</b>	<b>Carbonate, field (mg/L) (63788)</b>	<b>Carbonate, laboratory<sup>2</sup> (mg/L)</b>
<b>Benchmark type</b>	na	na	SMCL-US	SMCL-US	SMCL-CA	SMCL-CA	na	na	na	na	na	na
<b>Benchmark level</b>	na	na	<6.5 or >8.5	<6.5 or >8.5	<sup>1</sup> 900 (1,600)	<sup>1</sup> 900 (1,600)	na	na	na	na	na	na
<b>[RL]</b>	<b>[0.2]</b>	<b>[0.0–38.5]</b>	<b>[0–14]</b>	<b>[0–14]</b>	<b>[5]</b>	<b>[5]</b>	<b>[1]</b>	<b>[1]</b>	<b>[1]</b>	<b>[1]</b>	<b>[1]</b>	<b>[1]</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)												
Highlands study area wells (40 wells sampled)												
S-NSF-H01	1.1	14.5	6.5	7.0	304	305	nc	84	nc	102	nc	0.0
S-NSF-H02	5.3	12.0	6.5	7.1	310	315	nc	160	nc	195	nc	0.0
S-NSF-H03	8.9	17.0	7.0	7.5	182	186	nc	87	nc	106	nc	0.0
S-NSF-H04	0.4	16.5	7.7	7.9	841	844	nc	452	nc	551	nc	1.3
S-NSF-H05	0.4	18.0	7.1	7.6	513	517	nc	243	nc	296	nc	0.2
S-NSF-H06	0.7	17.0	7.0	7.4	750	752	nc	362	nc	441	nc	0.2
S-NSF-H07	4.8	13.0	7.0	7.4	404	403	nc	218	nc	266	nc	0.1
S-NSF-H08	<0.2	19.0	*8.7	*8.8	719	729	nc	351	nc	428	nc	9.4
S-NSF-H09	0.8	26.0	7.5	7.8	394	387	nc	160	nc	195	nc	0.3
S-NSF-H10	7.6	24.0	6.8	7.3	140	143	nc	58	nc	70	nc	0.0
S-NSF-H11	3.6	14.0	*6.2	6.8	193	191	80.1	85	97.6	104	—	0.0
S-NSF-H12	<0.2	14.0	*6.2	6.7	313	308	nc	63	nc	76	nc	0.0
S-NSF-H13	<0.2	20.0	*9.4	*9.4	567	566	nc	217	nc	263	nc	24.6
S-NSF-H14	0.4	15.0	7.8	8.1	564	566	nc	159	nc	194	nc	0.6
S-NSF-H15	5.8	17.0	7.2	7.7	324	328	nc	110	nc	134	nc	0.1

**Table 4.** Water-quality indicators in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and RL as of August 30, 2012. **Benchmark type:** SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; nc, not collected; na, not available; RL, reporting level or range; µS/cm, microsiemens per centimeter; <, less than; >, greater than; CaCO<sub>3</sub>, calcium carbonate; \*, concentration greater than (or outside of range of) the benchmark level; \*\*, concentration greater than the upper benchmark level; —, not detected]

GAMA well identification number	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (°C) (00010)	pH, field (standard units) (00400)	pH, laboratory (standard units) (00403)	Specific conductance, field (µS/cm at 25 °C) (00095)	Specific conductance, laboratory (µS/cm at 25 °C) (90095)	Alkalinity, field (mg/L as CaCO <sub>3</sub> ) (29802)	Alkalinity, laboratory (mg/L as CaCO <sub>3</sub> ) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory <sup>2</sup> (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory <sup>2</sup> (mg/L)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Highlands study area wells (40 wells sampled)—Continued												
S-NSF-H16	<0.2	17.5	6.8	7.2	325	321	nc	81	nc	99	nc	0.0
S-NSF-H17	1.3	18.0	7.8	8.0	710	717	nc	122	nc	149	nc	0.4
S-NSF-H18	0.6	19.5	6.5	6.9	599	622	nc	234	nc	285	nc	0.0
S-NSF-H19	6.7	17.0	6.8	7.4	319	322	nc	160	nc	195	nc	0.1
S-NSF-H20	4.2	18.5	*6.4	6.9	162	164	nc	80	nc	98	nc	0.0
S-NSF-H21	0.2	21.5	6.6	7.0	464	398	nc	180	nc	219	nc	0.0
S-NSF-H22	<0.2	20.5	7.9	8.2	*903	*910	nc	427	nc	521	nc	1.9
S-NSF-H23	6.4	16.0	*6.2	6.7	197	198	nc	88	nc	108	nc	0.0
S-NSF-H24	4.8	24.5	6.5	7.0	151	147	nc	65	nc	79	nc	0.0
S-NSF-H25	7.3	16.0	6.7	7.2	286	285	nc	144	nc	176	nc	0.0
S-NSF-H26	<0.2	19.5	7.2	7.4	733	731	nc	209	nc	255	nc	0.2
S-NSF-H27	1.4	16.5	6.8	7.2	*1,420	*1,450	nc	262	nc	319	nc	0.1
S-NSF-H28	6.1	20.0	6.6	7.0	170	168	nc	76	nc	93	nc	0.0
S-NSF-H29	6.9	21.0	*6.1	*6.4	*1,480	*1,480	nc	90	nc	109	nc	0.0
S-NSF-H30	2.5	24.0	6.6	7.0	123	121	nc	51	nc	62	nc	0.0
S-NSF-H31	0.8	16.0	7.2	7.8	*958	*944	324	335	394	408	0.4	0.3
S-NSF-H32	5	17.0	*6.3	6.8	175	177	nc	88	nc	108	nc	0.0
S-NSF-H33	2.6	23.0	*6.3	6.8	170	169	nc	77	nc	94	nc	0.0
S-NSF-H34	0.2	15.5	6.8	7.3	716	796	nc	327	nc	399	nc	0.1
S-NSF-H35	5.7	20.0	7.0	7.3	312	308	140	142	170	173	0.1	0.1



**Table 4.** Water-quality indicators in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and RL as of August 30, 2012. **Benchmark type:** SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; nc, not collected; na, not available; RL, reporting level or range; µS/cm, microsiemens per centimeter; <, less than; >, greater than; CaCO<sub>3</sub>, calcium carbonate; \*, concentration greater than (or outside of range of) the benchmark level; \*\*, concentration greater than the upper benchmark level; —, not detected]

GAMA well identification number	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (°C) (00010)	pH, field (standard units) (00400)	pH, laboratory (standard units) (00403)	Specific conductance, field (µS/cm at 25 °C) (00095)	Specific conductance, laboratory (µS/cm at 25 °C) (90095)	Alkalinity, field (mg/L as CaCO <sub>3</sub> ) (29802)	Alkalinity, laboratory (mg/L as CaCO <sub>3</sub> ) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory <sup>2</sup> (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory <sup>2</sup> (mg/L)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Highlands study area wells (40 wells sampled)—Continued												
S-NSF-H36	5.9	18.5	*6.0	*6.3	173	180	37.8	46	46.1	56	—	0.0
S-NSF-H37	5.4	20.5	6.5	7.2	123	120	nc	55	nc	67	nc	0.0
S-NSF-H38	<0.2	18.0	8.2	8.4	*1,170	*1,370	nc	668	nc	814	nc	5.8
S-NSF-H39	5.6	20.5	6.5	7.0	144	140	nc	59	nc	72	nc	0.0
S-NSF-H40	0.9	18.0	6.9	7.2	**1,620	**1,640	223	363	272	443	0.1	0.2
Valley and Plains study area wells (30 wells sampled)												
S-NSF-VP01	0.2	17.0	7.2	7.4	**1,750	**1,780	nc	427	nc	521	nc	0.4
S-NSF-VP02	1.2	16.5	6.8	7.2	799	780	nc	340	nc	415	nc	0.1
S-NSF-VP03	<0.2	16.5	7.5	7.8	*1,080	*1,030	nc	242	nc	295	nc	0.4
S-NSF-VP04	<0.2	18.5	6.6	7.0	361	350	nc	76	nc	93	nc	0.0
S-NSF-VP05	<0.2	23.0	7.5	7.8	526	516	nc	199	nc	243	nc	0.4
S-NSF-VP06	<0.2	20.5	7.2	7.9	502	499	230	245	279	299	0.4	0.2
S-NSF-VP07	0.4	20.5	7.2	7.5	678	666	258	276	314	336	0.5	0.2
S-NSF-VP08	1.8	20.5	6.8	7.2	400	399	177	105	216	128	—	0.0
S-NSF-VP09	<0.2	20.0	6.9	7.3	437	434	nc	138	nc	168	nc	0.1
S-NSF-VP10	<0.2	18.0	7.3	7.7	406	405	nc	140	nc	171	nc	0.2
S-NSF-VP11	3.2	17.5	6.9	7.3	867	827	nc	237	nc	289	nc	0.1
S-NSF-VP12	<0.2	20.0	8.0	8.1	625	621	nc	245	nc	299	nc	1.4
S-NSF-VP13	<0.2	23.5	8.3	8.3	582	564	258	269	308	328	3.1	3.0
S-NSF-VP14	<0.2	19.5	7.1	7.4	771	763	nc	387	nc	472	nc	0.3
S-NSF-VP15	3.5	18.0	6.6	7.0	558	544	nc	258	nc	315	nc	0.1

**Table 4.** Water-quality indicators in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and RL as of August 30, 2012. **Benchmark type:** SMCL-US, U.S. Environmental Protection Agency secondary maximum contaminant level; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; °C, degrees Celsius; mg/L, milligrams per liter; nc, not collected; na, not available; RL, reporting level or range; µS/cm, microsiemens per centimeter; <, less than; >, greater than; CaCO<sub>3</sub>, calcium carbonate; \*, concentration greater than (or outside of range of) the benchmark level; \*\*, concentration greater than the upper benchmark level; —, not detected]

GAMA well identification number	Dissolved oxygen, field (mg/L) (00300)	Water temperature, field (°C) (00010)	pH, field (standard units) (00400)	pH, laboratory (standard units) (00403)	Specific conductance, field (µS/cm at 25 °C) (00095)	Specific conductance, laboratory (µS/cm at 25 °C) (90095)	Alkalinity, field (mg/L as CaCO <sub>3</sub> ) (29802)	Alkalinity, laboratory (mg/L as CaCO <sub>3</sub> ) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory <sup>2</sup> (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory <sup>2</sup> (mg/L)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Valley and Plains study area wells (30 wells sampled)—Continued												
S-NSF-VP16	0.3	19.0	7.2	7.5	502	505	nc	212	nc	258	nc	0.2
S-NSF-VP17	4.5	16.0	6.5	6.9	568	570	nc	255	nc	311	nc	0.0
S-NSF-VP18	4.8	16.0	6.9	7.2	406	410	149	172	182	210	0.1	0.1
S-NSF-VP19	0.9	21.5	6.5	7.0	314	307	nc	101	nc	123	nc	0.0
S-NSF-VP20	0.8	18.5	6.7	7.1	224	225	nc	94	nc	115	nc	0.0
S-NSF-VP21	0.4	25.0	7.4	7.9	660	669	nc	237	nc	289	nc	0.3
S-NSF-VP22	0.3	17.5	6.6	7.1	460	456	134	158	163	193	0.1	0.0
S-NSF-VP23	0.4	22.0	7.3	7.6	893	854	nc	388	nc	473	nc	0.4
S-NSF-VP24	nc	19.0	8.1	8.2	897	892	nc	401	nc	489	nc	2.8
S-NSF-VP25	0.2	19.0	7.0	7.3	*1,420	*1,520	nc	165	nc	201	nc	0.1
S-NSF-VP26	0.3	18.5	6.5	6.9	316	317	nc	78	nc	95	nc	0.0
S-NSF-VP27	0.3	17.0	6.6	6.9	500	513	nc	151	nc	184	nc	0.0
S-NSF-VP28	<0.2	18.5	6.9	7.2	465	463	nc	185	nc	226	nc	0.1
S-NSF-VP29	3.8	18.0	7.0	7.4	499	497	nc	214	nc	261	nc	0.1
S-NSF-VP30	nc	22.0	6.9	7.3	434	409	nc	173	nc	211	nc	0.1
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)												
S-NSF-HU30	4	21	6.8	7.1	325	327	nc	163	nc	199	nc	0.1

<sup>1</sup> The SMCL-CA for specific conductance has recommended and upper benchmark values. The upper value is shown in parentheses.

<sup>2</sup> Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values using the advanced speciation method (<http://or.water.usgs.gov/alk/methods.html>) with pK<sub>1</sub> = 6.35, pK<sub>2</sub> = 10.33, and pK<sub>w</sub> = 14.

**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Benchmark type,** benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Trihalomethanes				Natural, organic synthesis	Gasoline oxygenate		Gasoline hydrocarbon		
GAMA well identifica- tion number	Chloroform (trichlo- romethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Dibromochloromethane (µg/L) (32105)	Tribromomethane (µg/L) (32104)	Carbon disulfide (µg/L) (77041)	Methyl <i>tert</i> - butyl ether (µg/L) (78032)	Diisopropyl ether (µg/L) (81577)	Styrene (µg/L) (77128)	Toluene (µg/L) (34010)	<i>o</i> -Ethyl toluene (µg/L) (77220)
Benchmark type	MCL-US	MCL-US	MCL-US	MCL-US	HBSL	MCL-CA	na	MCL-US	MCL-CA	na
Benchmark level	<sup>1</sup> 80	<sup>1</sup> 80	<sup>1</sup> 80	<sup>1</sup> 80	700	13	na	100	150	na
[LRL or SRL]	[0.03]	[0.034]	[0.12]	[0.1]	[0.03] <sup>2</sup>	[0.1]	[0.06]	[0.03]	[0.69] <sup>2</sup>	[0.032]
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)										
Number of wells with detections	13	1	1	1	6	4	3	2	2	1
Detection frequency (percent)	19	1.4	1.4	1.4	9	5.7	4.3	2.9	2.9	1.4
Total detections (number)										
Highlands study area wells (40 wells sampled)										
S-NSF-H01	—	—	—	—	—	0.3	0.1	—	—	—
S-NSF-H03	0.01	—	—	—	—	—	—	—	—	—
S-NSF-H08	—	—	—	—	E0.5	—	—	—	—	—
S-NSF-H10	0.02	—	—	—	—	—	—	—	—	—
S-NSF-H11	—	—	—	—	—	—	—	—	1	—
S-NSF-H13	—	—	—	—	E0.1	—	—	—	—	—
S-NSF-H18	—	—	—	—	—	—	2.24	—	—	—
S-NSF-H22	—	—	—	—	—	—	—	0.065	—	—
S-NSF-H23	0.16	—	—	—	—	—	—	—	—	—
S-NSF-H28	0.01	—	—	—	—	—	—	—	—	—

**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Trihalomethanes				Natural, organic synthesis	Gasoline oxygenate		Gasoline hydrocarbon		
GAMA well identifica- tion number	Chloroform (trichlo- romethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Dibromochloromethane (µg/L) (32105)	Tribromomethane (µg/L) (32104)	Carbon disulfide (µg/L) (77041)	Methyl <i>tert</i> - butyl ether (µg/L) (78032)	Diisopropyl ether (µg/L) (81577)	Styrene (µg/L) (77128)	Toluene (µg/L) (34010)	<i>o</i> -Ethyl toluene (µg/L) (77220)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued										
Highlands study area wells (40 wells sampled)—Continued										
S-NSF-H34	0.05	—	—	—	—	—	—	—	—	—
S-NSF-H36 <sup>3</sup>	2.1	—	—	—	—	—	—	—	—	—
S-NSF-H38 <sup>4</sup>	—	—	—	—	E3.6	—	—	0.032	10.3	0.035
S-NSF-H39	0.04	—	—	—	—	—	—	—	—	—
S-NSF-H40	0.01	—	—	—	—	—	—	—	—	—
Number of wells with detections	8	0	0	0	3	1	2	2	2	1
Detection frequency (percent)	20	0	0	0	7.5	2.5	5	5	5	2.5
Total detections (number)										
Valley and Plains study area wells (30 wells sampled)										
S-NSF-VP01 <sup>3</sup>	1.6	0.372	0.38	0.33	< 0.01 <sup>5</sup>	—	0.14	—	—	—
S-NSF-VP02	—	—	—	—	—	—	—	—	—	—
S-NSF-VP03	—	—	—	—	—	0.13	—	—	—	—
S-NSF-VP08	0.03	—	—	—	—	—	—	—	—	—
S-NSF-VP09	—	—	—	—	E0.1	—	—	—	—	—



**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Benchmark type, benchmark level, and LRL as of August 30, 2012.** **Benchmark type:** Maximum contaminant level benchmarks 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. **HBSL,** USGS health-based screening level; **MCL-US,** U.S. Environmental Protection Agency maximum contaminant level; **MCL-CA,** California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Trihalomethanes				Natural, organic synthesis	Gasoline oxygenate		Gasoline hydrocarbon		
GAMA well identifica- tion number	Chloroform (trichlo- romethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Dibromochloromethane (µg/L) (32105)	Tribromomethane (µg/L) (32104)	Carbon disulfide (µg/L) (77041)	Methyl <i>tert</i> - butyl ether (µg/L) (78032)	Diisopropyl ether (µg/L) (81577)	Styrene (µg/L) (77128)	Toluene (µg/L) (34010)	<i>o</i> -Ethyl toluene (µg/L) (77220)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued										
Valley and Plains study area wells (30 wells sampled)—Continued										
S-NSF-VP10	—	—	—	—	E0.1	—	—	—	—	—
S-NSF-VP11	0.06	—	—	—	—	—	—	—	—	—
S-NSF-VP14	—	—	—	—	E0.1	0.65	—	—	—	—
S-NSF-VP15	0.03	—	—	—	—	—	—	—	—	—
S-NSF-VP20	—	—	—	—	< 0.03 <sup>5</sup>	—	—	—	—	—
S-NSF-VP25	0.03	—	—	—	—	—	—	—	—	—
S-NSF-VP29	—	—	—	—	—	—	—	—	—	—
S-NSF-VP30	—	—	—	—	—	0.06	—	—	—	—
Number of wells with detections	5	1	1	1	3	3	1	0	0	0
Detection frequency (percent)	17	3.3	3.3	3.3	10	10	3.3	0	0	0
Total detections (number)										



**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Gasoline hydrocarbon			Solvent					
GAMA well identification number	Benzene (µg/L) (34030)	Isopropylbenzene (µg/L) (77223)	Naphthalene (µg/L) (34696)	Perchloroethene (µg/L) (34475)	1,1-Dichloroethane (µg/L) (34496)	Chlorobenzene (µg/L) (34301)	Dibromomethane (µg/L) (30217)	Tetrachloromethane (µg/L) (32102)	Trichloroethene (µg/L) (39180)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued									
Highlands study area wells (40 wells sampled)—Continued									
S-NSF-H34	—	—	—	—	—	—	—	—	—
S-NSF-H36	—	—	—	—	—	—	—	—	—
S-NSF-H38 3	*4.41	0.023	0.1	—	—	—	—	—	—
S-NSF-H39	—	—	—	—	—	—	—	—	—
S-NSF-H40	—	—	—	—	—	—	—	—	—
Number of wells with detections	1	1	1	0	0	0	0	0	1
Detection frequency (percent)	2.5	2.5	2.5	0	0	0	0	0	2.5
Total detections (number)									
Valley and Plains study area wells (30 wells sampled)—Continued									
S-NSF-VP01	—	—	—	—	—	—	0.022	—	—
S-NSF-VP02	—	—	—	0.017	—	—	—	—	—
S-NSF-VP03	—	—	—	—	—	0.054	—	—	—
S-NSF-VP08	—	—	—	—	—	—	—	—	—
S-NSF-VP09	—	—	—	—	—	—	—	—	—

**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

[illegible]



**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Refrigerant		Fire retardant	Detections per well	VOC detection summary <sup>1</sup>
GAMA well identification number	Trichlorotrifluoroethane (µg/L) (77652)	Trichlorofluoromethane (µg/L) (34488)	Bromochloromethane (µg/L) (77297)		
<b>Benchmark type</b>	<b>MCL-CA</b>	<b>MCL-CA</b>	<b>HBSL</b>		
<b>Benchmark level</b>	<b>1200</b>	<b>150</b>	<b>90</b>		
<b>[LRL or SRL]</b>	<b>[0.034]</b>	<b>[0.08]</b>	<b>[0.06]</b>		
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued					
Number of wells with detections	1	1	1		28
Detection frequency (percent)	1.4	1.4	1.4		40
Total detections (number)					48
Highlands study area wells (40 wells sampled)—Continued					
S-NSF-H01	—	—	—	2	
S-NSF-H03	—	—	—	1	
S-NSF-H08	—	—	—	1	
S-NSF-H10	—	—	—	1	
S-NSF-H11	—	—	—	1	
S-NSF-H13	—	—	—	1	
S-NSF-H18	—	—	—	2	
S-NSF-H22	—	—	—	1	
S-NSF-H23	—	—	—	1	
S-NSF-H28	—	—	—	1	
S-NSF-H34	—	—	—	1	
S-NSF-H36	—	—	—	1	
S-NSF-H38 <sup>3</sup>	—	—	—	7	
S-NSF-H39	—	—	—	1	
S-NSF-H40	0.191	0.35	—	3	

**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Refrigerant		Fire retardant	Detections per well	VOC detection summary <sup>1</sup>
GAMA well identification number	Trichlorotrifluoroethane (µg/L) (77652)	Trichlorofluoromethane (µg/L) (34488)	Bromochloromethane (µg/L) (77297)		
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued					
Highlands study area wells (40 wells sampled)—Continued					
Number of wells with detections	1	1	0		15
Detection frequency (percent)	2.5	2.5	0		37
Total detections (number)					25
Valley and Plains study area wells (30 wells sampled)—Continued					
S-NSF-VP01	—	—	0.03	7	
S-NSF-VP02	—	—	—	1	
S-NSF-VP03	—	—	—	2	
S-NSF-VP08	—	—	—	1	
S-NSF-VP09	—	—	—	1	
S-NSF-VP10	—	—	—	1	
S-NSF-VP11	—	—	—	1	
S-NSF-VP14	—	—	—	2	
S-NSF-VP15	—	—	—	2	
S-NSF-VP20	—	—	—	2	
S-NSF-VP25	—	—	—	1	
S-NSF-VP29	—	—	—	1	
S-NSF-VP30	—	—	—	1	

**Table 5.** Volatile organic compounds (VOCs) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3A](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS health-based screening level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; na, not available; SRL, study reporting level; ≤, less than or equal to; µg/L, micrograms per liter; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Refrigerant		Fire retardant	Detections per well	VOC detection summary <sup>1</sup>
GAMA well identification number	Trichlorotrifluoroethane (µg/L) (77652)	Trichlorofluoromethane (µg/L) (34488)	Bromochloromethane (µg/L) (77297)		
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued					
Valley and Plains study area wells (30 wells sampled)—Continued					
Number of wells with detections	0	0	1		13
Detection frequency (percent)	0	0	3.3		43
Total detections (number)					22

<sup>1</sup> The MCL-US threshold for trihalomethanes is for the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

<sup>2</sup> The SRLs for acetone (all detections censored), carbon disulfide (0.03 µg/L), ethylbenzene (0.1 µg/L), toluene (0.69 µg/L), tetrahydrofuran (all detections censored), 1,2,4-trimethylbenzene (0.56 µg/L), *m*-xylene plus *p*-xylene (0.33 µg/L), and *o*-xylene (0.56 µg/L) were defined by Fram and others (2012). Detections of acetone (S-NSF-H38: 27.8 µg/L) and tetrahydrofuran (S-NSF-H04: 2.1 µg/L; S-NSF-H11: 2.1 µg/L; S-NSF-H16: 0.4 µg/L; S-NSF-H34: 0.6 µg/L; S-NSF-H38: 3 µg/L; S-NSF-VP06: 5.2 µg/L; S-NSF-VP12: 0.4 µg/L; S-NSF-VP23: 0.8 µg/L) have been reclassified as non-detections and are not presented in this report. Detections of ethylbenzene (S-NSF-H38: E0.073 µg/L), 1,2,4-trimethylbenzene (S-NSF-H38: 0.046 µg/L; S-NSF-V29: 0.14 µg/L), *m*-xylene plus *p*-xylene (S-NSF-H38: 0.06 µg/L), and *o*-xylene (S-NSF-H38: 0.046 µg/L) have been reclassified as less than or equal to the SRL and are not presented in this report.

<sup>3</sup> Well periodically treated with downhole chlorination, which may have affected the trihalomethane results.

<sup>4</sup> This well had a vehicle parked next to the well head for long periods of time, and the vehicle is suspected to have leaked oil onto the ground which may account for the suite of gasoline hydrocarbon detections.

<sup>5</sup> Carbon disulfide concentration is less than the SRL (Fram and others, 2012).

**Table 6.** Pesticides and pesticide degradates detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Detected constituents are grouped by primary use or source and then listed in order of decreasing detection frequency in the 70 grid wells. All constituents are listed in [table 3B](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LRL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HBSL, USGS Health-Based Screening Level; MCL-US, U.S. Environmental Protection Agency (USEPA) maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; E, estimated or having a higher degree of uncertainty; LRL, laboratory reporting level; µg/L, micrograms per liter; na, not available; \*, concentration greater than the benchmark level; —, not detected]

Primary use or source	Herbicide				Herbicide degrade		Insecticide	Insecticide degrade	Detections per well	Pesticide detection summary
GAMA well identification number	Simazine (µg/L) (04035)	Atrazine (µg/L) (39632)	Prometon (µg/L) (04037)	Tebuthiuron (µg/L) (82670)	Deethylatrazine (µg/L) (04040)	3,4-Dichloroaniline (µg/L) (61625)	Dieldrin (µg/L) (39381)	Fipronil sulfide (µg/L) (62167)		
<b>Benchmark type</b>	<b>MCL-US</b>	<b>MCL-CA</b>	<b>HBSL</b>	<b>HBSL</b>	<b>na</b>	<b>na</b>	<b>HBSL</b>	<b>na</b>		
<b>Benchmark level</b>	<b>4</b>	<b>1</b>	<b>400</b>	<b>1,000</b>	<b>na</b>	<b>na</b>	<b>0.02</b>	<b>na</b>		
<b>[LRL]</b>	<b>[0.006]</b>	<b>[0.008]</b>	<b>[0.012]</b>	<b>[0.028]</b>	<b>[0.006]</b>	<b>[0.006]</b>	<b>[0.008]</b>	<b>[0.012]</b>		
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)										
Number of wells with detections	6	4	1	1	4	1	1	1		9
Detection frequency (percent)	8.6	5.7	1.4	1.4	5.7	1.4	1.4	1.4		13
Total detections (number)										19
Highlands study area wells (40 wells sampled)										
S-NSF-H27	—	—	—	E0.013	—	—	—	—	1	
S-NSF-H28	—	—	—	—	E0.004	—	—	—	1	
S-NSF-H30	0.005	0.007	—	—	E0.005	—	—	—	3	
S-NSF-H36	—	—	—	—	—	—	—	0.007	1	
Number of wells with detections	1	1	0	1	2	0	0	1		4
Detection frequency (percent)	2.5	2.5	0	2.5	5	0	0	2.5		10
Total detections (number)										6
Valley and Plains study area wells (30 wells sampled)										
S-NSF-VP01	0.007	0.005	0.01	—	E0.006	—	—	—	4	
S-NSF-VP02	0.028	0.004	—	—	E0.004	—	—	—	3	
S-NSF-VP17	0.006	—	—	—	—	—	—	—	1	
S-NSF-VP18	0.009	—	—	—	—	—	—	—	1	
S-NSF-VP25	0.01	0.007	—	—	—	E0.0894	*0.065	—	4	
Number of wells with detections	5	3	1	0	2	1	1	0		5
Detection frequency (percent)	17	10	3.3	0	6.7	3.3	3.3	0		17
Total detections (number)										13
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)										
S-NSF-HU30	0.005	—	0.004	—	—	—	—	—		

**Table 7.** Constituents of special interest detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[1,2,3-Trichloropropane (1,2,3-TCP) was not detected and is therefore not presented in this table. The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Information about the constituents given in [table 3C](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Benchmark type,** benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health maximum contaminant level; MCL-US, U.S. Environmental Protection Agency maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; µg/L, micrograms per liter]

<b>GAMA well identification number</b>	<b>Perchlorate (µg/L) (63790)</b>
<b>Benchmark type</b>	<b>MCL-CA</b>
<b>Benchmark level</b>	<b>6</b>
<b>[LT-MDL]</b>	<b>[0.10]</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)	
Highlands study area wells (40 wells sampled)	
S-NSF-H23	0.19
S-NSF-H24	0.25
S-NSF-H27	1.36
S-NSF-H28	0.19
S-NSF-H30	0.13
S-NSF-H33	0.14
S-NSF-H35	0.25
S-NSF-H36	0.46
S-NSF-H37	0.11
S-NSF-H39	0.17
S-NSF-H40	0.37
Valley and Plains study area wells (30 wells sampled)	
S-NSF-VP02	0.53
S-NSF-VP08	0.38
S-NSF-VP11	0.38
S-NSF-VP15	0.31
S-NSF-VP17	0.17
S-NSF-VP25	1.62
S-NSF-VP27	0.58
S-NSF-VP29	0.17
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)	
S-NSF-HU30	0.11



**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. **Benchmark type, benchmark level, and LT-MDL** as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. **AL-US**, U.S. Environmental Protection Agency (USEPA) action level; **HBSL**, USGS health-based screening level; **MCL-CA**, California Department of Public Health (CDPH) maximum contaminant level; **MCL-US**, USEPA maximum contaminant level; **NL-CA**, CDPH notification level; **SMCL-CA**, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; **LT-MDL**, long-term method detection limit; **SRL**, study reporting level;  $\mu\text{g/L}$ , micrograms per liter; **na**, not available; **—**, not detected;  $\leq$ , less than or equal to; **\***, concentration greater than the benchmark level; **nc**, not collected]

GAMA well identification number	Aluminum ( $\mu\text{g/L}$ ) (01106)	Antimony ( $\mu\text{g/L}$ ) (01095)	Arsenic ( $\mu\text{g/L}$ ) (01000)	Barium ( $\mu\text{g/L}$ ) (01005)	Beryllium ( $\mu\text{g/L}$ ) (01010)	Boron ( $\mu\text{g/L}$ ) (01020)	Cadmium ( $\mu\text{g/L}$ ) (01025)	Chromium ( $\mu\text{g/L}$ ) (01030)	Cobalt ( $\mu\text{g/L}$ ) (01035)	Copper ( $\mu\text{g/L}$ ) (01040)	Iron ( $\mu\text{g/L}$ ) (01046)	Lead ( $\mu\text{g/L}$ ) (01049)
<b>Benchmark type</b>	<b>MCL-CA</b>	<b>MCL-US</b>	<b>MCL-US</b>	<b>MCL-CA</b>	<b>MCL-US</b>	<b>HBSL</b>	<b>MCL-US</b>	<b>MCL-CA</b>	<b>na</b>	<b>AL-US</b>	<b>SMCL-CA</b>	<b>AL-US</b>
<b>Benchmark level</b>	<b>1,000</b>	<b>6</b>	<b>10</b>	<b>1,000</b>	<b>4</b>	<b>6,000</b>	<b>5</b>	<b>50</b>	<b>na</b>	<b>1,300</b>	<b>300</b>	<b>15</b>
<b>[LT-MDL or SRL]</b>	<b>[2.2]</b>	<b>[0.027]</b>	<b>[0.03]</b>	<b>[0.36]</b> <sup>1</sup>	<b>[0.006]</b>	<b>[3]</b>	<b>[0.016]</b>	<b>[0.42]</b> <sup>1</sup>	<b>[0.05]</b> <sup>2</sup>	<b>[3.2]</b> <sup>2</sup>	<b>[6.0]</b> <sup>1</sup>	<b>[0.82]</b> <sup>2</sup>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)												
Highlands study area wells (40 wells sampled)												
S-NSF-H01	—	—	0.18	4.23	—	7	—	$\leq 0.07$	0.10	—	*1,080	$\leq 0.09$
S-NSF-H02	—	—	0.13	49	—	38	—	1.3	—	$\leq 1.1$	—	0.88
S-NSF-H03	—	0.039	1.8	150	—	12	—	—	$\leq 0.04$	$\leq 1.9$	6.2	$\leq 0.36$
S-NSF-H04	2.3	0.765	—	18	0.011	*8,270	0.062	2.5	$\leq 0.05$	—	$\leq 4.6$	$\leq 0.22$
S-NSF-H05	7.3	0.086	0.58	112	—	45	—	—	$\leq 0.04$	$\leq 0.86$	14.8	$\leq 0.19$
S-NSF-H06	—	0.039	0.24	52.4	0.006	205	—	—	$\leq 0.04$	$\leq 1.8$	$\leq 3.8$	$\leq 0.23$
S-NSF-H07	—	0.027	0.12	17.3	—	49	—	3.7	$\leq 0.03$	$\leq 2.1$	$\leq 3.5$	$\leq 0.43$
S-NSF-H08	—	—	—	316	0.295	*10,400	—	—	—	—	15.1	—
S-NSF-H09	—	0.103	0.95	6.62	0.011	183	—	—	$\leq 0.03$	—	22.2	$\leq 0.08$
S-NSF-H10	11.8	0.034	0.14	29.6	—	8	—	0.98	—	12	$\leq 5.6$	$\leq 0.26$
S-NSF-H11	39.4	—	0.12	62.3	—	68	—	$\leq 0.15$	$\leq 0.04$	7.8	19.5	$\leq 0.23$
S-NSF-H12	14.9	0.048	1.9	15.2	0.018	16	—	$\leq 0.29$	0.18	—	*3,040	$\leq 0.10$
S-NSF-H13	38.4	—	—	12.9	—	146	—	4.7	0.05	—	38.9	$\leq 0.04$
S-NSF-H14	—	—	0.09	182	—	37	—	—	0.08	—	12	$\leq 0.24$
S-NSF-H15	—	—	6.4	0.54	—	8	—	—	$\leq 0.02$	—	*1,120	—

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Highlands study area wells (40 wells sampled)—Continued												
S-NSF-H16	2.6	—	1.7	6.9	—	27	—	—	0.06	—	688	—
S-NSF-H17	—	—	—	5.35	—	12	—	—	0.08	—	162	≤0.08
S-NSF-H18	—	—	0.42	60.2	—	62	—	—	0.07	—	17.2	≤0.20
S-NSF-H19	4.1	—	—	75.5	—	53	0.025	—	—	≤0.93	6.9	—
S-NSF-H20	6.2	—	—	51.5	0.033	17	—	—	—	—	19.4	≤0.23
S-NSF-H21	2.8	0.03	7	98.1	—	81	—	—	0.12	—	*1,200	<0.07
S-NSF-H22	8.5	—	1.5	81.6	0.019	803	0.02	0.55	≤0.04	—	26	≤0.18
S-NSF-H23	—	—	0.21	2.15	0.006	5	—	1.1	≤0.03	≤2.3	≤3.3	≤0.15
S-NSF-H24	9.4	0.032	2.7	3.55	—	12	—	3.3	—	—	—	—
S-NSF-H25	11.8	—	0.76	7.24	—	24	—	2.1	—	—	≤5.6	—
S-NSF-H26	—	—	5.7	55.3	—	18	—	—	0.15	≤1.1	*356	≤0.41
S-NSF-H27	—	—	0.2	37.5	—	240	—	≤0.16	0.05	≤1.2	≤4.9	≤0.28
S-NSF-H28	—	0.046	2.9	4.43	—	50	—	1.1	≤0.03	≤1.2	≤3.4	≤0.11
S-NSF-H29	—	—	0.31	23.2	0.052	9	—	—	0.49	—	*11,900	—
S-NSF-H30	6.2	0.054	2.3	23.2	—	16	—	≤0.09	≤0.02	≤2.5	≤3.7	1.14
S-NSF-H31	2.7	0.333	6.9	143	0.053	<sup>3</sup> 2,650	0.029	—	0.38	≤0.86	—	≤0.55
S-NSF-H32	2.4	0.095	4.5	23.2	0.006	13	—	3.9	—	≤1.3	—	3.83
S-NSF-H33	2.3	0.052	7.2	7.45	0.044	26	—	≤0.18	—	≤2.1	—	≤0.28
S-NSF-H34	3.1	0.05	1.6	532	—	364	—	—	0.19	—	*584	≤0.04
S-NSF-H35	—	0.058	3.6	17.9	—	106	—	2.6	0.08	14.2	—	≤0.79

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Highlands study area wells (40 wells sampled)—Continued												
S-NSF-H36	42.1	0.118	1.7	42.7	0.127	153	0.029	—	0.18	8.4	18.7	1.04
S-NSF-H37	16.5	0.055	0.7	17.4	0.007	16	—	1.7	≤0.03	3.9	≤4.4	≤0.36
S-NSF-H38	29.3	0.075	0.7	110	0.057	<sup>3</sup> 3,560	—	≤0.11	≤0.03	—	40.8	≤0.08
S-NSF-H39	2.3	0.037	3.8	6.74	0.016	24	—	0.42	—	≤1.6	—	≤0.36
S-NSF-H40	—	0.22	0.21	74	0.009	76	—	—	0.14	—	≤5.9	≤0.39
Valley and Plains study area wells (30 wells sampled)												
S-NSF-VP01	—	0.097	2.5	251	—	84	—	≤0.12	0.16	≤3.1	32.7	≤0.37
S-NSF-VP02	—	0.089	4.5	40.8	—	49	—	2.3	0.11	6.3	—	4.28
S-NSF-VP03	2.7	0.045	*19.2	299	—	190	0.035	—	0.12	≤0.92	22.9	≤0.20
S-NSF-VP04	—	—	0.85	57.4	—	13	—	≤0.09	0.14	≤1.2	*335	≤0.05
S-NSF-VP05	—	—	*58.1	58.6	0.011	465	—	≤0.11	—	≤0.92	29.6	0.94
S-NSF-VP06	7.9	0.034	1	194	—	120	0.018	—	0.17	≤2.3	9.2	≤0.07
S-NSF-VP07	2.3	—	0.09	1.29	—	109	—	—	≤0.03	—	8.1	≤0.41
S-NSF-VP08	—	—	6.2	44	—	20	—	≤0.32	—	≤1.7	6.2	≤0.41
S-NSF-VP09	2.3	—	*43.6	170	0.007	55	—	—	≤0.03	—	*2,200	—
S-NSF-VP10	—	—	5.7	144	—	53	—	—	0.10	—	279	—
S-NSF-VP11	3.6	0.086	5.4	180	—	42	—	3.7	0.06	—	—	≤0.15
S-NSF-VP12	2.3	—	*11.5	49.6	—	378	—	≤0.11	0.11	—	45.2	≤0.04
S-NSF-VP13	7.3	—	0.72	52.6	0.024	<sup>3</sup> 1,300	0.021	≤0.08	≤0.03	5.4	12.7	≤0.33
S-NSF-VP14	—	—	6.1	145	—	98	0.041	—	≤0.03	—	*1,760	≤0.14
S-NSF-VP15	—	0.039	0.43	122	—	205	—	1	0.16	—	258	—

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued												
Valley and Plains study area wells (30 wells sampled)—Continued												
S-NSF-VP16	2.6	0.028	6.6	223	0.014	432	0.024	≤0.12	0.06	—	*609	—
S-NSF-VP17	8.6	0.034	0.32	200	—	118	—	3.8	≤0.04	4.5	8.9	≤0.53
S-NSF-VP18	6.7	0.106	0.32	127	0.007	267	—	1.5	≤0.04	3.5	16.1	1.02
S-NSF-VP19	2.3	—	1.5	72.4	—	26	—	—	—	—	*1,260	—
S-NSF-VP20	179	1.36	6.3	44.2	0.027	53	0.067	1.3	1.47	18	97	≤0.45
S-NSF-VP21	—	0.043	*20.4	92	0.018	766	0.049	—	≤0.04	—	20.2	≤0.48
S-NSF-VP22	—	0.095	3.4	111	—	50	—	1.1	—	≤1.7	—	≤0.46
S-NSF-VP23	2.5	—	*43	65.8	0.019	604	0.024	—	—	—	*694	≤0.15
S-NSF-VP24	6.9	0.028	4.2	67.4	0.01	277	0.072	—	0.09	—	≤4.2	≤0.23
S-NSF-VP25	13.7	0.18	1.7	420	0.006	112	0.029	≤0.16	0.19	3.4	278	≤0.09
S-NSF-VP26	—	0.036	1.2	70.8	—	42	—	≤0.15	≤0.02	—	13.4	≤0.12
S-NSF-VP27	7.1	—	0.3	83.3	—	49	—	—	0.09	≤2.3	≤3.5	≤0.16
S-NSF-VP28	—	0.054	3	165	—	68	—	—	0.35	—	35.9	≤0.03
S-NSF-VP29	—	0.041	0.63	95	—	140	—	4.2	≤0.03	—	≤3.4	≤0.16
S-NSF-VP30	3.8	0.118	*22.6	17.7	—	109	—	—	0.09	≤1.4	8.5	≤0.34
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)												
S-NSF-HU30	4.1	0.072	0.59	46.7	—	45	—	7.7	≤0.04	4.3	—	≤0.43

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Benchmark type	na	HBSL	HBSL	MCL-CA	MCL-US	HBSL	HBSL	MCL-US	MCL-US	NL-CA	HBSL
Benchmark level	na	300	40	100	50	100	4,000	2	30	50	2,000
[LT-MDL or SRL]	[0.22]	[0.2] <sup>1</sup>	[0.014]	[0.2] <sup>2</sup>	[0.03]	[0.005]	[0.2]	[0.01]	[0.003]	[0.08]	[6.4] <sup>2</sup>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)											
Highlands study area wells (40 wells sampled)											
S-NSF-H01	10.3	<sup>4</sup> 94.5	0.359	3.9	—	—	95.4	—	—	—	≤6.3
S-NSF-H02	0.75	—	0.142	8.8	0.14	—	143	—	0.010	0.47	≤1.5
S-NSF-H03	13.1	33.4	0.725	—	—	—	424	—	0.686	—	7.2
S-NSF-H04	11.9	0.6	15	1.7	1.5	0.006	271	—	11.8	7.9	78.5
S-NSF-H05	11.3	21.2	1.35	0.5	—	—	545	—	0.128	0.22	≤1.7
S-NSF-H06	15.3	12.7	0.604	0.8	—	0.007	3,700	—	0.217	2.3	≤2
S-NSF-H07	0.41	—	0.192	1.6	0.04	—	144	—	0.060	3.6	≤1.6
S-NSF-H08	54.8	3.5	0.073	—	—	—	408	0.02	0.008	—	—
S-NSF-H09	12.1	35.2	2.64	≤0.2	0.07	—	333	—	0.032	0.94	—
S-NSF-H10	4	0.4	0.127	1.2	0.24	—	105	—	0.021	0.79	22.6
S-NSF-H11	5.78	0.3	0.069	1	0.07	—	179	—	0.023	0.23	30.2
S-NSF-H12	15.6	<sup>4</sup> 212	3.02	0.3	0.13	—	88.1	—	0.235	3.8	—
S-NSF-H13	13.9	1.5	0.539	1.4	—	—	27.4	—	0.007	0.15	—
S-NSF-H14	20.3	25.1	0.471	0.2	—	—	933	—	0.010	—	≤2.7
S-NSF-H15	17.3	<sup>4</sup> 285	0.599	≤0.1	—	—	13.6	—	—	—	≤2.2



**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H16	11.3	<sup>4</sup> 82.2	1.34	0.8	—	—	191	—	—	—	—
S-NSF-H17	42	<sup>4</sup> 202	0.381	0.6	—	—	247	—	0.011	—	—
S-NSF-H18	8.76	*625	0.372	3.7	—	—	282	—	0.332	0.72	≤2.6
S-NSF-H19	8.82	0.5	0.019	0.4	0.08	—	143	—	0.030	0.08	≤2.5
S-NSF-H20	0.76	0.6	0.954	≤0.15	0.07	—	209	—	—	0.17	≤2.7
S-NSF-H21	20.6	<sup>4</sup> 159	1.32	0.6	—	—	299	—	0.019	0.12	≤5.2
S-NSF-H22	81.7	18.8	7.88	0.3	—	—	36.1	—	—	—	≤1.9
S-NSF-H23	0.64	0.4	—	0.2	—	—	72.4	—	0.019	12	≤4.7
S-NSF-H24	3.63	0.7	0.727	0.8	0.53	—	30.3	—	0.014	34.6	—
S-NSF-H25	3.96	0.3	0.600	0.4	0.09	—	72.4	—	0.476	11.7	—
S-NSF-H26	15.8	<sup>4</sup> 64	2.31	0.7	—	—	285	0.02	0.102	0.09	≤5.9
S-NSF-H27	20.4	12.6	0.565	3.2	0.20	0.005	1,100	—	1.37	0.98	≤4
S-NSF-H28	21	1.1	0.591	≤0.2	0.06	—	29.3	—	0.038	19.5	≤4.1
S-NSF-H29	9.88	*2,800	0.440	1.5	—	—	2,110	—	—	—	≤3
S-NSF-H30	7.79	0.2	0.348	≤0.1	0.18	—	27.1	—	0.051	9.5	23.9
S-NSF-H31	19.7	12.8	8.86	10.2	0.05	—	618	0.04	0.212	2.1	≤5
S-NSF-H32	14.8	≤0.2	0.100	3.7	0.36	—	38.8	—	0.053	8.3	19.1
S-NSF-H33	10.4	0.6	0.371	—	0.08	—	69.8	—	0.157	0.83	27.9
S-NSF-H34	35.8	*773	0.680	3.6	0.26	—	412	0.01	0.378	0.28	—
S-NSF-H35	20.9	≤0.2	0.449	0.9	0.29	—	78.9	—	0.411	17	9.7

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H36	10.7	1.2	0.086	1.8	0.04	—	73.5	0.04	0.269	1.6	15.5
S-NSF-H37	6.01	—	0.074	7.8	0.08	—	43.2	—	0.079	9.0	66.8
S-NSF-H38	21.6	48	1.53	≤0.2	—	—	52.1	—	0.043	0.29	≤2.4
S-NSF-H39	20.2	—	0.367	≤0.1	0.23	—	26.8	—	0.035	10.7	≤3.3
S-NSF-H40	22.6	1.1	1.11	3	0.18	—	942	—	1.00	1.0	≤2
Valley and Plains study area wells (30 wells sampled)											
S-NSF-VP01	29	*623	1.70	3.1	0.45	—	838	—	5.37	3.2	≤3.1
S-NSF-VP02	11.1	≤0.1	0.209	1.6	0.13	0.006	256	—	4.20	46.9	≤5.5
S-NSF-VP03	12.2	*560	12.1	0.7	0.10	—	448	—	0.448	2.1	≤6.3
S-NSF-VP04	13	<sup>4</sup> 62.7	0.157	3	—	—	154	—	0.007	0.47	10.1
S-NSF-VP05	20.5	30.7	4.24	0.3	0.05	—	59.9	—	0.025	1.6	≤1.8
S-NSF-VP06	2.93	*509	0.878	0.7	—	—	258	—	0.298	1.6	49.9
S-NSF-VP07	8.96	1.8	0.225	0.4	—	—	178	—	0.014	2.3	≤5
S-NSF-VP08	14.4	0.7	0.542	0.8	0.12	—	93	—	0.025	5.9	≤5.6
S-NSF-VP09	23.6	*1,570	0.243	≤0.1	—	—	139	0.02	—	—	—
S-NSF-VP10	13	*485	0.731	0.4	—	—	146	—	—	—	—
S-NSF-VP11	37.4	15.5	0.582	1.2	0.83	—	369	—	2.79	22.7	≤3.2
S-NSF-VP12	34.9	45.4	2.80	0.2	—	—	332	0.09	0.060	0.08	13.5
S-NSF-VP13	87.9	21.6	4.75	≤0.1	—	—	37.1	—	0.020	0.11	≤4.5
S-NSF-VP14	47.1	*942	10.5	0.7	—	—	237	—	0.005	—	≤4.6
S-NSF-VP15	4.08	<sup>4</sup> 104	0.632	3.4	0.24	—	221	—	0.281	3.2	≤1.6

**Table 8.** Trace elements detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3D](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. AL-US, U.S. Environmental Protection Agency (USEPA) action level; HBSL, USGS health-based screening level; MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; MCL-US, USEPA maximum contaminant level; NL-CA, CDPH notification level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected; ≤, less than or equal to; \*, concentration greater than the benchmark level; nc, not collected]

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)	Uranium (µg/L) (22703)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Valley and Plains study area wells (30 wells sampled)—Continued											
S-NSF-VP16	213	*542	5.74	0.4	—	—	94.1	—	0.008	—	≤1.7
S-NSF-VP17	16.9	1.2	0.511	6.4	3.6	—	214	—	1.08	1.2	8.1
S-NSF-VP18	6.01	0.4	0.332	2.3	0.10	—	300	—	0.108	1.1	22.8
S-NSF-VP19	42.6	*1,080	0.626	—	—	—	121	—	—	—	—
S-NSF-VP20	0.49	2.4	1.50	14.7	2.9	0.006	100	0.02	0.178	28.1	≤2.1
S-NSF-VP21	32.3	<sup>4</sup> 139	19.4	0.5	0.04	—	74.4	—	0.096	0.64	8.9
S-NSF-VP22	16.8	0.5	0.274	2.2	1.2	—	157	—	0.648	15.7	—
S-NSF-VP23	58.3	<sup>4</sup> 230	10.7	≤0.1	—	—	50.1	0.02	0.004	—	59.3
S-NSF-VP24	31.1	5.1	14.7	0.4	0.16	—	114	—	1.89	1.4	31.9
S-NSF-VP25	43.6	17.3	1.10	2	2.5	—	1,110	—	0.986	4.3	8.1
S-NSF-VP26	23.2	22.7	0.235	1.4	0.06	—	142	—	0.009	1.7	≤4.9
S-NSF-VP27	27	<sup>4</sup> 183	0.292	0.6	0.06	—	294	—	0.185	0.83	≤1.8
S-NSF-VP28	21.7	*1,470	0.982	1.3	0.10	—	196	—	0.177	2.8	≤5.6
S-NSF-VP29	8.06	—	0.446	1.3	0.24	—	285	—	0.429	2.9	10.8
S-NSF-VP30	23.3	*978	4.42	0.8	—	—	107	0.02	0.279	1.4	12.9
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)											
S-NSF-HU30	3.11	—	0.371	8.8	0.11	—	86.6	—	0.130	4.0	11.8

<sup>1</sup> The SRL was defined by Olsen and others (2010).

<sup>2</sup> The SRL was defined by Tracy Davis and is based on an updated assessment of field blank detections of trace elements (Tracy Davis, U.S. Geological Survey, written commun., April 2013).

<sup>3</sup> Concentration of boron greater than the California notification level of 1,000 µg/L.

<sup>4</sup> Concentration greater than California secondary maximum contaminant level for manganese of 50 µg/L.

**Table 9.** Nutrients detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Information about the constituents given in [table 3E](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; \*, concentration greater than the benchmark level; na, not available; —, not detected]

<b>GAMA well identification number</b>	<b>Ammonia (as nitrogen) (mg/L) (00608)</b>	<b>Nitrite (as nitrogen) (mg/L) (00613)</b>	<b>Nitrite plus nitrate (as nitrogen) <sup>1</sup> (mg/L) (00631)</b>	<b>Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen) (mg/L) (62854)</b>	<b>Phosphate, orthophosphate (as phosphorus) (mg/L) (00671)</b>
<b>Benchmark type</b>	<b>HAL-US</b>	<b>MCL-US</b>	<b>MCL-US</b>	<b>na</b>	<b>na</b>
<b>Benchmark level</b>	<b><sup>2</sup> 24.7</b>	<b>1</b>	<b>10</b>	<b>na</b>	<b>na</b>
<b>[LT-MDL]</b>	<b>[0.01]</b>	<b>[0.001]</b>	<b>[0.04]</b>	<b>[0.05]</b>	<b>[0.004]</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)					
Highlands study area wells (40 wells sampled)					
S-NSF-H01	—	—	—	—	0.021
S-NSF-H02	—	—	0.14	0.11	0.019
S-NSF-H03	—	—	—	—	0.042
S-NSF-H04	—	—	—	—	0.004
S-NSF-H05	0.04	0.001	—	—	0.007
S-NSF-H06	0.09	—	0.08	0.15	0.01
S-NSF-H07	—	—	0.09	0.09	0.014
S-NSF-H08	0.14	—	—	0.15	0.006
S-NSF-H09	0.01	—	—	—	0.014
S-NSF-H10	—	—	0.05	—	0.065
S-NSF-H11	0.01	—	—	—	0.028
S-NSF-H12	0.03	—	—	—	0.097
S-NSF-H13	0.24	—	—	0.26	0.039
S-NSF-H14	0.22	—	—	0.24	0.008
S-NSF-H15	0.04	—	—	—	0.129
S-NSF-H16	0.02	—	—	—	0.739
S-NSF-H17	0.09	0.017	0.14	0.18	0.034
S-NSF-H18	—	0.012	0.28	0.30	0.038
S-NSF-H19	—	—	—	—	0.004
S-NSF-H20	—	—	0.19	0.19	0.042
S-NSF-H21	0.03	—	—	—	0.066
S-NSF-H22	0.17	—	—	0.18	0.181
S-NSF-H23	—	—	1.28	1.30	0.081
S-NSF-H24	—	—	0.80	0.82	0.439
S-NSF-H25	—	—	0.07	0.08	0.077

**Table 9.** Nutrients detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Information about the constituents given in [table 3E](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; \*, concentration greater than the benchmark level; na, not available; —, not detected]

<b>GAMA well identification number</b>	<b>Ammonia (as nitrogen) (mg/L) (00608)</b>	<b>Nitrite (as nitrogen) (mg/L) (00613)</b>	<b>Nitrite plus nitrate (as nitrogen) <sup>1</sup> (mg/L) (00631)</b>	<b>Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen) (mg/L) (62854)</b>	<b>Phosphate, orthophosphate (as phosphorus) (mg/L) (00671)</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued					
Highlands study area wells (40 wells sampled)—Continued					
S-NSF-H26	—	—	0.07	—	0.038
S-NSF-H27	—	—	4.64	4.63	0.034
S-NSF-H28	0.01	—	0.40	0.41	0.293
S-NSF-H29	1.5	0.002	0.05	1.62	0.045
S-NSF-H30	—	—	0.38	0.4	0.216
S-NSF-H31	0.01	—	—	—	0.021
S-NSF-H32	—	—	0.05	—	0.272
S-NSF-H33	—	—	0.06	0.06	0.186
S-NSF-H34	1.02	0.006	0.12	1.41	0.101
S-NSF-H35	—	—	0.47	0.46	0.198
S-NSF-H36	—	—	2.07	1.99	0.152
S-NSF-H37	—	—	0.56	0.59	0.152
S-NSF-H38	0.60	—	—	0.70	0.052
S-NSF-H39	0.01	—	0.46	0.47	0.443
S-NSF-H40	—	0.004	5.37	6.20	0.007
Valley and Plains study area wells (30 wells sampled)					
S-NSF-VP01	0.10	0.003	0.94	1.22	0.13
S-NSF-VP02	—	—	7.53	7.59	0.191
S-NSF-VP03	0.18	0.003	0.21	0.46	0.358
S-NSF-VP04	—	0.002	0.46	0.44	0.042
S-NSF-VP05	0.11	0.004	0.72	0.79	0.443
S-NSF-VP06	0.13	—	—	0.15	0.126
S-NSF-VP07	0.01	—	—	—	0.032
S-NSF-VP08	—	—	1.98	1.90	0.225
S-NSF-VP09	0.40	—	—	0.42	0.219
S-NSF-VP10	0.05	—	—	0.06	0.267



**Table 9.** Nutrients detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed, but only samples with detections are listed. Information about the constituents given in [table 3E](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. HAL-US, U.S. Environmental Protection Agency (USEPA) lifetime health advisory level; MCL-US, USEPA maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; \*, concentration greater than the benchmark level; na, not available; —, not detected]

<b>GAMA well identification number</b>	<b>Ammonia (as nitrogen) (mg/L) (00608)</b>	<b>Nitrite (as nitrogen) (mg/L) (00613)</b>	<b>Nitrite plus nitrate (as nitrogen)<sup>1</sup> (mg/L) (00631)</b>	<b>Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen) (mg/L) (62854)</b>	<b>Phosphate, orthophosphate (as phosphorus) (mg/L) (00671)</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued					
Valley and Plains study area wells (30 wells sampled)—Continued					
S-NSF-VP11	—	—	*14	13	0.099
S-NSF-VP12	0.16	—	—	0.14	0.045
S-NSF-VP13	0.20	—	—	0.16	0.184
S-NSF-VP14	0.30	—	—	0.32	0.332
S-NSF-VP15	—	0.001	1.87	2.01	0.071
S-NSF-VP16	0.79	0.002	—	0.85	0.223
S-NSF-VP17	—	—	1.12	1.20	0.046
S-NSF-VP18	—	—	1.94	1.99	0.018
S-NSF-VP19	0.04	—	—	—	0.043
S-NSF-VP20	0.04	—	—	—	0.425
S-NSF-VP21	0.18	—	—	0.21	0.663
S-NSF-VP22	—	—	3.2	3.29	0.178
S-NSF-VP23	0.15	—	—	0.15	1.61
S-NSF-VP24	0.06	0.001	0.10	0.26	0.129
S-NSF-VP25	—	0.007	*10	10.1	0.09
S-NSF-VP26	—	—	4.41	4.22	0.237
S-NSF-VP27	—	0.007	4.72	5.17	0.093
S-NSF-VP28	0.07	—	—	0.10	0.329
S-NSF-VP29	—	—	1.53	1.53	0.063
S-NSF-VP30	0.09	—	—	0.11	0.512
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)					
S-NSF-HU30	—	—	0.38	0.42	0.086

<sup>1</sup> Nitrite plus nitrate (as nitrogen) is referred to as nitrate in the text for clarity.

<sup>2</sup> The HAL-US is 30 mg/L “as ammonia.” To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L “as nitrogen.”

**Table 10.** Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3F](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. The SMCL-CA benchmark for chloride, sulfate, and TDS have recommended and upper benchmark levels. The upper benchmark level is shown in parentheses. MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; SiO<sub>2</sub>, silicon dioxide; na, not available; —, not detected; \*, concentration greater than the recommended benchmark level; \*\*, concentration greater than upper benchmark level]

<b>GAMA well identification number</b>	<b>Bromide (mg/L) (71870)</b>	<b>Calcium (mg/L) (00915)</b>	<b>Chloride (mg/L) (00940)</b>	<b>Fluoride (mg/L) (00950)</b>	<b>Iodide (mg/L) (71865)</b>	<b>Magnesium (mg/L) (00925)</b>	<b>Potassium (mg/L) (00935)</b>	<b>Sodium (mg/L) (00930)</b>	<b>Sulfate (mg/L) (00945)</b>	<b>Silica (as SiO<sub>2</sub>) (mg/L) (00955)</b>	<b>TDS (mg/L) (70300)</b>
<b>Benchmark type</b>	na	na	SMCL-CA	MCL-CA	na	na	na	na	SMCL-CA	na	SMCL-CA
<b>Benchmark level</b>	na	na	250 (500)	2	na	na	na	na	250 (500)	na	500 (1,000)
<b>[LT-MDL]</b>	<b>[0.01]</b>	<b>[0.022]</b>	<b>[0.06]</b>	<b>[0.04]</b>	<b>[0.001]</b>	<b>[0.011]</b>	<b>[0.03]</b>	<b>[0.06]</b>	<b>[0.09]</b>	<b>[0.018]</b>	<b>[10]</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)											
Highlands study area wells (40 wells sampled)											
S-NSF-H01	0.11	13.4	20.1	0.1	0.002	20.9	1.13	16.6	39.7	53.8	214
S-NSF-H02	0.02	19.4	6.53	0.06	—	27.9	0.64	7.19	6.08	21.8	186
S-NSF-H03	0.02	18.1	4.78	0.24	—	6.05	0.6	13.1	3.94	37.3	138
S-NSF-H04	0.03	17.6	4.68	*5.2	0.009	13.9	0.91	175	14	14.5	*532
S-NSF-H05	0.03	64.9	6.39	0.37	—	21.7	1.46	20.4	34.9	22.1	311
S-NSF-H06	0.04	71	5.57	0.54	—	38.9	2.85	48.1	63.9	33.5	468
S-NSF-H07	0.04	12.6	5.67	—	—	48.3	0.35	4.4	8.2	30.8	230
S-NSF-H08	0.06	2.17	19	1.87	0.016	1.5	1.11	183	21.6	11	474
S-NSF-H09	0.03	37.4	6.08	0.42	0.007	13.5	0.51	31.2	37.9	47	263
S-NSF-H10	0.03	15.5	4.33	0.07	—	3.06	0.85	10	9.23	29.9	99
S-NSF-H11	0.03	19	7.58	0.08	0.001	6.08	1.24	11.5	4.1	18.7	132
S-NSF-H12	0.06	15	24.5	0.27	0.003	17.1	1.43	18.6	47.2	52	225
S-NSF-H13	0.11	0.922	41.3	0.23	0.009	0.046	0.36	126	13.1	11.6	312
S-NSF-H14	0.14	32.8	48.4	0.09	0.003	13.1	0.58	70	58.9	19.2	338
S-NSF-H15	0.12	21.4	21.7	0.1	0.014	17.4	0.28	19.6	26.6	44.4	207

**Table 10.** Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3F](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. The SMCL-CA benchmark for chloride, sulfate, and TDS have recommended and upper benchmark levels. The upper benchmark level is shown in parentheses. MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; SiO<sub>2</sub>, silicon dioxide; na, not available; —, not detected; \*, concentration greater than the recommended benchmark level; \*\*, concentration greater than upper benchmark level]

GAMA well identification number	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Silica (as SiO <sub>2</sub> ) (mg/L) (00955)	TDS (mg/L) (70300)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H16	0.08	22.6	17.9	0.11	0.011	12.2	1.38	26.7	54.1	64.7	256
S-NSF-H17	0.08	64.8	23.7	0.07	0.002	46.2	2.97	23.3	240	28.6	*521
S-NSF-H18	0.22	33.5	27.7	0.17	0.07	42.2	0.8	38.9	58.5	31.8	348
S-NSF-H19	0.02	28.3	4.86	0.14	—	23.5	1.3	6.4	11.3	11.8	184
S-NSF-H20	0.02	17.1	2.49	0.09	—	6.4	1.62	8.05	2.12	24.9	106
S-NSF-H21	0.04	31.7	10.2	0.21	0.002	21.6	4.36	23.1	23.1	81.5	300
S-NSF-H22	0.19	3.86	50.1	0.75	0.206	1.1	7.78	210	—	59.4	*612
S-NSF-H23	0.04	17.3	8.41	—	—	9.35	0.83	10.9	1.25	75	138
S-NSF-H24	0.03	11.1	5.19	0.27	—	5.46	1.02	12.4	1.08	93.9	148
S-NSF-H25	0.02	28.4	5.31	0.12	—	13.9	2.92	12.1	2.83	54.5	181
S-NSF-H26	0.26	95.5	97.7	0.15	0.012	14.2	1.19	36.9	26.6	60.2	471
S-NSF-H27	0.34	91.3	135	0.36	0.045	82.4	0.35	114	*360	21.5	**1,040
S-NSF-H28	0.03	9.66	8.07	0.21	—	6.66	3.44	14.9	2.45	89	192
S-NSF-H29	0.23	254	54.1	0.14	0.01	37.2	8.83	39.4	**667	76.7	**1,280
S-NSF-H30	0.02	7.6	4.5	0.14	—	4.19	2.55	10.7	2.93	85.4	149
S-NSF-H31	0.03	89.4	7.28	0.2	0.028	82.6	1.77	13.9	228	53.8	*691
S-NSF-H32	0.03	10.2	4.17	0.1	—	10.5	3.75	10.5	0.92	68.7	178
S-NSF-H33	0.02	13	4.75	0.12	—	5.72	3.34	13.5	4.18	87.2	187
S-NSF-H34	—	31.4	71	0.22	0.095	29.3	5.27	110	32.9	43.4	487
S-NSF-H35	0.04	18.8	9.6	0.17	—	20.6	3.11	15.3	7.44	85.3	247

**Table 10.** Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3F](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. The SMCL-CA benchmark for chloride, sulfate, and TDS have recommended and upper benchmark levels. The upper benchmark level is shown in parentheses. MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; SiO<sub>2</sub>, silicon dioxide; na, not available; —, not detected; \*, concentration greater than the recommended benchmark level; \*\*, concentration greater than upper benchmark level]

<b>GAMA well identification number</b>	<b>Bromide (mg/L) (71870)</b>	<b>Calcium (mg/L) (00915)</b>	<b>Chloride (mg/L) (00940)</b>	<b>Fluoride (mg/L) (00950)</b>	<b>Iodide (mg/L) (71865)</b>	<b>Magnesium (mg/L) (00925)</b>	<b>Potassium (mg/L) (00935)</b>	<b>Sodium (mg/L) (00930)</b>	<b>Sulfate (mg/L) (00945)</b>	<b>Silica (as SiO<sub>2</sub>) (mg/L) (00955)</b>	<b>TDS (mg/L) (70300)</b>
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H36	0.02	10.1	16.5	0.05	0.004	6.03	4.92	14.2	9.89	61.5	154
S-NSF-H37	0.03	8.77	4.63	0.08	0.001	5.78	1.73	7.6	1.13	54.3	112
S-NSF-H38	—	3.37	121	*2.1	0.388	0.375	1.08	384	6.89	10.2	*941
S-NSF-H39	0.03	7.7	7.4	0.17	—	4.7	3	13.9	2.04	90.5	178
S-NSF-H40	0.89	152	212	0.26	0.005	75.1	3.32	92.8	166	16.6	*965
Valley and Plains study area wells (30 wells sampled)											
S-NSF-VP01	—	121	*278	0.17	0.065	69.7	3.22	155	104	37.9	**1,060
S-NSF-VP02	0.01	84.7	31.5	0.12	0.008	41.2	1.32	36.2	30.4	64.6	490
S-NSF-VP03	0.30	52.2	198	0.15	0.094	45.5	2.14	107	32.8	33.5	*577
S-NSF-VP04	0.15	21.4	51.2	0.09	0.007	9.17	1.28	36.1	19.2	52.6	224
S-NSF-VP05	0.12	7.19	42.7	0.19	0.032	5.74	1.36	103	3.41	44	334
S-NSF-VP06	0.15	25.8	9.09	0.09	0.038	35.7	0.71	32.5	23.1	30.2	312
S-NSF-VP07	0.12	59	28.7	0.2	0.003	37.9	0.55	35	47.9	65.6	430
S-NSF-VP08	0.19	19	56.3	0.26	—	21.3	4.26	26.1	3.95	51.1	252
S-NSF-VP09	0.15	22	50.9	0.09	0.018	18.6	14.2	31.6	2.59	77.9	302
S-NSF-VP10	0.12	27.2	40.5	0.13	0.01	19.6	1.4	26	8.8	46.3	269
S-NSF-VP11	0.22	70.9	72.8	0.21	0.013	28.2	1.89	63.8	32.7	75.7	*527
S-NSF-VP12	0.09	20.6	47.4	0.24	0.013	14.6	1.72	100	20	22.2	371
S-NSF-VP13	0.07	3.95	26.2	0.42	0.037	1.13	2.47	134	8.18	38.9	363
S-NSF-VP14	—	64.4	22.6	0.21	0.019	41.5	8.33	51.8	22.3	70.5	*516
S-NSF-VP15	0.08	37	18.3	0.12	0.002	42.4	1.06	20.4	18.6	40.1	329

**Table 10.** Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3F](#). **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type, benchmark level, and LT-MDL as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. The SMCL-CA benchmark for chloride, sulfate, and TDS have recommended and upper benchmark levels. The upper benchmark level is shown in parentheses. MCL-CA, California Department of Public Health (CDPH) maximum contaminant level; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; LT-MDL, long-term method detection limit; mg/L, milligrams per liter; SiO<sub>2</sub>, silicon dioxide; na, not available; —, not detected; \*, concentration greater than the recommended benchmark level; \*\*, concentration greater than upper benchmark level]

GAMA well identification number	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Silica (as SiO <sub>2</sub> ) (mg/L) (00955)	TDS (mg/L) (70300)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Valley and Plains study area wells (30 wells sampled)—Continued											
S-NSF-VP16	0.07	14.6	18.7	0.13	0.006	10.7	20.1	70	24.7	75.7	359
S-NSF-VP17	0.14	21.6	32.7	0.14	0.002	47.6	2.37	39.4	34.3	29.7	373
S-NSF-VP18	0.14	34.6	8.64	0.11	—	29.8	0.74	9.51	30.8	22.5	270
S-NSF-VP19	0.09	22.3	15.5	0.08	0.003	16.2	4.51	15.2	31.9	91	254
S-NSF-VP20	0.04	13.3	6.61	0.09	0.002	13.2	6.37	10	13.1	83.2	198
S-NSF-VP21	0.20	7.25	73.6	0.24	0.142	3.66	3.24	147	14.6	57.4	447
S-NSF-VP22	0.14	24.1	32.6	0.14	0.005	30.2	2.05	27.7	23.2	66.9	328
S-NSF-VP23	0.29	5.77	59	0.52	0.259	2.42	9.67	202	1.9	51	*587
S-NSF-VP24	0.16	10.3	36.3	0.23	0.085	3.97	1.23	192	36.4	23.3	*570
S-NSF-VP25	0.66	116	*369	0.25	0.034	49.9	2.41	122	37	30.2	**1,020
S-NSF-VP26	0.08	17.2	22.7	0.21	0.003	11.1	1.46	28.4	25.4	49.6	221
S-NSF-VP27	0.10	35.7	33.5	0.2	0.01	23.6	1.28	36.4	40.7	41.4	322
S-NSF-VP28	1.25	26.7	15	0.14	0.022	34.4	3.07	19.8	47.6	64.4	303
S-NSF-VP29	0.08	31.7	11.4	0.11	—	39.1	1.71	16	34.2	40.6	290
S-NSF-VP30	0.05	27.7	17.2	0.2	0.02	16.8	8.23	31.4	12.6	66.3	260
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)											
S-NSF-HU30	0.02	20.3	7.1	0.08	—	27.1	1.93	10.5	6.81	44.6	193



**Table 11.** Isotopic tracers detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Information about the constituents given in [table 3G](#). Samples from all 71 wells were analyzed. Stable isotope ratios of hydrogen, oxygen, and carbon are reported in the standard delta notation ( $\delta$ ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; B, boron; C, Carbon; H, hydrogen; O, oxygen; Sr, strontium; na, not available]

GAMA well identification number	$^{11}\text{B}/^{10}\text{B}$ in water (per mil) (62648)	$\delta^{13}\text{C}$ in dissolved inorganic carbon (per mil) (82081)	Carbon-14 in water (percent modern) (49933)	$\delta^2\text{H}$ in water (per mil) (82082)	$\delta^{18}\text{O}$ in water (per mil) (82085)	$^{87}\text{Sr}/^{86}\text{Sr}$ (atom ratio) (75978)
<b>Benchmark type</b>	na	na	na	na	na	na
<b>Benchmark level</b>	na	na	na	na	na	na
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)						
Highlands study area wells (40 wells sampled)						
S-NSF-H01	na	-21.00	95.97	-32.5	-5.71	0.71947
S-NSF-H02	na	-17.76	100.3	-33.8	-5.88	0.71257
S-NSF-H03	na	-16.19	101.4	-38.8	-6.59	0.70891
S-NSF-H04	4.14	-16.18	11.96	-44.5	-6.84	0.70651
S-NSF-H05	na	-17.77	52.94	-45.6	-7.11	0.70726
S-NSF-H06	3.98	-12.67	33.80	-46.8	-7.29	0.70637
S-NSF-H07	na	-15.56	106.5	-44.1	-7.07	0.70703
S-NSF-H08	4.11	-15.26	18.88	-54.0	-8.14	0.70611
S-NSF-H09	4.06	-18.89	42.9	-43.9	-6.83	0.70651
S-NSF-H10	na	-16.95	103.3	-40.0	-6.69	0.70634
S-NSF-H11	4.15	-18.13	100.9	-36.0	-6.06	0.70906
S-NSF-H12	na	-20.06	94.70	-34.0	-5.69	0.70638
S-NSF-H13	4.00	-21.52	16.42	-35.8	-5.81	0.70738
S-NSF-H14	na	-21.79	96.35	-35.1	-5.58	0.70730
S-NSF-H15	na	-21.24	90.18	-36.3	-5.78	0.70542
S-NSF-H16	4.05	-21.75	102	-36.9	-5.81	0.70598
S-NSF-H17	3.98	-21.03	56.87	-35.2	-5.62	0.70565
S-NSF-H18	4.06	-19.68	101.9	-38.8	-6.10	0.70681
S-NSF-H19	na	-12.78	36.89	-41.1	-6.58	0.70650
S-NSF-H20	na	-15.88	96.83	-42.8	-6.47	0.70511
S-NSF-H21	na	-15.59	33.18	-42.4	-6.70	0.70601
S-NSF-H22	4.11	-3.43	5.21	-50.7	-8.00	0.70580
S-NSF-H23	na	-21.71	98.10	-39.5	-6.31	0.70371
S-NSF-H24	na	-17.58	66.90	-39.5	-6.04	0.70425
S-NSF-H25	na	-17.69	89.66	-43.4	-6.87	0.70414

**Table 11.** Isotopic tracers detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Information about the constituents given in [table 3G](#). Samples from all 71 wells were analyzed. Stable isotope ratios of hydrogen, oxygen, and carbon are reported in the standard delta notation ( $\delta$ ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; B, boron; C, Carbon; H, hydrogen; O, oxygen; Sr, strontium; na, not available]

GAMA well identification number	$^{11}\text{B}/^{10}\text{B}$ in water (per mil) (62648)	$\delta^{13}\text{C}$ in dissolved inorganic carbon (per mil) (82081)	Carbon-14 in water (percent modern) (49933)	$\delta^2\text{H}$ in water (per mil) (82082)	$\delta^{18}\text{O}$ in water (per mil) (82085)	$^{87}\text{Sr}/^{86}\text{Sr}$ (atom ratio) (75978)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued						
Highlands study area wells (40 wells sampled)—Continued						
S-NSF-H26	4.07	-16.14	53.22	-39.3	-6.07	0.70653
S-NSF-H27	4.10	-18.27	99.63	-31.0	-4.01	0.70639
S-NSF-H28	na	-19.13	76.25	-40.7	-6.43	0.70435
S-NSF-H29	na	-18.95	78.31	-41.2	-6.62	0.70449
S-NSF-H30		-18.41	72.57	-41.0	-6.49	0.70421
S-NSF-H31	4.09	-16.15	55.95	-44.1	-6.94	0.70642
S-NSF-H32	na	-20.57	90.42	-44.7	-7.12	0.70519
S-NSF-H33	na	-18.83	66.66	-44.8	-7.00	0.70476
S-NSF-H34	4.11	-19.86	81.71	-41.3	-6.20	0.70686
S-NSF-H35	4.08	-14.88	75.15	-42.6	-6.37	0.70522
S-NSF-H36	na	-21.14	101.8	-40.0	-6.50	0.70522
S-NSF-H37	na	-19.93	87.58	-41.5	-6.53	0.70529
S-NSF-H38	4.13	-11.03	22.70	-37.3	-6.06	0.70706
S-NSF-H39	na	-18.40	58.76	-40.2	-6.35	0.70439
S-NSF-H40	3.99	-17.84	70.60	-42.2	-6.14	0.70741
Valley and Plains study area wells (30 wells sampled)						
S-NSF-VP01	4.01	-17.75	100.7	-38.4	-5.81	0.70607
S-NSF-VP02	4.09	-20.72	105.4	-37.0	-5.76	0.70492
S-NSF-VP03	4.02	-19.34	49.42	-39.5	-6.09	0.70596
S-NSF-VP04	na	-22.38	80.54	-36.3	-5.90	0.70618
S-NSF-VP05	4.02	-15.89	37.39	-41.0	-6.28	0.70591
S-NSF-VP06	4.09	-18.17	97.76	-37.1	-6.01	0.70665
S-NSF-VP07	3.98	-17.95	73.11	-38.4	-5.92	0.70484
S-NSF-VP08	na	-20.63	84.08	-38.5	-6.14	0.70557
S-NSF-VP09	na	-20.47	84.19	-36.7	-5.92	0.70537
S-NSF-VP10	4.04	-18.49	96.27	-38.6	-5.85	0.70537

**Table 11.** Isotopic tracers detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Information about the constituents given in [table 3G](#). Samples from all 71 wells were analyzed. Stable isotope ratios of hydrogen, oxygen, and carbon are reported in the standard delta notation ( $\delta$ ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; B, boron; C, Carbon; H, hydrogen; O, oxygen; Sr, strontium; na, not available]

GAMA well identification number	$^{11}\text{B}/^{10}\text{B}$ in water (per mil) (62648)	$\delta^{13}\text{C}$ in dissolved inorganic carbon (per mil) (82081)	Carbon-14 in water (percent modern) (49933)	$\delta^2\text{H}$ in water (per mil) (82082)	$\delta^{18}\text{O}$ in water (per mil) (82085)	$^{87}\text{Sr}/^{86}\text{Sr}$ (atom ratio) (75978)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued						
Valley and Plains study area wells (30 wells sampled)—Continued						
S-NSF-VP11	4.05	-20.46	103.6	-37.1	-5.52	0.70636
S-NSF-VP12	3.98	-16.47	56.96	-39.9	-6.08	0.70609
S-NSF-VP13	3.96	-16.63	4.60	-51.0	-7.61	0.70566
S-NSF-VP14	4.00	-21.09	87.64	-40.9	-6.05	0.70506
S-NSF-VP15	4.05	-19.91	102.2	-40.2	-6.29	0.70602
S-NSF-VP16	3.98	-18.96	41.48	-45.7	-6.85	0.70569
S-NSF-VP17	4.07	-17.99	98.97	-40.2	-6.31	0.70635
S-NSF-VP18	4.02	-17.21	94.67	-44.4	-6.79	0.70631
S-NSF-VP19	na	-19.85	75.04	-38.1	-5.89	0.70503
S-NSF-VP20	na	-21.3	93.11	-39.5	-6.29	0.70673
S-NSF-VP21	4.09	-19.36	7.24	-48.3	-7.48	0.70565
S-NSF-VP22	na	-19.45	104	-38.5	-5.86	0.70552
S-NSF-VP23	4.15	-13.60	1.18	-50.7	-7.73	0.70611
S-NSF-VP24	4.02	-15.88	63.41	-35.3	-4.70	0.70621
S-NSF-VP25	4.05	-16.18	79.37	-37.5	-5.83	0.70704
S-NSF-VP26	4.10	-18.62	85.88	-38.9	-5.96	0.70680
S-NSF-VP27	4.08	-20.09	97.17	-39.4	-5.85	0.70684
S-NSF-VP28	4.02	-20.30	99.18	-40.0	-6.12	0.70603
S-NSF-VP29	4.05	-16.70	96.13	-39.0	-5.76	0.70648
S-NSF-VP30	na	-19.77	89.31	-42.5	-6.62	0.70459
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)						
S-NSF-HU30	na	-15.8	102.8	-39.5	-6.51	0.70516

**Table 12.** Radioactive constituents detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3G](#). Measured values less than the sample-specific critical level ( $ssL_c$ ) are reported as non-detections (—). Tritium activities were not measured less than the  $ssL_c$ ; therefore, the  $ssL_c$  is not reported. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; RL, reporting level; CSU, 1-sigma combined standard uncertainty; pCi/L, picocuries per liter; —, not detected; \*, concentration greater than the benchmark level; ±, plus or minus; nc, not collected]

GAMA well identification number	Radon-222 (pCi/L) (82303)		Gross alpha radioactivity, 72-hour count (pCi/L) (62636)		Gross alpha radioactivity, 30-day count (pCi/L) (62639)		Gross beta radioactivity, 72-hour count (pCi/L) (62642)		Gross beta radioactivity, 30-day count (pCi/L) (62645)		Tritium (pCi/L) (07000)
Benchmark type	Proposed MCL-US		MCL-US		MCL-US		MCL-CA		MCL-CA		MCL-CA
Benchmark level	4,000		15		15		50		50		20,000
[RL]	Result ± CSU	ssL <sub>c</sub>	Result ± CSU	ssL <sub>c</sub>	Result ± CSU	ssL <sub>c</sub>	Result ± CSU	ssL <sub>c</sub>	Result ± CSU	ssL <sub>c</sub>	Result ± CSU
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)											
Highlands study area wells (40 wells sampled)											
S-NSF-H01	127 ± 12	12	—	0.49	—	0.51	—	0.75	1.04 ± 0.55	0.82	2.9 ± 0.37
S-NSF-H02	300 ± 21	12	—	0.64	—	0.63	0.75 ± 0.46	0.72	0.8 ± 0.5	0.80	5.7 ± 0.44
S-NSF-H03	—	13	0.67 ± 0.47	0.50	—	0.48	—	0.65	—	0.68	5.1 ± 0.36
S-NSF-H04	157 ± 14	12	—	1.10	—	1.20	1.02 ± 0.35	0.54	—	0.57	0.8 ± 0.5
S-NSF-H05	104 ± 12	13	2.88 ± 0.71	0.63	—	0.66	1.80 ± 0.43	0.64	1.63 ± 0.41	0.63	5 ± 0.42
S-NSF-H06	300 ± 21	11	1.66 ± 0.87	0.93	—	1.20	1.74 ± 0.61	0.90	2.46 ± 0.57	0.81	4.7 ± 0.46
S-NSF-H07	55 ± 8.8	11	—	0.57	—	0.71	—	0.85	—	0.83	6.9 ± 0.44
S-NSF-H08	45 ± 8.1	11	1.68 ± 0.92	0.98	—	1.10	1.83 ± 0.61	0.96	—	1.20	1.5 ± 0.4
S-NSF-H09	163 ± 13	11	2.94 ± 0.63	0.45	—	0.75	1.07 ± 0.34	0.51	—	0.91	0.8 ± 0.36
S-NSF-H10	—	12	0.8 ± 0.5	0.62	—	0.64	1.45 ± 0.45	0.66	—	0.76	4.5 ± 0.41
S-NSF-H11	980 ± 56	12	0.48 ± 0.24	0.30	1.17 ± 0.46	0.39	0.49 ± 0.29	0.46	—	0.66	6.2 ± 0.6
S-NSF-H12	220 ± 18	14	—	0.62	—	0.55	1.12 ± 0.48	0.74	1.14 ± 0.45	0.69	3.9 ± 0.59
S-NSF-H13	204 ± 15	11	1.39 ± 0.76	0.88	—	0.89	—	0.75	—	0.70	—
S-NSF-H14	93 ± 10	12	0.93 ± 0.61	0.66	—	0.76	—	0.84	—	0.63	4.1 ± 0.38
S-NSF-H15	165 ± 15	14	—	0.65	—	0.63	—	0.59	—	0.74	2.5 ± 0.53

**Table 12.** Radioactive constituents detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3G](#). Measured values less than the sample-specific critical level ( $ssL_c$ ) are reported as non-detections (—). Tritium activities were not measured less than the  $ssL_c$ ; therefore, the  $ssL_c$  is not reported. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; RL, reporting level; CSU, 1-sigma combined standard uncertainty; pCi/L, picocuries per liter; —, not detected; \*, concentration greater than the benchmark level; ±, plus or minus; nc, not collected]

GAMA well identification number	Radon-222 (pCi/L) (82303)		Gross alpha radioactivity, 72-hour count (pCi/L) (62636)		Gross alpha radioactivity, 30-day count (pCi/L) (62639)		Gross beta radioactivity, 72-hour count (pCi/L) (62642)		Gross beta radioactivity, 30-day count (pCi/L) (62645)		Tritium (pCi/L) (07000)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H16	400 ± 26	11	—	0.48	—	0.60	0.95 ± 0.39	0.60	1.08 ± 0.42	0.62	6.7 ± 0.59
S-NSF-H17	176 ± 16	15	—	1.20	—	0.83	2.78 ± 0.57	0.85	2.11 ± 0.56	0.84	1.4 ± 0.51
S-NSF-H18	460 ± 29	12	2.3 ± 1.1	1.00	—	1.10	—	1.30	—	1.40	8.1 ± 0.66
S-NSF-H19	280 ± 20	11	—	0.61	—	0.66	0.90 ± 0.48	0.74	—	0.79	3.8 ± 0.31
S-NSF-H20	3,070 ± 170	13	2.13 ± 0.46	0.41	—	0.58	1.9 ± 0.3	0.40	2.09 ± 0.56	0.82	5.6 ± 0.38
S-NSF-H21	560	11	1 ± 0.5	0.58	—	0.81	3.74 ± 0.52	0.71	3.88 ± 0.54	0.77	0.2 ± 0.33
S-NSF-H22	*14,700 ± 790	11	—	1.30	—	1.30	7.40 ± 0.59	0.51	7.01 ± 0.57	0.51	0.6 ± 0.26
S-NSF-H23	158 ± 15	14	—	0.44	—	0.51	0.74 ± 0.29	0.45	—	0.64	2.1 ± 0.56
S-NSF-H24	460 ± 31	16	—	0.52	—	0.43	1.31 ± 0.49	0.72	—	0.67	0.1 ± 0.31
S-NSF-H25	540 ± 33	11	—	0.45	—	0.56	2.12 ± 0.43	0.61	2.20 ± 0.37	0.51	5.0 ± 0.34
S-NSF-H26	*16,700 ± 890	11	—	0.88	2.42 ± 0.93	1.10	—	1.10	1.55 ± 0.66	0.98	—
S-NSF-H27	nc		nc		nc		nc		nc		6.3 ± 0.34
S-NSF-H28	890 ± 51	12	—	0.55	—	0.54	2.36 ± 0.49	0.69	1.38 ± 0.51	0.75	1.2 ± 0.47
S-NSF-H29	nc		8.1 ± 2.1	1.80	—	2.00	7.89 ± 0.91	1.10	6.7 ± 0.7	0.87	2.0 ± 0.3
S-NSF-H30	1,420 ± 80	14	0.97 ± 0.56	0.55	—	0.57	2.08 ± 0.56	0.83	—	0.82	—
S-NSF-H31	41 ± 8.3	11	—	1.20	—	1.30	2.15 ± 0.41	0.57	2.60 ± 0.81	1.20	2.4 ± 0.31
S-NSF-H32	940 ± 56	16	0.60 ± 0.31	0.40	—	0.52	1.94 ± 0.35	0.51	1.36 ± 0.42	0.64	—
S-NSF-H33	2,250 ± 120	12	1.27 ± 0.46	0.47	—	0.62	2.87 ± 0.37	0.48	3.05 ± 0.58	0.74	—
S-NSF-H34	165 ± 15	13	1.53 ± 0.82	1.10	—	1.00	4.98 ± 0.66	0.86	3.86 ± 0.73	1.00	5.9 ± 0.42
S-NSF-H35	810 ± 49	16	0.93 ± 0.34	0.33	—	0.54	2.75 ± 0.46	0.64	1.7 ± 0.4	0.62	—

**Table 12.** Radioactive constituents detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3G](#). Measured values less than the sample-specific critical level ( $ssL_c$ ) are reported as non-detections (—). Tritium activities were not measured less than the  $ssL_c$ ; therefore, the  $ssL_c$  is not reported. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; RL, reporting level; CSU, 1-sigma combined standard uncertainty; pCi/L, picocuries per liter; —, not detected; \*, concentration greater than the benchmark level; ±, plus or minus; nc, not collected]

GAMA well identification number	Radon-222 (pCi/L) (82303)		Gross alpha radioactivity, 72-hour count (pCi/L) (62636)		Gross alpha radioactivity, 30-day count (pCi/L) (62639)		Gross beta radioactivity, 72-hour count (pCi/L) (62642)		Gross beta radioactivity, 30-day count (pCi/L) (62645)		Tritium (pCi/L) (07000)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Highlands study area wells (40 wells sampled)—Continued											
S-NSF-H36	1,170 ± 67	14	0.83 ± 0.31	0.34	0.82 ± 0.43	0.47	4.47 ± 0.45	0.51	4.69 ± 0.54	0.61	72 ± 2.18
S-NSF-H37	380 ± 24	11	—	0.55	—	0.55	1.0 ± 0.6	0.94	1.54 ± 0.48	0.72	2.6 ± 0.31
S-NSF-H38	34 ± 8.3	12	—	2.20	—	2.60	1.78 ± 0.61	0.93	—	0.93	2.7 ± 0.56
S-NSF-H39	1,140 ± 64	11	0.42 ± 0.24	0.28	—	0.33	—	0.64	0.67 ± 0.39	0.62	0.7 ± 0.59
S-NSF-H40	270 ± 22	18	3.0 ± 1.6	1.90	—	2.40	3.80 ± 0.68	0.93	2.84 ± 0.62	0.96	5.7 ± 0.6
Valley and Plains study area wells (30 wells sampled)											
S-NSF-VP01	760 ± 45	14	6.6 ± 2.4	2.70	—	2.40	3.19 ± 0.67	0.98	4.87 ± 0.75	0.98	4.0 ± 0.58
S-NSF-VP02	780 ± 46	13	2.76 ± 0.99	1.10	1.50 ± 0.82	1.00	0.8 ± 0.3	0.46	1.90 ± 0.46	0.65	5.3 ± 0.64
S-NSF-VP03	520 ± 32	12	—	1.70	—	1.20	1.88 ± 0.35	0.50	2.03 ± 0.39	0.52	1.0 ± 0.48
S-NSF-VP04	137 ± 15	15	—	0.49	—	0.44	1.08 ± 0.39	0.60	1.2 ± 0.4	0.61	1.4 ± 0.5
S-NSF-VP05	790 ± 47	13	—	0.90	—	0.67	—	0.68	1.29 ± 0.45	0.69	—
S-NSF-VP06	310 ± 21	13	1.69 ± 0.53	0.61	—	0.80	0.6 ± 0.3	0.48	—	0.87	5.6 ± 0.36
S-NSF-VP07	72 ± 9.7	12	1.28 ± 0.71	0.77	—	1.50	—	0.97	—	1.40	4.4 ± 0.44
S-NSF-VP08	540 ± 34	13	1.02 ± 0.56	0.60	—	0.52	3.25 ± 0.63	0.86	3.02 ± 0.52	0.71	0.8 ± 0.53
S-NSF-VP09	770 ± 46	13	1.1 ± 0.5	0.60	—	0.91	10.9 ± 0.78	0.60	11.6 ± 0.95	0.78	2.7 ± 0.32
S-NSF-VP10	600 ± 37	13	0.93 ± 0.41	0.49	—	0.56	—	0.69	1.15 ± 0.46	0.73	0.8 ± 0.6
S-NSF-VP11	520 ± 33	13	3.3 ± 1.2	1.30	—	1.10	1.98 ± 0.38	0.53	2.56 ± 0.41	0.60	3.3 ± 0.53
S-NSF-VP12	400 ± 25	11	—	1.10	—	0.73	1.08 ± 0.42	0.66	1.54 ± 0.61	0.93	1.0 ± 0.56
S-NSF-VP13	1,770 ± 98	11	1.96 ± 0.82	0.99	—	1.20	2.6 ± 0.52	0.76	2.03 ± 0.56	0.86	0.6 ± 0.31
S-NSF-VP14	480 ± 31	14	1.12 ± 0.76	0.99	—	0.86	9.39 ± 0.68	0.55	7.38 ± 0.58	0.50	4.4 ± 0.54
S-NSF-VP15	700 ± 43	16	<sup>1</sup> 1.12 ± 0.61	0.72	—	0.84	<sup>1</sup> 1.48 ± 0.61	0.90	—	1.10	6.2 ± 0.43



**Table 12.** Radioactive constituents detected in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 71 wells were analyzed. Information about the constituents given in [table 3G](#). Measured values less than the sample-specific critical level ( $ssL_c$ ) are reported as non-detections (—). Tritium activities were not measured less than the  $ssL_c$ ; therefore, the  $ssL_c$  is not reported. **GAMA well identification number:** S-NSF-H, North San Francisco Bay Shallow Aquifer study unit Highlands study area well; S-NSF-HU, North San Francisco Bay Shallow Aquifer study unit Highlands study area understanding well; S-NSF-VP, North San Francisco Bay Shallow Aquifer study unit Valley and Plains study area well. Benchmark type and benchmark level as of August 30, 2012. **Benchmark type:** Maximum contaminant level benchmarks 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. MCL-US, U.S. Environmental Protection Agency maximum contaminant level; MCL-CA, California Department of Public Health maximum contaminant level. **Other abbreviations:** USGS, U.S. Geological Survey; RL, reporting level; CSU, 1-sigma combined standard uncertainty; pCi/L, picocuries per liter; —, not detected; \*, concentration greater than the benchmark level; ±, plus or minus; nc, not collected]

GAMA well identification number	Radon-222 (pCi/L) (82303)		Gross alpha radioactivity, 72-hour count (pCi/L) (62636)		Gross alpha radioactivity, 30-day count (pCi/L) (62639)		Gross beta radioactivity, 72-hour count (pCi/L) (62642)		Gross beta radioactivity, 30-day count (pCi/L) (62645)		Tritium (pCi/L) (07000)
North San Francisco Bay Shallow Aquifer study unit grid wells (70 wells sampled)—Continued											
Valley and Plains study area wells (30 wells sampled)—Continued											
S-NSF-VP16	490 ± 31	14	2.49 ± 0.65	0.45	—	0.69	20.2 ± 1.3	0.66	18.5 ± 1.2	0.65	1.4 ± 0.43
S-NSF-VP17	280 ± 20	12	2.6 ± 0.8	0.80	3.62 ± 0.93	0.71	2.85 ± 0.82	1.20	1.94 ± 0.61	0.92	4.5 ± 0.55
S-NSF-VP18	234 ± 17	11	2.03 ± 0.45	0.28	—	0.57	1.34 ± 0.34	0.52	1.31 ± 0.46	0.69	5.4 ± 0.42
S-NSF-VP19	720 ± 42	11	1.13 ± 0.61	0.56	—	0.58	3.26 ± 0.63	0.83	2.92 ± 0.57	0.73	1 ± 0.29
S-NSF-VP20	480 ± 30	13	0.87 ± 0.28	0.24	0.6 ± 0.3	0.34	3.74 ± 0.41	0.52	3.0 ± 0.36	0.46	3.6 ± 0.53
S-NSF-VP21	780 ± 46	12	—	1.10	—	1.00	3.62 ± 0.82	1.20	2.54 ± 0.57	0.90	0.4 ± 0.4
S-NSF-VP22	1,100 ± 62	11	1.06 ± 0.61	0.68	—	0.87	1.68 ± 0.61	0.92	1.0 ± 0.55	0.93	5.3 ± 0.37
S-NSF-VP23	1,220 ± 68	11	—	1.60	—	1.20	7.71 ± 0.63	0.59	8.18 ± 0.56	0.41	0.4 ± 0.29
S-NSF-VP24	590 ± 35	11	6.3 ± 1.4	0.98	3.4 ± 1.2	1.20	1.88 ± 0.61	0.95	1.2 ± 0.6	0.95	3.9 ± 0.43
S-NSF-VP25	660 ± 39	11	—	2.10	—	2.30	3.25 ± 0.58	0.78	2.40 ± 0.61	0.87	5.6 ± 0.57
S-NSF-VP26	1,040 ± 59	11	—	0.50	—	0.48	1.11 ± 0.39	0.60	1.37 ± 0.35	0.52	0.5 ± 0.38
S-NSF-VP27	1,220 ± 69	11	—	0.57	—	0.74	1.26 ± 0.41	0.62	0.68 ± 0.39	0.61	5.8 ± 0.43
S-NSF-VP28	790 ± 47	14	0.79 ± 0.34	0.36	—	0.60	2.78 ± 0.47	0.64	1.75 ± 0.45	0.69	4.8 ± 0.39
S-NSF-VP29	510 ± 31	12	1.0 ± 0.4	0.45	—	0.59	1.84 ± 0.32	0.45	1.27 ± 0.55	0.86	4.8 ± 0.41
S-NSF-VP30	690 ± 41	12	0.72 ± 0.56	0.72	—	0.64	7.20 ± 0.68	0.73	7.38 ± 0.72	0.73	3.5 ± 0.39
North San Francisco Bay Shallow Aquifer study unit understanding well (1 well sampled)											
S-NSF-HU30	1,290 ± 74	14	0.83 ± 0.61	0.67	—	0.57	1.18 ± 0.55	0.81	1.65 ± 0.56	0.80	4.8 ± 0.46

<sup>1</sup> Counted 4–6 days after sample collection.



## Appendix A

This appendix includes discussions of the methods used to collect and analyze groundwater samples and report the resulting water-quality data. These methods were selected to obtain representative samples of the groundwater from each well and to minimize the potential for contamination of the samples or bias in the data. Procedures used to collect and assess QC data and the results of the QC assessments also are discussed.

In the NSF-SA study unit, groundwater samples were collected, and QA procedures were implemented by using standard and modified USGS protocols from the NAWQA Program (Koterba and others, 1995) and the NFM (U.S. Geological Survey, variously dated) and protocols described by Shelton and others (2001) and Wright and others (2005). The QA plan followed by the NWQL, the primary laboratory used to analyze samples for this study, is described in Maloney (2005) and Pirkey and Glodt (1998).

### Sample Collection and Analysis

Samples were collected from two types of sites: production wells and springs (“springs” in this study unit include horizontal wells). Sites classified as production wells are vertically drilled into the ground and have pumps that bring the groundwater from the aquifer to a distribution system. Sites were classified as springs if groundwater could discharge from the aquifer into the distribution system without a pump and if the well was either drilled horizontally or had no drilled hole. A few springs had pumps to transport groundwater from the spring to a storage tank at a higher elevation.

In most cases, wells were pumped continuously to purge at least three casing volumes of water from the well prior to sampling (Wilde and others, 1999). Drought conditions during the period of sampling for the NSF-SA study unit (April through August 2012) resulted in limitations on the amount of groundwater that could be pumped from some of the wells. In some cases, continuous pumping was limited to 2 hours, either because of limited space in storage tanks for the pumped water or because of drawdown of the water table. A minimum of one casing volume of groundwater was pumped from each well before sampling. The limitation on pumping did not allow sufficient time to complete the sampling of a few wells, and some constituent groups were not collected from these wells. Wells were sampled by using Teflon® tubing with brass and stainless-steel fittings attached to a sampling point (usually a hose-bib fitting) on the well discharge pipe as close to the well head as possible. The sampling point was located upstream from water-storage tanks and from the well-head treatment system (if a system existed). If a chlorinating

system was attached to the well, the chlorinator was shut off, when possible, before the well was purged and sampled, in order to clear all chlorine out of the system. The absence of free chlorine was verified by using a Hach® field test kit. All samples were collected outdoors by connecting a 1- to 3-ft length of Teflon® tubing to the sampling point (Lane and others, 2003). All fittings and lengths of tubing were cleaned between samples (Wilde, 2004).

For the field measurements, groundwater was pumped through a flow-through chamber that was attached to the sampling point and fitted with a multi-probe meter that simultaneously measures the field water-quality indicators—dissolved oxygen, temperature, pH, and specific conductance. Field measurements were made in accordance with protocols in the NFM (Radtke and others, 2005; Wilde and Radtke, 2005; Lewis, 2006; Wilde, 2006; Wilde and others, 2006). All sensors on the multi-probe meter were calibrated daily. Measured dissolved oxygen, temperature, pH, and specific-conductance values were recorded at 3- to 5-minute (min) intervals, and when these values remained stable, samples for laboratory analyses then were collected.

Field measurements and instrument calibrations were recorded by hand on field record sheets and electronically in the Personal Computer Field Form (PCFF) program. Analytical service requests also were managed by PCFF, whereas analytical service requests for non-NWQL analysis were entered into laboratory-specific spreadsheets. Information from PCFF was uploaded directly into the USGS NWIS at the end of every week of sample collection.

Prior to sample collection, polyethylene sample bottles were pre-rinsed three times with deionized water and then once with native sample water before sample collection. Samples requiring acidification were acidified to a pH of between 2 and 1 with the appropriate acids using ampoules of certified, traceable concentrated acids obtained from the 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 and stable isotopes of hydrogen, oxygen, boron, and strontium in water were shipped monthly. Temperature-sensitive or time-sensitive samples for VOCs, pesticides and pesticide degradates, 1,2,3-TCP, perchlorate, trace elements, nutrients, major and minor ions, silica, TDS, laboratory alkalinity, radon-222, and gross alpha and gross beta radioactivity were shipped daily whenever possible. The temperature-sensitive samples for stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance were stored on ice, archived in a laboratory refrigerator, and shipped after all of the laboratory alkalinity measurements were received.

Detailed sampling protocols for individual analyses and groups of analytes are described in Koterba and others (1995), the NFM (Wilde and others, 1999, 2004), and in the references for analytical methods listed in [table A1](#); only brief descriptions are given here. Samples for analyses of VOCs and 1,2,3-TCP were collected in 40-milliliter (mL) sample vials that were purged with three vial volumes of unfiltered groundwater before bottom filling to eliminate atmospheric contamination. One to one (1:1) hydrochloric acid to water (HCl/H<sub>2</sub>O) solution was added as a preservative to the VOC samples but not to the 1,2,3-TCP samples. Each sample to be analyzed for perchlorate was collected in a 125-mL polystyrene bottle and then filtered in two or three 20-mL aliquots of groundwater through a 0.20-micrometer (μm) pore-size Corning® syringe-tip disk filter into a sterilized 125-mL bottle. Samples for analysis of tritium were collected by bottom filling one 1-L polyethylene bottle and one 1-L glass bottle with unfiltered groundwater, after first overfilling the bottles with three volumes of unfiltered groundwater. Samples for analysis of stable isotopes of hydrogen and oxygen in water were collected in a 60-mL clear glass bottle filled with unfiltered groundwater, sealed with a conical cap, and secured with electrical tape to prevent leakage and evaporation.

Samples for analysis of pesticides and pesticide degradates were collected in 1-L baked amber glass bottles. These samples were filtered through a 0.7-μm nominal pore-size glass fiber filter during collection.

Groundwater samples for trace elements, major and minor ions, silica, laboratory alkalinity, and TDS analyses required filling one 250-mL polyethylene bottle with unfiltered groundwater and one 500-mL and one 250-mL polyethylene bottle with filtered groundwater (Wilde and others, 2004). Filtration was done by using a 0.45-μm pore-size PALL® unvented capsule filter that was pre-rinsed with 2 L of deionized water and then rinsed with 1 L of groundwater prior to sampling. Each 250-mL filtered sample then was preserved with 7.5-Normal (N) nitric acid. Nutrient samples were collected by filtering groundwater into 125-mL brown polyethylene bottles. Samples for analyses of stable isotopes of boron and strontium were filtered into one 250-mL polyethylene bottle and secured with electrical tape to prevent leakage and evaporation. Samples to be analyzed for gross alpha and gross beta particle activities were filtered into 1-L polyethylene bottles and acidified with 7.5-N nitric acid. Stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance samples were filtered and bottom filled into 500-mL glass bottles that first were overfilled with three bottle volumes of filtered groundwater. These samples had no headspace and were sealed with conical caps to avoid atmospheric contamination.

For the collection of samples for radon-222 analysis, a stainless-steel and Teflon® valve assembly was attached to the sampling port at the well head (Wilde and others, 2004). The valve was closed partially to create back pressure, and a 10-mL groundwater sample was taken through a Teflon® septum on the valve assembly by using a glass syringe affixed with a stainless-steel needle. The sample was then injected into a 25-mL vial partially filled with a scintillation mixture (mineral oil and 1,2,4-trimethylbenzene) and shaken. The vial then was placed in an insulated cardboard tube to protect the sample during shipping.

Field alkalinity was measured in the mobile laboratory at the well site. Samples for field alkalinity titrations were collected by filtering groundwater into a 500-mL polyethylene bottle. Alkalinity was measured on filtered samples by using the Gran titration method (Gran, 1952). Titration data were entered directly into PCFF, and the concentrations of bicarbonate (HCO<sub>3</sub><sup>-</sup>) and carbonate (CO<sub>3</sub><sup>2-</sup>) were automatically calculated from the titration data by using the advanced speciation method (<http://or.water.usgs.gov/alk/methods.html>) with  $pK_1 = 6.35$ ,  $pK_2 = 10.33$ , and  $pK_w = 14$ . Concentrations of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> also were calculated from the laboratory alkalinity and laboratory pH measurements.

Seven laboratories performed chemical analyses for this study ([table A1](#)), although most of the analyses were performed at the NWQL or by laboratories contracted by the NWQL. The NWQL maintains a rigorous QA program (Pirkey and Glodt, 1998; Maloney, 2005). Laboratory QC 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 tested continuously, and laboratory reporting levels are updated accordingly. The NWQL maintains National Environmental Laboratory Accreditation Program (NELAP) and other certifications (<http://www.nelac-institute.org/accred-labs.php>). The USGS Branch of Quality Systems (BQS) maintains independent oversight of QA at the NWQL and laboratories contracted by the NWQL. The BQS also runs the National Field Quality Assurance Program (NFQA) that includes annual testing of all USGS field personnel for proficiency in making field water-quality measurements (<http://bqs.usgs.gov/nfqa/>). Results for analyses made at the NWQL or by laboratories contracted by the NWQL are uploaded directly into NWIS. Results of analyses made at other laboratories are compiled in a project database and uploaded from there into NWIS.

## Data Reporting

The following section gives details for the laboratory reporting conventions and the constituents that are determined by multiple methods or by multiple laboratories.

## Reporting Limits

The USGS NWQL uses different conventions for reporting results for organic and inorganic constituents. For organic constituents, a laboratory reporting level (LRL) and a long-term method detection level (LT-MDL) are used as thresholds for reporting analytical results. The LRL is set to minimize the reporting of false negatives (not detecting a compound when it actually is present in a sample) to less than 1 percent (Childress and others, 1999). The LRL usually is set at two times the LT-MDL. The LT-MDL is derived from the standard deviation of at least 24 method detection limit (MDL) determinations made over an extended period of time. The 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 the MDL there is less than 1-percent chance of a false positive) (Childress and others, 1999; U.S. Environmental Protection Agency, 2002). Concentrations less than the LT-MDL are reported as non-detections with a dash (–) in the data tables. The USGS NWQL updates LRL and LT-MDL values regularly, and the values listed in this report were in effect during the period that analyses were made for groundwater samples from the NSF-SA study unit (April to August 2012).

For organic constituents, concentrations between the LRL and the LT-MDL are reported as having a higher degree of uncertainty (coded by the letter “E” preceding the values in the tables and text). For information-rich methods, detections less than the LT-MDL have a high certainty of presence, but the precise concentration is uncertain. These values are also E-coded. Information-rich methods are those that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection, such as those methods used to analyze VOCs and pesticides. 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-coded values also may result from detections outside the range of calibration standards, from detections that did not meet all laboratory QC criteria, and from samples that were diluted prior to analysis (Childress and others, 1999).

For most inorganic constituents, the LT-MDL is the only threshold used by the NWQL for reporting analytical results. All non-detections for inorganics constituents are reported in the NWIS database as less than the LT-MDL (except for

non-detections of bromide which are reported as less than the MDL); E-codes are not used to designate results with concentrations less than LRLs or LT-MDLs.

Total dissolved solids and perchlorate are reported by using minimum reporting levels (MRLs). The MRL is the smallest measurable concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995).

Isotopes of hydrogen, oxygen, and carbon are reported using method uncertainties (MUs). The MU generally indicates the precision of a particular analytical measurement; it gives a range of values wherein the true value will be found.

Results for most constituents are presented using the LRL, LT-MDL, MDL, MRL, or MU values provided by the analyzing laboratories. Results for some organic and inorganic constituents are presented using study reporting levels (SRLs) derived from assessment of data from QC samples associated with groundwater samples collected as part of the GAMA-PBP [see the section in this appendix titled “Blanks: Study Reporting Levels (SRLs)”].

The reporting limits for radiochemical constituents (carbon-14, tritium, radon-222, and gross alpha and gross beta radioactivity) are based on sample-specific critical levels ( $ssL_C$ ) (McCurdy and others, 2008). The critical level is analogous to the LT-MDL used for reporting analytical results for organic and non-radioactive inorganic constituents. Here, the critical level is defined as the minimum measured activity that indicates a positive detection of the radionuclide in the sample with less than a 5-percent probability of a false positive detection. Sample-specific critical levels are used for radiochemical measurements because the critical level is sensitive to sample size and sample yield during analytical processing and is dependent on instrument background, on counting times for the sample and background, and on the characteristics of the instrument being used and the nuclide being measured. An  $ssL_C$  is calculated for each sample, and the measured activity in the sample is compared to the  $ssL_C$  associated with that sample. Measured activities less than the  $ssL_C$  are reported as non-detections with a dash (–) in the data tables.

The analytical uncertainties associated with measurement of activities are also sensitive to sample-specific parameters, including sample size, sample yield during analytical processing, and time elapsed between sample collection and various steps in the analytical procedure, as well as parameters associated with the instrumentation. Therefore, measured activities of radioactive constituents are reported with sample-specific combined standard uncertainties (CSUs). The CSU is reported at the 68-percent confidence level (1-sigma). The  $ssL_C$  was not reported by the laboratory for some tritium results, in which case the CSU was used as an estimated reporting level.



## Notation

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

$$\delta^i E = \left[ \frac{R_{\text{sample}}}{R_{\text{reference}}} - 1 \right] \times 1,000 \text{ per mil}, \quad (\text{A1})$$

where  $i$  is the atomic mass of the heavier isotope of the element,  
 $E$  is the element (H for hydrogen, O for oxygen, C for carbon),  
 $R_{\text{sample}}$  is the ratio of the abundance of the heavier isotope of the element ( $^2\text{H}$ ,  $^{18}\text{O}$ ,  $^{13}\text{C}$ ) to the lighter isotope of the element ( $^1\text{H}$ ,  $^{16}\text{O}$ ,  $^{12}\text{C}$ ) in the sample, and  
 $R_{\text{reference}}$  is the ratio of the abundance of the heavier isotope of the element to the lighter isotope of the element 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  $\delta^2\text{H}$  is sometimes written as  $\delta\text{D}$  because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium) (Coplen and others, 2002). The reference material for carbon is Vienna Pee Dee Belemnite (VPDB), which is assigned a  $\delta^{13}\text{C}$  value of 0 per mil (Coplen and others, 2002). 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

Four constituents targeted in this study were measured by more than one analytical method or by more than one laboratory (table A2). Preferred analytical methods generally were selected on the basis of better performance or sensitivity for the constituent, or (in some cases) to provide consistency with historical data from the same method (U.S. Geological Survey, 2009). One organic constituent (1,2,3-TCP; table 3C) was analyzed by two analytical methods for the NSF-SA study unit; however, 1,2,3-TCP was not detected by either method.

The field water-quality indicators—pH, specific conductance, and alkalinity—were measured in the field and at the NWQL. The field measurements are generally preferred for all three constituents, although results from field and laboratory measurements were reported. The field and laboratory results were compared statistically to assess potential bias in datasets consisting of field values for some samples and laboratory values for other samples.

The field and laboratory data were compared by using the Wilcoxon signed-rank or rank-sum tests, which are

nonparametric statistical tests that are analogous to the parametric paired Student's  $t$  or Student's  $t$ -tests, respectively (Helsel and Hirsch, 2002). A nonparametric test was used because the data were not normally distributed. The Wilcoxon signed-rank test evaluates the null hypothesis that the median of the paired differences between the two datasets is zero, and the Wilcoxon rank-sum test evaluates the null hypothesis that the difference between the medians of the two datasets is zero. Results are reported as the probability,  $p$ , of obtaining the observed distribution of data or a distribution even less likely when the null hypothesis is true. Tests yielding a  $p$ -value of less than 0.05 were considered significant and indicate a greater than 95-percent confidence that the two datasets are different.

For specific conductance, all 71 samples were measured in the field and the laboratory, and no significant differences were observed between the field and laboratory values ( $p = 0.56$ ). The values measured in the field were used to describe and assess groundwater quality because field values were available for all samples, and they are considered more representative of groundwater conditions (Hem, 1985).

For pH, all 71 samples were measured in the field and the laboratory, and there was a systematic difference between the field and laboratory values ( $p < 0.001$ ). Laboratory pH values were higher than field pH values by a median of 0.4 pH units. Laboratory pH values ranged from 0.7 pH units higher than the field pH values to the same as the field pH values; no samples had laboratory pH values that were lower than field pH values. The increase in pH of the groundwater samples between field and laboratory measurements may be explained by equilibration of the samples with the atmosphere after collection and by analytical methods that may introduce bias in the laboratory values (Fram and others, 2009). The field values for pH were used to describe and assess groundwater quality because field values are available for all samples, and field values are preferred because they are considered more representative of groundwater conditions (Hem, 1985).

For alkalinity, 10 samples were measured in both the field and the laboratory; the other 61 samples were measured only in the laboratory. Analyzing alkalinity in the field is time-consuming and can limit the number of wells that can reasonably be visited in a single day. The following evaluation of paired field and laboratory alkalinity data demonstrates that use of laboratory alkalinity data yields data of acceptable quality.

The evaluation of paired field and laboratory alkalinity data was made by using data from all of the GAMA-PBP studies between May 2004 and October 2012 to have sufficient data for a robust statistical assessment. Between May 2004 and October 2012, 616 groundwater samples collected by the GAMA-PBP had alkalinity measurements made in the field by using the Gran titration method and made in the laboratory by using the fixed-endpoint titration method. Also, 187 replicate pairs were analyzed in the laboratory by using the fixed-endpoint titration method, and 43 replicate pairs were analyzed in the field by using the Gran titration method.



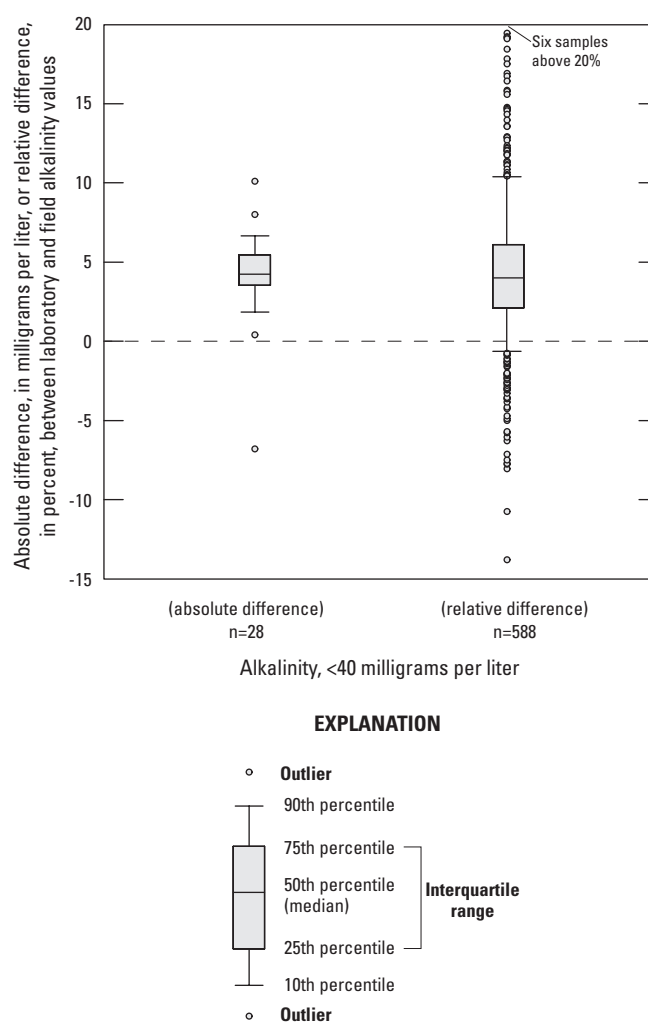
The three types of paired alkalinity values first were evaluated by using the same methods used to evaluate replicate pairs for other constituents (see section in this appendix titled “Replicates”). Briefly, for samples with alkalinity values less than 40 mg/L as  $\text{CaCO}_3$  (5 times the laboratory reporting limit of 8 mg/L as  $\text{CaCO}_3$ ), percent relative standard deviation (RSD) was used to assess agreement between the paired values, and RSDs less than 10 percent were considered to indicate acceptable agreement between the paired values. For values less than 40 mg/L as  $\text{CaCO}_3$ , standard deviation (SD) was used, and SDs less than 4 mg/L as  $\text{CaCO}_3$  (half of the reporting limit) were considered to indicate acceptable agreement between the paired values. Of the 28 samples with alkalinity values less than 40 mg/L, 21 samples (75 percent) had SDs less than 4 mg/L as  $\text{CaCO}_3$ . Of the 588 samples with alkalinity values greater than 40 mg/L, 548 samples (93 percent) had RSDs less than 10 percent. These results indicate that the agreement between paired laboratory and field measurements of alkalinity generally was within the range of variability for replicate pairs considered acceptable for this study. For comparison, of the 187 replicate pairs consisting of 2 laboratory measurements, 185 pairs (99 percent) had RSDs less than 10 percent. All 43 of the replicate pairs consisting of 2 field measurements had RSDs less than 10 percent.

Despite the apparent acceptable agreement between laboratory and field alkalinity data when the data were evaluated by using the methods used to assess agreement between replicate pairs for other constituents, the laboratory and field alkalinity data were significantly different. Laboratory alkalinity values were systematically greater than field alkalinity values for samples with alkalinity less than 40 mg/L as  $\text{CaCO}_3$  ( $p < 0.001$ ) and for samples with alkalinity greater than 40 mg/L as  $\text{CaCO}_3$  ( $p < 0.001$ ). Of the 616 groundwater samples with both field and laboratory alkalinity values, 542 samples (88 percent) had a laboratory alkalinity value greater than the field alkalinity value. The median difference between the field and laboratory alkalinity values is +4.3 mg/L as  $\text{CaCO}_3$  for samples with alkalinity less than 40 mg/L and +4.0 percent for samples with alkalinity greater than 40 mg/L as  $\text{CaCO}_3$  (fig. A1).

The greater alkalinity values from laboratory measurements compared with those from field measurements likely were due to differences between the fixed-endpoint titration method and the Gran titration method rather than to chemical changes in the groundwater sample during the time between the two measurements.

For the fixed-endpoint method, alkalinity is determined by using an automatic titrator that measures the amount of acid required to lower the pH of the sample to 4.5. For the Gran titration method, alkalinity is determined from the amount of acid required to lower the pH of the sample to the equivalence point where the buffering capacity of the sample from weak bases is exhausted, and the volume of acid to reach the equivalence point is calculated from a linear regression that uses multiple points from the titration

(Gran, 1952; Stumm and Morgan, 1996). The pH at this equivalence point is inversely correlated with the dissolved inorganic carbon content of the sample and usually occurs at a pH between 4.2 and 5.1 in freshwater (Wetzel and Likens, 2000); the fixed-endpoint method therefore may overestimate alkalinity in samples with low dissolved inorganic carbon. The fixed-endpoint method also may overestimate alkalinity because the amount of acid required to reach a pH of 4.5 may be overestimated by up to one of the increments used by the titrator.



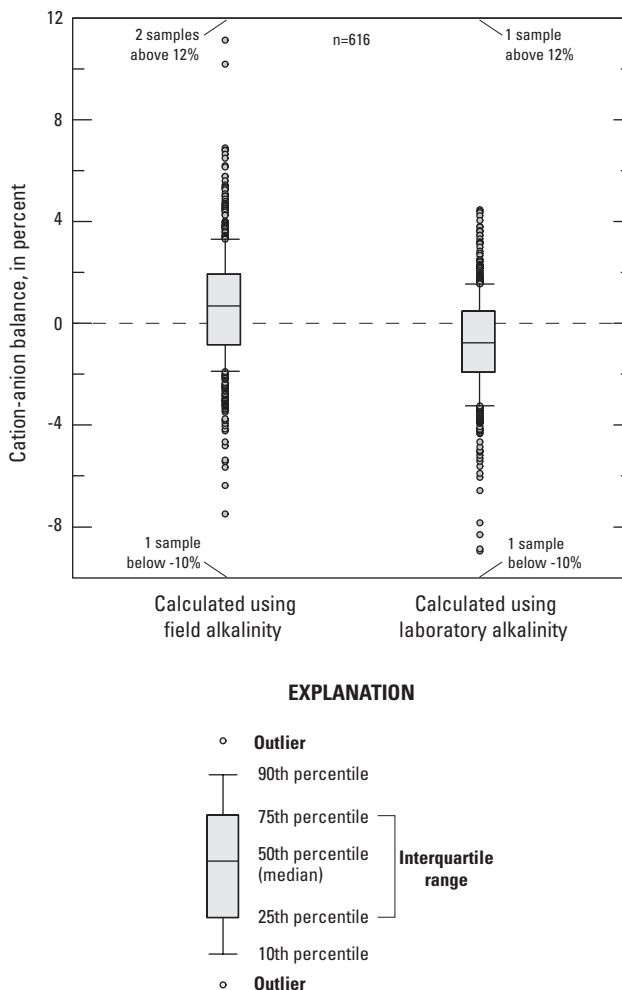
**Figure A1.** Absolute difference or percent relative difference of replicate alkalinity pairs. Replicate pairs are composed of an alkalinity measurement made at a field site by using the Gran titration method and a measurement made at the USGS National Water Quality Laboratory by using the fixed-endpoint titration method, North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project.

Chemical changes that may occur in the sample during the time between the field and laboratory alkalinity measurements either do not affect alkalinity or likely would result in a decrease in alkalinity. Equilibration of the sample with the atmosphere by loss or gain of carbon dioxide does not change alkalinity (although pH and dissolved inorganic carbon concentration will change) (Stumm and Morgan, 1996). Oxygenation of anoxic groundwater samples likely would decrease alkalinity because oxidation of dissolved iron (II), manganese (II), sulfide, or ammonium consumes oxygen and produces acidity, thereby reducing the buffering capacity of the sample (Stumm and Morgan, 1996).

The systematic difference between the field and laboratory alkalinity values is unlikely to affect interpretation of the chemical data because the difference is too small to significantly disrupt the cation-anion balances. The balance between cations and anions is commonly used as an indicator of data quality for major-ion analyses of water samples. A cation-anion balance of plus or minus 2 percent or less suggests that the major-ion data are of high quality (Hem, 1985), and a balance of plus or minus 10 percent or less may be considered acceptable (for example, Landon and others, 2010). The cations included in the sum are calcium, magnesium, potassium, and sodium, and the anions included in the sum are chloride, sulfate, bicarbonate, carbonate, fluoride, bromide, and nitrate.

Cation-anion balances calculated by using the bicarbonate and carbonate concentrations determined from the field alkalinity and pH values were compared to those calculated by using the bicarbonate and carbonate values determined from the laboratory alkalinity and pH values, and to those calculated by using the bicarbonate and carbonate values determined from the laboratory alkalinity and field pH values. The bicarbonate and carbonate concentrations were calculated from alkalinity and pH values assuming the carbonate system was the only source of alkalinity and equilibrium constants of  $pK_1 = 6.35$ ,  $pK_2 = 10.33$ , and  $pK_w = 14$ . The median cation-anion balance calculated by using the field alkalinity and pH values, +0.68 percent, was significantly different from the median cation-anion balance calculated by using the laboratory alkalinity and pH values, -0.77 percent, or laboratory alkalinity and field pH values, -0.74 percent ( $p < 0.001$  for both comparisons; [fig. A2](#)). The difference between cation-anion balances calculated by using laboratory alkalinity values and laboratory or pH values was not significant ( $p = 0.74$ ).

Among the 616 groundwater samples, 70 percent had a cation-anion balance within plus or minus 2 percent when using the laboratory alkalinity values, and 67 percent had a cation-anion balance within plus or minus 2 percent when using the field alkalinity values ([fig. A2](#)). Ninety-seven percent had a cation-anion balance within plus or minus 5 percent when using either alkalinity value. These results indicate that the field and laboratory alkalinity values both yield high-quality major-ion data.



**Figure A2.** Cation-anion balance calculated using alkalinity values obtained from field sites by using the Gran titration method and cation-anion balances calculated by using laboratory alkalinity values and the fixed-endpoint titration method, North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project.

## Quality-Control Methods and Results

The purpose of QC is to identify which data best represent environmental conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, and (or) laboratory analysis. Four types of QC measurements were evaluated in this study: (1) blank samples were collected to assess positive bias as a result of contamination during sample handling or analysis, (2) replicate samples were collected to assess variability, (3) matrix-spike tests were done to assess positive or negative bias, and (4) surrogate compounds were added to samples analyzed for organic constituents to assess potential bias of laboratory analytical methods.

## Blanks

The primary purposes of collecting blanks are to evaluate the magnitude of potential contamination of samples with compounds of interest during sample handling or analysis and to identify and mitigate the sources of sample contamination. Results from blanks collected for the NSF-SA study unit and for previous GAMA study units were used to establish SRLs for some constituents detected in blanks. SRLs have higher concentrations than the reporting levels used by the laboratory. Detections reported by the laboratory with concentrations less than SRLs may have significant contamination bias. These data were flagged with an appropriate remark code (described in subsequent sections).

### Blank Collection and Analysis

Blanks were collected by using blank water certified by the NWQL to contain less than the reporting levels for selected constituents investigated in the study (James A. Lewis, National Water Quality Laboratory, written commun., 2012). Nitrogen-purged, organic-free blank water was used for blanks of organic constituents, and inorganic-free blank water was used for blanks of other constituents.

Source-solution blanks are collected at the beginning of a study or when using a new lot of blank water to assess potential contamination of samples during transport and analysis and potential contamination of the certified blank water obtained from the NWQL. A “lot” is a unique batch of blank water with defined production and expiration dates. Source-solution blanks were collected in the USGS Sacramento Projects Office laboratory by pouring blank water directly into sample containers that were preserved, stored, shipped, and analyzed in the same manner as the groundwater samples. Source-solution blanks were analyzed for VOCs, 1,2,3-TCP, perchlorate, trace elements, major and minor ions, silica, and TDS. One additional source-solution blank was collected at a sampling site for perchlorate analysis.

Field blanks were collected to assess potential contamination of samples during collection, processing, transport, and analysis. To collect field blanks at the sampling sites, blank water was either pumped or poured through the sampling equipment (fittings and tubing) used to collect groundwater samples, then processed and transported using the same protocols used for the groundwater samples. Four liters of blank water were pumped or poured through the sampling equipment before each field blank was collected. Field blanks were analyzed for VOCs, pesticides and pesticide degradates, 1,2,3-TCP, perchlorate, trace elements, nutrients, major and minor ions, silica, and TDS.

Field or source-solution blanks were not collected for gross alpha and gross beta radioactivity or radon because the laboratory determines an  $ssL_c$  value for each sample. The  $ssL_c$  is the minimum measured value that indicates a non-zero

amount of the radionuclide in the sample, in other words, an amount of the radionuclide that is statistically significantly greater than the amount in a blank. Blanks were not collected for tritium. Tritium is in the atmosphere and would dissolve into any solution used in collecting a blank, making it impractical to collect a blank for these analytes. Isotopic ratios of carbon, hydrogen, and oxygen are an intrinsic property of any of these elements; therefore, the concept of a blank does not apply to these ratios.

### Study Reporting Levels (SRLs)

SRLs for VOCs detected in field blanks collected for the first 32 GAMA-PBP study units (May 2004 through September 2010) were defined by Fram and others (2012) on the basis of assessment of results from field blanks, source-solution blanks, laboratory instrument blanks, and groundwater samples. Detections of VOCs having concentrations less than the SRLs are reported as non-detections in [table 5](#).

SRLs for trace elements detected in field blanks collected in the first 20 GAMA-PBP study units (May 2004 through January 2008) were defined by Olsen and others (2010) on the basis of statistical assessment of results from the field blanks. The assessment used order statistics and binomial probabilities to construct an upper confidence limit (Hahn and Meeker, 1991) for the maximum concentration of constituents possibly introduced while groundwater samples were collected, handled, transported, and analyzed. Since the publication of trace element SRLs by Olsen and others (2010), SRLs for some of the constituents have been updated. The updated SRLs were calculated by using the same methods and techniques that Olsen and others (2010) used, but more recent GAMA-PBP field blank data were used in the calculations (January 2008 through September 2012; Tracy Davis, U.S. Geological Survey, written commun., 2013). If the SRL changed based on the analyses of the more recent blank data, the newer SRL is used in this report. Detections of trace elements having concentrations less than the SRLs are marked with a  $\leq$  symbol preceding the reported value in [table 8](#) to indicate that the true value may be less than or equal to the reported value (including the possibility of being a non-detection).

SRLs for other classes of constituents detected in field blanks collected for the NSF-SA study unit were defined as equal to the highest concentration measured in the field blanks.

### Detections in Field Blanks and Application of SRLs

[Table A3](#) presents a summary of detections in the field blanks and the SRLs applied for the NSF-SA study unit. Eight field blanks (representing approximately 11 percent of the sampled wells) were collected in the NSF-SA study unit. No constituents were detected in the source-solution blanks collected during the NSF-SA study.

VOCs were not detected in the field blanks for the NSF-SA study unit ([table A3](#)). Of the 10 VOCs with SRLs defined by Fram and others (2012), 8 were detected in groundwater samples from the NSF-SA study unit: acetone, carbon disulfide, ethylbenzene, tetrahydrofuran, toluene, 1,2,4-trimethylbenzene, *m*-xylene plus *p*-xylene, and *o*-xylene. All detections of acetone, ethylbenzene, tetrahydrofuran, 1,2,4-trimethylbenzene, *m*-xylene plus *p*-xylene, and *o*-xylene had concentrations less than the SRL and were thus reclassified as non-detections in the NSF-SA study unit dataset ([tables 5](#) and [A3](#)). For the GAMA-PBP, concentrations of 1,2,4-trimethylbenzene in blanks and groundwater samples below 0.56 µg/L were found to be correlated with the presence of equipment in field vehicles used for collecting radon samples (Fram and others, 2012). The vials used to collect radon samples contain a scintillation cocktail made of mineral oil and 1,2,4-trimethylbenzene. 1,2,4-Trimethylbenzene was detected in two wells in the NSF-SA, and both detections were below the SRL ([table 5](#)). Acetone and tetrahydrofuran were found to be associated with contamination of equipment by the methanol used to clean equipment and with the cement used on polyvinyl chloride (PVC) piping that is sometimes found in distribution systems connected to domestic wells (Fram and others, 2012). Samples from eight NSF-SA wells had detections of tetrahydrofuran, one of which also had a detection of acetone ([table 5](#)). A sample from one NSF-SA well had detections of ethylbenzene, *m*-xylene plus *p*-xylene, and *o*-xylene with concentrations less than the SRLs ([table 5](#)).

The SRL of 0.02 µg/L for chloroform was defined by Fram and others (2012) for wells that required the use of a portable submersible pump. The portable submersible pump is lowered into wells that do not have a permanent pump installed in them. The length and complexity of the lines used with the portable submersible pump are much greater than for the short line sampling configurations. Two wells sampled in the NSF-SA study unit required the use of the portable submersible pump. One of the wells (S-NSF-VP15) had a detection of chloroform at a concentration greater than the SRL, thus no censoring of the data was required. One of the seven detections of carbon disulfide had a concentration less than the SRL of 0.03 µg/L and was censored. The application and concentration of an SRL for each trace element were determined primarily by guidance from Olsen and others (2010) with more recent updates provided by Tracy Davis (U.S. Geological Survey, written commun., 2013) based on a statistical assessment of quality-control results during 2004–2012. GAMA SRLs from Olsen and others (2010) were used for barium, chromium, iron, and manganese; updated SRLs from Tracy Davis were used for cobalt, copper, lead, nickel, and zinc ([table A3](#)). Seven of these trace elements

were detected in at least one NSF-SA field blank: chromium, cobalt, copper, lead, manganese, nickel, and zinc. Detections in field blanks were typically at concentrations below the SRL for each constituent, with the following three exceptions: six detections of cobalt ranging from 0.08 µg/L to 0.22 µg/L, one detection of lead at 1.67 µg/L, and five detections of manganese ranging from 0.21 to 0.44 µg/L ([table A3](#)).

Between October 2009 and September 2012, a marked increase in the detection frequency of cobalt and manganese in GAMA-PBP field blanks was observed (Tracy Davis, U.S. Geological Survey, written commun., 2013). Cobalt and manganese were detected in about 96 and 79 percent of field blanks, respectively, during this period. It is hypothesized that the same source of contamination is responsible, and the filter used to filter groundwater for collection of trace elements is a likely source of the detections (Tracy Davis, U.S. Geological Survey, written commun., 2013).

Three trace elements, arsenic, molybdenum, and silver, were detected at low concentrations in field blanks. The concentrations in blanks were below the range of concentrations observed in groundwater samples and therefore were not considered to have affected groundwater results.

Aluminum was detected in one field blank in the NSF-SA study unit at a concentration of 29.9 µg/L ([table A3](#)). Aluminum has rarely been detected in GAMA-PBP field blanks, with the last recorded detection occurring in January 2008. Olsen and others (2010) assigned an SRL of 1.6 µg/L for aluminum; however, the NWQL has since raised the detection level to 1.7 µg/L based on laboratory performance. See the [appendix A](#) section titled “Other Quality-Control Results” for analysis of BQS data for aluminum. Applying an SRL based on the concentration observed in the field blank would be overly conservative in this case, given that the median aluminum concentration in groundwater samples collected in the NSF-SA study unit was 6.2 µg/L. At this time, the aluminum detection in the field blank has no explanation and is considered anomalous. It is not considered to have affected the groundwater samples, and no SRL was defined for aluminum for the NSF-SA study unit.

Calcium was detected in one field blank at a concentration of 0.027 mg/L ([table A3](#)). The minimum concentration detected in groundwater samples in the NSF-SA study unit was 0.922 mg/L, or about 30 times greater than the concentration detected in the blank; therefore, the blank detection is not considered to have an effect on the quality of the measured concentrations observed in groundwater samples.

Constituents were not detected in field blanks for the following analyte groups or analytes: VOCs, pesticides and pesticide degradates, perchlorate, 1,2,3-TCP, and TDS.



## Replicates

Sequential replicate samples were collected to assess the precision of the water-quality data. Estimates of data precision are needed to assess whether differences between concentrations in samples are because of differences in groundwater quality or because of variability that may result from collecting, processing, and analyzing the samples.

### Assessment of Replicate Samples

Two methods for measuring variability were needed to adequately assess precision over the broad range of measured concentrations of most constituents. The variability between measured concentrations in the pairs of sequential replicate samples was represented by the standard deviation (SD) for low concentrations and by relative standard deviation (RSD) for high concentrations (Anderson, 1987; Mueller and Titus, 2005). The RSD is defined as the SD divided by the mean concentration for each replicate sample expressed as a percentage. The boundary between concentrations for which variability is assessed with SD and concentrations for which variability is assessed with RSD was defined as five times the reporting level (RL) for each constituent. The RL may be an LRL, SRL, MDL, or MRL for each constituent.

Replicate samples for all constituents except for radiochemical constituents were evaluated as follows:

- If both values were reported as detections, the SD was calculated if the mean concentration was  $< 5$  RL for the constituent, or the RSD was calculated if the mean concentration was  $\geq 5$  RL for the constituent. Acceptable precision is defined as an SD of less than  $\frac{1}{2}$  RL or an RSD of less than 10 percent. For comparison, an RSD of 10 percent is equivalent to a relative percent difference (RPD) of 14 percent.
- If both values were reported as non-detections, the variability was set to zero by definition.
- If one value was reported as a non-detection, and the other value was reported as a detection less than the RL, then a value of zero was substituted for the non-detection and the SD calculated. Substituting zero for the non-detection yielded the maximum estimate of variability for the replicate sample.
- If one value for a sample pair was reported as a non-detection and the other value was reported as a  $\leq$ -coded value (less than or equal to the SRL), or if both values were reported as  $\leq$ -coded values (less than or equal to the SRL), the SD was not calculated because the values may be analytically identical. The  $\leq$  code indicates that the value is a maximum potential concentration, and that concentration may be low enough to be reported as a non-detection.

- If one value was reported as a non-detection and the other value was reported as a detection greater than the RL, the variability for the pair was considered unacceptable.

Replicate samples of radiochemical constituents were evaluated by using the following equation (McCurdy and others, 2008) to calculate the normalized absolute difference (NAD):

$$NAD = \frac{|R_1 - R_2|}{\sqrt{(CSU_1^2 + CSU_2^2)}}, \quad (A2)$$

where

$R_1$  and  $R_2$  are the results for the two samples in the replicate sample, and  
 $CSU_1$  and  $CSU_2$  are the combined standard uncertainties associated with the results.

Values  $< 1.65$  for the NAD correspond to a significance level ( $\alpha$ ) of 5 percent ( $\alpha = 0.05$ ), indicating differences that are acceptably small and not statistically significant.

If results from replicate samples indicate that precision is unacceptable for a constituent and no specific reason can be identified, then this greater variability must be considered when interpreting the data. If measured concentrations are slightly greater than a water-quality benchmark, then actual concentrations could be slightly less than that benchmark. Similarly, if measured concentrations are slightly less than a water-quality benchmark, then actual concentrations could be slightly greater than a benchmark. Also, if a constituent has high variability in replicate samples, then a larger difference between concentrations measured in two samples is required to conclude that the two samples have significantly different concentrations.

### Variability in Replicate Samples

[Tables A4A–C](#) summarize the results of replicate samples for constituents detected in groundwater samples collected in the NSF-SA study unit. Replicate samples were made at seven wells, representing approximately 10 percent of all the samples collected.

Of the 1,344 replicate samples analyzed, 227 pairs had a detection in 1 or both samples of the pair. Of these 227 pairs, 5 pairs (nitrate, total nitrogen, gross alpha radioactivity [72-hour and 30-day count], and gross beta radioactivity) were outside the limits for acceptable precision. Results for replicate samples for constituents that were not detected in groundwater samples are not reported in [tables A4A–C](#). All replicate samples for VOCs, 1,2,3-TCP, perchlorate, and pesticides and pesticide degradates were within acceptable precision.

Seven replicate samples were analyzed for the 23 trace elements. Of the 154 replicate samples, 55 were composed of either two values reported as non-detections, a value reported as a non-detection and less than or equal to the SRL, or two values reported as less than or equal to the SRL. Of the

remaining 99 pairs of constituents, all were within acceptable precision ([table A4B](#)).

Replicate samples analyzed for nutrients, major ions, and TDS resulted in SD and RSD values within acceptable precision, with the exceptions of one pair for nitrate and one pair for total nitrogen ([table A4B](#)).

Replicate samples of radioactive constituents were analyzed for variability. Most pairs yielded statistically similar results ( $p \leq 0.05$ ) and were, therefore, considered acceptable. The exceptions were one replicate sample for gross alpha radioactivity (72-hour count), two replicate samples for gross alpha radioactivity (30-day count), and one replicate sample for gross beta radioactivity (30-day count) ([table A4C](#)).

Environmental detections were not modified on the basis of the replicate samples.

## Matrix Spikes

The addition of a known concentration of a constituent (spike) to a replicate environmental sample enables the laboratory to determine the effect of the matrix, in this case groundwater, on the analytical technique used to measure the constituent. The known compounds added in matrix spikes are the same as those analyzed in the environmental samples. This enables an analysis of matrix interferences on a compound-by-compound basis. For this study, matrix spikes were added by the laboratory performing the analysis rather than in the field. Low matrix-spike recovery may indicate that the compound might not be detected in some samples if it were present at very low concentrations. Low and high matrix-spike recoveries may be a potential concern if the concentration of a compound in a groundwater sample is close to the health-based benchmark; a low recovery could result in a falsely measured concentration less than the health-based benchmark, whereas a high recovery could result in a falsely measured concentration greater than the health-based benchmark.

The GAMA-PBP defined the data-quality objective range for acceptable median matrix-spike recoveries as 70 to 130 percent. Only constituents with median matrix-spike recoveries outside of this range were flagged as having unacceptable recoveries. For some constituents, an acceptable range of 70 to 130 percent for median matrix-spike recovery was more restrictive than the acceptable control limits 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 control limits for set spikes are defined relative to the long-term variability in recovery. For example, for many NWQL analyses, acceptable set-spike recovery is within  $\pm 3$  F-pseudosigma of the median recovery for at least 30 set spikes (Connor and others, 1998). The F-pseudosigma is calculated

by dividing the fourth-spread (analogous to interquartile range) by 1.349; therefore, the smaller the F-pseudosigma, the more precise the determinations (Hoaglin, 1983).

Matrix spikes were performed for VOCs, 1,2,3-TCP, and pesticides and pesticide degradates because the analytical methods for these constituents may be susceptible to matrix interferences.

## Matrix-Spike Recoveries

[Tables A5A–B](#) present a summary of matrix-spike recoveries for the NSF-SA study unit. Replicate samples for spike additions of organic constituents were collected at nine wells for VOCs and 1,2,3-TCP, representing approximately 13 percent of all the wells sampled, and at seven wells for pesticides and pesticide degradates, representing approximately 10 percent of all the wells sampled.

Groundwater samples were spiked with 85 VOCs to calculate matrix-spike recoveries. Median matrix-spike recoveries were between 70 and 130 percent for all VOCs ([table A5A](#)). The special-interest constituent 1,2,3-TCP was analyzed at Weck Laboratories, Inc., and matrix-spike results presented in [table A5A](#) for 1,2,3-TCP are from their laboratory.

Groundwater samples were spiked with 63 pesticides and pesticide degradates to calculate matrix-spike recoveries. Thirteen compounds had median matrix-spike recoveries less than 70 percent, none of which were detected in groundwater samples ([table A5B](#)). One compound, tebuthiuron, had median matrix-spike recoveries greater than 130 percent and was detected in one groundwater sample ([table 6](#)).

Environmental detections were not modified on the basis of the matrix-spike recovery analysis.

## Surrogates

Surrogate compounds are added to environmental samples in the laboratory prior to analysis to evaluate the recovery of similar constituents. Surrogate compounds were added in the laboratory to all groundwater and QC samples that were analyzed by the NWQL for VOCs and pesticides and pesticide degradates. Surrogates are used to identify general problems that may arise during laboratory sample analysis that could affect the 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 because of improper maintenance and calibration of analytical equipment) that produces a negative bias. A 70 to 130 percent recovery of surrogates, in general, is considered acceptable; values outside this range indicate possible problems with the processing and analysis of samples (Connor and others, 1998; Sandstrom and others, 2001).



## Surrogate Compound Recoveries

[Table A6](#) presents a summary of the surrogate recoveries for the NSF-SA study unit. The table lists the surrogates, the analytical schedule for which each surrogate was used, the number of analyses for field blanks and environmental samples, the number of surrogate recoveries less than 70 percent, and the number of surrogate recoveries greater than 130 percent for the blank and environmental samples. Field blanks and environmental samples were considered separately to assess whether or not the matrixes present in environmental samples affect surrogate recoveries.

Most surrogate recoveries for the field blanks and environmental samples were within the acceptable range of 70 to 130 percent. For VOC analyses, about 30 percent of field blanks and about 36 percent of environmental samples had surrogate recoveries for 1,2-dichloroethane-*d*4 greater than 130 percent. For all other VOC surrogates, 100 percent were within the acceptable range. For pesticides and pesticide degradates, 100 percent of the field blank surrogate recoveries and 98 percent of the environmental sample surrogate recoveries were within the acceptable range.

Environmental detections were not modified on the basis of the surrogate recovery analysis.

## Other Quality-Control Results

Two other laboratory QC issues arose during the analysis of samples collected for the NSF-SA study unit: the effect of holding-time violations on the results of radioactive constituent data and the effect of internal laboratory QC tests indicating bias on the results of trace element data.

### Effect of Holding-Time Violations

Holding time refers to the time in calendar days from sample collection to the analysis of the sample. A holding-time violation occurs when a sample is analyzed past the given holding time for a particular analysis. Analyses for some samples in the NSF-SA study unit were completed after the holding time due to a scheduling error at the laboratory or shipping error. A delay in the analysis at the laboratory may result in different measured activities or concentrations than what may have been present in the sample.

The gross alpha and beta radioactivity reported result is the amount measured in the sample. Radioactive decay occurs between the time of sample collection and measurement; therefore, gross alpha and gross beta radioactivity can change with time. Gross alpha and beta radioactivity (72-hour counts) were analyzed past the holding time in one groundwater sample. The result for this sample is footnoted in [table 12](#). Gross alpha radioactivity (72-hour) may be lower and gross beta radioactivity (72-hour) may be lower or higher in samples analyzed past the holding time than they would have been if analyzed on time.

### Laboratory Bias

Laboratory bias as indicated from internal laboratory QC tests is another issue that must be investigated to determine whether or not the data are affected. The BQS operates independent, external quality-assurance projects called the Inorganic Blind Sample Project (IBSP) and Blind Blank Program (BBP) to monitor and evaluate the quality of results for analyses of trace elements, nutrients, major and minor ions, silica, and TDS by the NWQL. The IBSP submits standard reference samples consisting of natural matrix water samples spiked with reagent chemicals to contain known concentrations of the inorganic constituents (Farrar and Long, 1997). The IBSP samples are disguised as regular environmental samples for submission to the NWQL; the BBP samples are disguised as regular blank samples. The BQS uses results from the IBSP and BBP samples to evaluate potential bias in the results reported by the NWQL on a continuous basis. The BQS data are readily available on the BQS website, and the BQS issues summaries of the results, reporting the amount of bias (if any) observed in the results (U.S. Geological Survey, 2013e–f, website at <http://bqs.usgs.gov/ibsp/>).

The April, June, and August 2012 BQS summaries were examined, which includes a review of data for the time period March 2, 2012, through October 4, 2012. The BQS reported that eight inorganic constituents showed evidence of bias during this period: a positive bias for aluminum, barium, cadmium, fluoride, lead, and lithium, and a negative bias for selenium and zinc. Examination of the results for the IBSP samples for these eight constituents indicated that the analytical biases reported by the BQS were not significant for the data collected for the NSF-SA study unit.

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

[Laboratory entity codes in the USGS National Water Information System (NWIS) for laboratories other than the USGS National Water Quality Laboratory (NWQL) are given in parentheses after the laboratory names. **Abbreviations:** USEPA, U.S. Environmental Protection Agency; VOC, volatile organic compound; NRP, USGS National Research Program]

Analyte	Analytical method	Laboratory and analytical schedule	Citation(s)
Water-quality indicators			
Field parameters	Calibrated field meters and test kits	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
Pesticides and pesticide degradates	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, Schedule 2003	Zaugg and others, 1995; Lindley and others, 1996; Sandstrom and others, 2001; Madsen and others, 2003
Constituents of special interest			
Perchlorate	Liquid chromatography with mass spectrometry/mass spectrometry (USEPA Method 331.0)	Weck Laboratories, Inc. [Weck], City of Industry, California (CA-WECK), standard operating procedure ORG099.R01	U.S. Environmental Protection Agency, 2005
1,2,3-Trichloropropane (1,2,3-TCP)	Isotopic dilution purge and trap/gas chromatography/mass spectrometry	Weck Laboratories, Inc., standard operating procedure ORG083	Okamoto and others, 2002
Inorganic constituents			
Major and minor ions and trace elements	Atomic absorption spectrometry, colorimetry, ion-exchange chromatography, inductively-coupled plasma atomic emission spectrometry, and mass spectrometry	NWQL, Schedule 1948	Fishman and Friedman, 1989; Faires, 1993; Fishman, 1993; McLain, 1993; American Public Health Association, 1998; Garbarino, 1999; Garbarino and others, 2006
Nutrients	Alkaline persulfate digestion, Kjeldahl digestion	NWQL, Schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Isotopic tracers			
Stable isotopes of hydrogen and oxygen in water	Gaseous hydrogen and carbon dioxide–water equilibration and stable-isotope mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA), NWQL Schedule 1142	Epstein and Mayeda, 1953; Coplen and others, 1991; Coplen, 1994
Stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance	Accelerator mass spectrometry	Woods Hole Oceanographic Institution, National Ocean Sciences Accelerator Mass Spectrometry Facility [NOSAMS], Woods Hole, Massachusetts (MA-WHAMS), NWQL Schedule 2255	Vogel and others, 1987; Donahue and others, 1990; McNichol and others, 1992; Gagnon and Jones, 1993; McNichol and others, 1994; Schneider and others, 1994
Stable isotopes of boron in water	Negative thermal-ionization mass spectrometry	USGS NRP Metals Isotope Research Laboratory, Menlo Park, California (USGSMICA)	Vengosh and others, 1989; Dwyer and Vengosh, 2008
Stable isotopes of strontium in water	Chemical separations and thermal-ionization mass spectrometry	USGS NRP Metals Isotope Research Laboratory, Menlo Park, California (USGSMICA)	Bullen and others, 1996

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

[Laboratory entity codes in the USGS National Water Information System (NWIS) for laboratories other than the USGS National Water Quality Laboratory (NWQL) are given in parentheses after the laboratory names. **Abbreviations:** USEPA, U.S. Environmental Protection Agency; VOC, volatile organic compound; NRP, USGS National Research Program]

Analyte	Analytical method	Laboratory and analytical schedule	Citation(s)
Radioactive constituents			
Tritium	Electrolytic enrichment-liquid scintillation	USGS Stable Isotope and Tritium Laboratory [SITL], Menlo Park, California (USGSH3CA), NWQL Schedule 1565	Thatcher and others, 1977
Radon-222	Liquid scintillation counting	NWQL, Schedule 1369	American Society for Testing and Materials, 1998
Gross alpha and gross beta radioactivity (72-hour and 30-day counts)	Alpha and beta activity counting (USEPA Method 900.0)	Eberline Analytical Services, Richmond, California (CA-EBERL), NWQL Schedule 1792	Krieger and Whittaker, 1980

**Table A2.** Preferred analytical methods or laboratories for selected constituents in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[Preferred analytical schedules/methods are selected on the basis of the procedure recommended by the NWQL ([http://www.nwql.cr.usgs.gov/dyn.shtml?Preferred\\_method\\_selection\\_procedure](http://www.nwql.cr.usgs.gov/dyn.shtml?Preferred_method_selection_procedure)).

**Abbreviations:** NWQL, USGS National Water Quality Laboratory, Denver, Colorado; VOC, volatile organic compound; Weck, Weck Laboratories, Inc.]

Constituent (synonym or abbreviation)	Primary constituent classification	Analytical methods or laboratory	Preferred analytical method or laboratory
Alkalinity	Water-quality indicator	field, Schedule 1948 (NWQL)	field
pH	Water-quality indicator	field, Schedule 1948 (NWQL)	field
Specific conductance	Water-quality indicator	field, Schedule 1948 (NWQL)	field
1,2,3-Trichloropropane (1,2,3-TCP)	VOC	Schedule 2020 (NWQL), Weck	Weck

**Table A3.** Constituents detected in the field blank samples and the study reporting levels (SRLs) used for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[Abbreviations: RL, reporting level; VOC, volatile organic compound; ≤, less than or equal to; µg/L, micrograms per liter; mg/L, milligrams per liter; na, not applicable; nv, no value in category; —, not detected]

Constituent	Number of field blank detections / total number of field blank samples	RL	Concentration(s) detected in field blank sample(s)	SRL	Source of SRL	Number of groundwater samples ≤ coded / total number of groundwater detections
Volatile organic compounds (VOCs) (µg/L)						
Acetone	0/8	3.4	—	All data	Fram and others, 2012	1/1
2-Butanone	0/8	1.6	—	All data	Fram and others, 2012	0/0
Carbon disulfide	0/8	0.03	—	0.03	Fram and others, 2012	1/7
Chloroform <sup>1</sup>	0/8	0.03	—	0.02	Fram and others, 2012	0/13
Ethylbenzene	0/8	0.04	—	0.06	Fram and others, 2012	0/0
Tetrahydrofuran	0/8	1.4	—	All data	Fram and others, 2012	8/8
Toluene	0/8	0.02	—	0.69	Fram and others, 2012	0/0
1,2,4-Trimethylbenzene	0/8	0.03	—	0.56	Fram and others, 2012	0/0
<i>m</i> - and <i>p</i> -Xylenes	0/8	0.08	—	0.33	Fram and others, 2012	0/0
<i>o</i> -Xylene	0/8	0.03	—	0.12	Fram and others, 2012	0/0
Trace elements (µg/L)						
Aluminum	1/8	2.2	29.9	<sup>2</sup> 1.6	Olsen and others, 2010	0/40
Arsenic	1/8	0.03	0.04	nv	na	0/65
Boron	1/8	3	29	nv	na	0/71
Chromium	1/8	0.14	0.08	0.42	Olsen and others, 2010	16/22
Cobalt	8/8	0.021	0.05, 0.05, 0.08, 0.12, 0.17, 0.18, 0.18, 0.22	0.05	Tracy Davis <sup>3</sup>	24/32
Copper	1/8	0.08	2	3.2	Tracy Davis <sup>3</sup>	24/12
Lead	5/8	0.025	0.06, 0.13, 0.19, 0.25, 1.67	0.82	Tracy Davis <sup>3</sup>	52/7
Manganese	7/8	0.13	0.15, 0.16, 0.21, 0.24, 0.3, 0.35, 0.44	0.2	Olsen and others, 2010	3/62
Molybdenum	1/8	0.014	0.019	nv	na	0/70
Nickel	1/8	0.09	0.1	0.2	Tracy Davis <sup>3</sup>	10/57
Silver	1/8	0.005	0.007	nv	na	0/5
Zinc	2/8	1.4	1.6, 6.4	6.4	Tracy Davis <sup>3</sup>	36/22
Major and minor ions (mg/L)						
Calcium	1/8	0.022	0.027	nv	na	0/71

<sup>1</sup> SRL established by Fram and others (2012) for chloroform only applies to samples collected at monitoring wells.

<sup>2</sup> SRL established by Olsen and others (2010) is now lower than current long-term method detection limit of 2.2 µg/L.

<sup>3</sup> Based on written communication with Tracy Davis, U.S. Geological Survey, who is preparing updated SRLs using recent Groundwater Ambient Monitoring and Assessment (GAMA) blank data.

**Table A4A.** Quality-control summary for replicate pair analyses of organic constituents in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[Constituents for which all replicate pairs were non-detections are not listed. **Abbreviations:** SD, percent standard deviation; >, greater than; <, less than; RL, reporting level]

Constituent	Number of non-detections / number of replicate pairs	Number of SDs > ½ RL / number of replicate pairs with concentration < 5 times the RL
Volatile organic compounds (VOCs)		
Carbon tetrachloride (Tetrachloromethane)	6/7	0/1
Chloroform (Trichloromethane)	4/7	0/3
Perchloroethene (PCE, Tetrachloroethene)	6/7	0/1
Pesticides and pesticide degradates		
All replicate pairs considered acceptable for pesticides and pesticide degradates		
Constituent of special interest		
Perchlorate	3/7	0/4

**Table A4B.** Quality-control summary for replicate sample analyses of inorganic constituents in samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.

[Constituents for which all replicate samples were non-detections are not listed. **Abbreviations:** SD, percent standard deviation; RSD, percent relative standard deviation; RL, reporting level; >, greater than; <, less than; ≤, less than or equal to; nv, no value in category]

Constituent	Number of non-detections or ≤-coded replicate samples / number of replicate samples	Number of SDs > ½ RL / number of replicate samples with concentrations < 5 times the RL	Number of RSDs > 10 per- cent / number of replicate samples with concentrations > 5 times the RL
Trace Elements			
Aluminum	3/7	0/4	nv
Antimony	1/7	0/6	nv
Arsenic	1/7	nv	0/6
Barium	0/7	nv	0/7
Beryllium	4/7	0/2	0/1
Boron	0/7	nv	0/7
Cadmium	6/7	0/1	nv
Chromium	3/7	nv	0/4
Cobalt	2/7	0/5	nv
Copper	2/7	0/3	0/2
Iron	3/7	nv	0/4
Lithium	0/7	0/1	0/6
Manganese	2/7	nv	0/5
Molybdenum	0/7	nv	0/7
Nickel	2/7	nv	0/5
Selenium	1/7	0/2	0/4
Strontium	0/7	nv	0/7
Vanadium	0/7	0/2	0/5
Zinc	4/7	0/1	0/2
Nutrients			
Ammonia (as nitrogen)	4/7	0/2	0/1
Nitrate plus nitrite (as nitrogen) <sup>1</sup>	2/7	0/1	1/4
Nitrite (as nitrogen)	6/7	0/1	nv
Total nitrogen (ammonia + nitrite + nitrate + organic nitrogen)	1/7	0/2	1/4
Phosphate, orthophosphate (as phosphorus)	0/7	nv	0/7
Major and minor ions, silica, and total dissolved solids (TDS)			
Calcium	0/7	nv	0/7
Chloride	0/7	nv	0/7
Fluoride	0/7	0/4	0/3
Magnesium	0/7	nv	0/7
Potassium	0/7	nv	0/7
Sodium	0/7	nv	0/7
Sulfate	0/7	nv	0/7
Silica (as SiO <sub>2</sub> )	0/7	nv	0/7
TDS	0/7	nv	0/7

<sup>1</sup> Nitrite plus nitrate (as nitrogen) is referred to as nitrate in the text for clarity.



**Table A4C.** Quality-control summary for replicate pair analyses of radioactive constituents in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California GAMA Priority Basin Project, April to August 2012.

[For activities of radioactive constituents, a replicate pair analyses is defined as acceptable if the p-value for the normalized absolute difference is less than the significance level,  $\alpha = 0.05$ . **Abbreviations:** <, less than; >, greater than; —, not detected; ±, plus or minus; nv, no values]

Constituent	Number of non-detections or <-coded replicate samples / number of replicate samples	Number of detections paired with non-detections	Number of replicate samples with $p > 0.05$ / number of replicate pairs	Activities for replicate samples with $p > 0.05$ (groundwater sample, replicate sample)
Gross alpha radioactivity, 72-hour count	0/7	4	1/7	$(0.42 \pm 0.24; — \pm 0.19)$
Gross alpha radioactivity, 30-day count	5/7	2	2/7	$(— \pm 0.41, 0.75 \pm 0.49; — \pm 0.46, 1.18 \pm 0.66)$
Gross beta radioactivity, 72-hour count	1/7	1	1/7	$(1.48 \pm 0.61; — \pm 0.7)$
Gross beta radioactivity, 30-day count	1/7	0	0/7	nv
Uranium	1/7	0/1	0/5	nv
Radon-222	0/7	0	0/7	nv

**Table A5A.** Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and the special-interest constituent 1,2,3-trichloropropane in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.

[Acceptable recovery range is between 70 and 130 percent]

Constituent (synonym or abbreviation)	Number of matrix- spike samples collected	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetone	9	100	127	111
Acrylonitrile	9	103	118	112
<i>tert</i> -Amyl methyl ether (TAME)	9	85	106	97
Benzene <sup>1</sup>	9	96	112	104
Bromobenzene	9	91	108	100
Bromochloromethane <sup>1</sup>	9	90	116	104
Bromodichloromethane <sup>1</sup>	9	80	105	95
Bromoform (Tribromomethane) <sup>1</sup>	9	74	106	90
Bromomethane (Methyl bromide)	9	92	135	117
<i>n</i> -Butylbenzene	9	84	105	95
<i>sec</i> -Butylbenzene	9	88	111	102
<i>tert</i> -Butylbenzene	9	96	112	103
Carbon disulfide <sup>1</sup>	9	71	97	84
Carbon tetrachloride (Tetrachloromethane) <sup>1</sup>	9	85	109	98
Chlorobenzene <sup>1</sup>	9	91	109	99
Chloroethane	9	98	126	102
Chloroform (Trichloromethane) <sup>1</sup>	9	-88	124	103
Chloromethane	9	97	138	112
3-Chloropropene	9	92	110	100
2-Chlorotoluene	9	95	111	101
4-Chlorotoluene	9	94	113	102
Dibromochloromethane <sup>1</sup>	9	82	109	91
1,2-Dibromo-3-chloropropane (DBCP)	9	77	106	92
1,2-Dibromoethane (EDB)	9	92	106	102
Dibromomethane <sup>1</sup>	9	82	109	91
1,2-Dichlorobenzene	9	104	126	107
1,3-Dichlorobenzene	9	91	109	103
1,4-Dichlorobenzene	9	97	114	105
<i>trans</i> -1,4-Dichloro-2-butene	9	91	110	103
Dichlorodifluoromethane (CFC-12)	9	98	134	110
1,1-Dichloroethane (1,1-DCA) <sup>1</sup>	9	95	122	107
1,2-Dichloroethane (1,2-DCA)	9	94	128	105
1,1-Dichloroethene (1,1-DCE)	9	96	110	106
<i>cis</i> -1,2-Dichloroethene ( <i>cis</i> -1,2-DCE)	9	93	109	101
<i>trans</i> -1,2-Dichloroethene ( <i>trans</i> -1,2-DCE)	9	96	114	105
1,2-Dichloropropane	9	88	108	103
1,3-Dichloropropane	9	96	113	102
2,2-Dichloropropane	9	56	98	87
1,1-Dichloropropene	9	85	100	94
<i>cis</i> -1,3-Dichloropropene	9	84	103	95

**Table A5A.** Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and the special-interest constituent 1,2,3-trichloropropane in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent (synonym or abbreviation)	Number of matrix- spike samples collected	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
<i>trans</i> -1,3-Dichloropropene	9	79	103	90
Diethyl ether	9	93	114	108
Diisopropyl ether (DIPE) <sup>1</sup>	9	94	111	105
Ethylbenzene	9	89	110	96
Ethyl <i>tert</i> -butyl ether (ETBE)	9	89	107	104
Ethyl methacrylate	9	88	104	95
<i>o</i> -Ethyl toluene (1-Ethyl-2-methyl benzene) <sup>1</sup>	9	90	111	101
Hexachlorobutadiene	9	72	98	89
Hexachloroethane	9	71	110	90
2-Hexanone ( <i>n</i> -Butyl methyl ketone)	9	90	113	103
Iodomethane (Methyl iodide)	9	91	119	107
Isopropylbenzene <sup>1</sup>	9	86	110	92
4-Isopropyl-1-methyl benzene	9	86	108	96
Methyl acrylate	9	87	103	98
Methyl acrylonitrile	9	100	121	109
Methyl <i>tert</i> -butyl ether (MTBE) <sup>1</sup>	9	92	109	104
Methyl <i>iso</i> -butyl ketone (MIBK)	9	91	111	102
Methylene chloride (Dichloromethane)	9	94	121	107
Methyl ethyl ketone (2-butanone, MEK)	9	98	122	113
Methyl methacrylate	9	87	103	98
Naphthalene <sup>1</sup>	9	79	109	92
Perchloroethene (PCE, Tetrachloroethene) <sup>1</sup>	9	94	119	102
<i>n</i> -Propylbenzene	9	86	107	94
Styrene <sup>1</sup>	9	89	109	95
1,1,1,2-Tetrachloroethane	9	84	106	97
1,1,2,2-Tetrachloroethane	9	88	118	99
Tetrahydrofuran	9	99	119	108
1,2,3,4-Tetramethylbenzene	9	81	114	92
1,2,3,5-Tetramethylbenzene	9	90	118	97
Toluene <sup>1</sup>	9	56	112	105
1,2,3-Trichlorobenzene	9	89	110	101
1,2,4-Trichlorobenzene	9	83	106	92
1,1,1-Trichloroethane (1,1,1-TCA)	9	90	113	104
1,1,2-Trichloroethane (1,1,2-TCA)	9	88	111	103
Trichloroethene (TCE) <sup>1</sup>	9	91	107	98
Trichlorofluoromethane (CFC-11) <sup>1</sup>	9	105	141	119
1,2,3-Trichloropropane (1,2,3-TCP) <sup>2</sup>	9	100	114	107
Trichlorotrifluoroethane (CFC-113) <sup>1</sup>	9	94	113	97
1,2,3-Trimethylbenzene	9	98	116	105
1,2,4-Trimethylbenzene	9	96	116	107

**Table A5A.** Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and the special-interest constituent 1,2,3-trichloropropane in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent (synonym or abbreviation)	Number of matrix-spike samples collected	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
1,3,5-Trimethylbenzene	9	92	112	100
Vinyl bromide (Bromoethene)	9	94	117	104
Vinyl chloride (Chloroethene)	9	98	135	110
<i>m</i> - plus <i>p</i> -Xylene	9	92	112	100
<i>o</i> -Xylene	9	89	109	97

<sup>1</sup> Constituent detected in groundwater sample(s).<sup>2</sup> Spike results from Weck Laboratories, Inc.**Table A5B.** Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.

[Acceptable recovery range is between 70 and 130 percent]

Constituent (synonym or abbreviation)	Number of matrix-spike samples collected	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetochlor	7	78	112	101
Alachlor	7	87	111	108
Atrazine <sup>1</sup>	7	88	117	100
Azinphos-methyl	7	63	135	104
Azinphos-methyl oxon	7	22	189	107
Benfluralin	7	67	85	75
Carbaryl	7	87	131	110
2-Chloro-2,6-diethylacetanilide	7	83	110	99
4-Chloro-2-methylphenol	7	64	73	64
Chlorpyrifos	7	79	99	82
Chlorpyrifos oxon	7	20	65	40
Cyfluthrin	7	56	84	76
Cypermethrin	7	53	82	71
DCPA (Dacthal)	7	99	110	107
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-s-triazine) <sup>1</sup>	7	55	152	70
Desulfinylfipronil	7	83	113	102
Desulfinylfipronil amide	7	96	147	117
Diazinon	7	85	104	100
3,4-Dichloroaniline <sup>1</sup>	7	73	95	76
Dichlorvos	7	16	82	45
Dicrotophos	7	7	39	22
Dieldrin <sup>1</sup>	7	76	109	94
2,6-Diethylaniline	7	77	97	88
Dimethoate	7	45	73	57
Ethion	7	68	90	80

**Table A5B.** Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent (synonym or abbreviation)	Number of matrix-spike samples collected	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Ethion monoxon	7	75	100	88
2-Ethyl-6-methylaniline	7	81	107	89
Fenamiphos	7	75	90	83
Fenamiphos sulfone	7	78	112	101
Fenamiphos sulfoxide	7	8	40	24
Fipronil	7	77	118	102
Fipronil sulfide <sup>1</sup>	7	73	100	91
Fipronil sulfone	7	70	96	82
Fonofos	7	81	98	96
Hexazinone	7	34	76	46
Iprodione	7	59	92	77
Isofenphos	7	81	110	103
Malaoxon	7	81	117	97
Malathion	7	79	108	96
Metalaxyl	7	85	114	100
Methidathion	7	76	97	90
Metolachlor	7	77	114	104
Metribuzin	7	96	108	91
Myclobutanil	7	75	99	90
1-Naphthol	7	24	88	39
Paraoxon-methyl	7	61	100	72
Parathion-methyl	7	79	107	90
Pendimethalin	7	72	111	86
<i>cis</i> -Permethrin	7	54	85	67
Phorate	7	54	83	64
Phorate oxon	7	73	110	83
Phosmet	7	11	78	20
Phosmet oxon	7	12	50	49
Prometon <sup>1</sup>	7	69	114	93
Prometryn	7	79	110	98
Pronamide	7	82	107	98
Simazine <sup>1</sup>	7	78	116	91
Tebuthiuron <sup>1</sup>	7	103	190	133
Terbufos	7	61	93	80
Terbufos oxon sulfone	7	68	121	88
Terbuthylazine	7	93	111	107
Tribufos	7	51	75	61
Trifluralin	7	71	91	78

<sup>1</sup> Constituent detected in groundwater sample(s).

**Table A6.** Quality-control summary for surrogate compound recoveries of volatile organic compounds (VOCs) and pesticides and pesticide degradates in groundwater samples collected for the North San Francisco Bay Shallow Aquifer study unit, California Groundwater Ambient Monitoring and Assessment (GAMA) Priority Basin Project, April to August 2012.

[Abbreviations: NWQL, U.S. Geological Survey National Water Quality Laboratory; <, less than; >, greater than]

Surrogate compound	NWQL analytical schedule	Constituent class analyzed	Number of blanks analyzed	Median recovery in blanks (percent)	Number of surrogate recoveries < 70 percent in blanks	Number of surrogate recoveries > 130 percent in blanks	Number of groundwater samples analyzed	Median recovery in groundwater samples (percent)	Number of surrogate recoveries < 70 percent in groundwater samples	Number of surrogate recoveries > 130 percent in groundwater samples
1-Bromo-4-fluorobenzene	2020	VOC	9	93	0	0	71	87	0	0
1,2-Dichloroethane- <i>d</i> 4	2020	VOC	9	125	0	3	71	128	0	26
Toluene- <i>d</i> 8	2020	VOC	9	91	0	0	71	95	0	0
Diazinon- <i>d</i> 10	2003	Pesticide	8	82	0	0	71	86	1	0
$\alpha$ -HCH- <i>d</i> 6	2003	Pesticide	8	96	0	0	71	95	1	0



## Appendix B

This appendix describes the effects of the change in prioritization of comparison benchmarks between the first and second phases of the GAMA-PBP ([fig. 4](#)).

Of the approximately 350 constituents analyzed by USGS-GAMA in one or more GAMA-PBP study units, 139 constituents had an MCL-CA, MCL-US, proposed MCL-US, AL-US, SMCL-CA, NL-CA, HAL-US, or RSD5-US benchmark and therefore could be assigned a comparison benchmark and assessed during the first phase of the GAMA-PBP. HBSLs were available for an additional 64 constituents, raising the total number of constituents that could be assigned a comparison benchmark and assessed during the second phase of the GAMA-PBP to 203. These 64 additional constituents are mostly pesticides or pesticide degradates. Of these 64 additional constituents, 25 constituents were detected in one or more samples collected by USGS-GAMA between May 2004 and October 2012; however, none of the detections had concentrations greater than the HBSL.

Of the 139 constituents assigned comparison benchmarks under the prioritization used in the first phase of the GAMA-PBP, 117 constituents were assigned a benchmark with the same concentration under the prioritization used in the second phase of the GAMA-PBP. Changing the order of the prioritization and adding the HBSLs will have no effect on the presentation of results for these 117 constituents.

Of the 139 constituents assigned comparison benchmarks under the prioritization used in the first phase of the GAMA-PBP, 19 constituents were assigned a benchmark with a different value under the prioritization used in the second phase of the GAMA-PBP. Of these 19 constituents, 10 have not been detected in any sample collected by USGS-GAMA between May 2004 and October 2012, and 6 were only detected at concentrations below the lower of the 2 benchmarks. Changing the order of the prioritization and adding the HBSLs likely will have no effect on the presentation of results for these 16 constituents.

The three constituents that are affected by changing the order of the prioritization of the benchmarks and adding the HBSLs and which may have had an effect on the presentation of the results are the following inorganic constituents:

- Boron: In the first phase of the GAMA-PBP, boron concentrations were compared to the NL-CA of 1,000 µg/L; in the second phase, boron concentrations are compared to the HBSL of 6,000 µg/L. The HBSL is equal to the HAL-US.
  - Manganese: In the first phase of the GAMA-PBP, manganese concentrations were compared to the SMCL-CA of 50 µg/L; in the second phase, manganese concentrations are compared to the HBSL of 300 µg/L. The HBSL is equal to the HAL-US. The NL-CA for manganese is 500 µg/L.
  - Chromium (VI): The first phase of the GAMA-PBP did not assess chromium (VI) because no comparison benchmark was available under the old system during that time period. However, in July 2014, CDPH announced an MCL-CA for chromium (VI) of 10 µg/L (California Department of Public Health, 2014). The MCL-CA will be used as the comparison benchmark for the second phase of the GAMA-PBP. Note that chromium (VI) was not analyzed in the NSF-SA study unit.
- Finally, 139 constituents were assigned comparison benchmarks under the prioritization used in the first phase of the GAMA-PBP; however, the new prioritization order was not used to select the comparison benchmark for 3 special-interest constituents. All three constituents have NL-CA benchmarks and do not have HBSL benchmarks. These constituents were assigned a benchmark with a different value under the prioritization used in the second phase of the GAMA-PBP.
- 1,2,3-TCP: In first phase of the GAMA-PBP, 1,2,3-TCP concentrations were compared to the HAL-US of 40 µg/L because the NL-CA for 1,2,3-TCP of 0.005 µg/L was set at the analytical reporting limit. However, the HAL-US, originally developed in 1989 (U.S. Environmental Protection Agency, 1989), no longer appears to be in use (U.S. Environmental Protection Agency, 2013). 1,2,3-TCP does not have an HBSL. The CDPH is expected to release a proposed MCL-CA for 1,2,3-TCP in 2014 (California Department of Public Health, 2013b). Until that proposed MCL-CA is released, 1,2,3-TCP concentrations will be compared to the MCL of 0.6 µg/L established by the State of Hawaii (Hawaii Department of Health, 2005). 1,2,3-TCP was not detected in the NSF-SA study unit.
  - 1,4-Dioxane: In the first phase of the GAMA-PBP, 1,4-dioxane concentrations were compared to the initial NL-CA of 3 µg/L and then to the new NL-CA of 1 µg/L after it was revised in 2010 (California Department of Public Health, 2011). 1,4-Dioxane does not have an HBSL and has a HAL-US of 200 µg/L. 1,4-Dioxane concentrations will continue to be compared to the NL-CA of 1 µg/L during the second phase of the GAMA-PBP. 1,4-Dioxane was not analyzed in the NSF-SA study unit.
  - *N*-Nitrosodimethylamine (NDMA): In the first phase of the GAMA-PBP, NDMA concentrations were compared to the NL-CA of 0.01 µg/L. NDMA has an HBSL range of 0.0007 to 0.07 µg/L and an RSD5-US of 0.007 µg/L. For consistency with 1,4-dioxane, NDMA concentrations will continue to be compared to the NL-CA during the second phase of the GAMA-PBP. NDMA was not analyzed in the NSF-SA study unit.

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