Prepared in cooperation with the California State Water Resources Control Board

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

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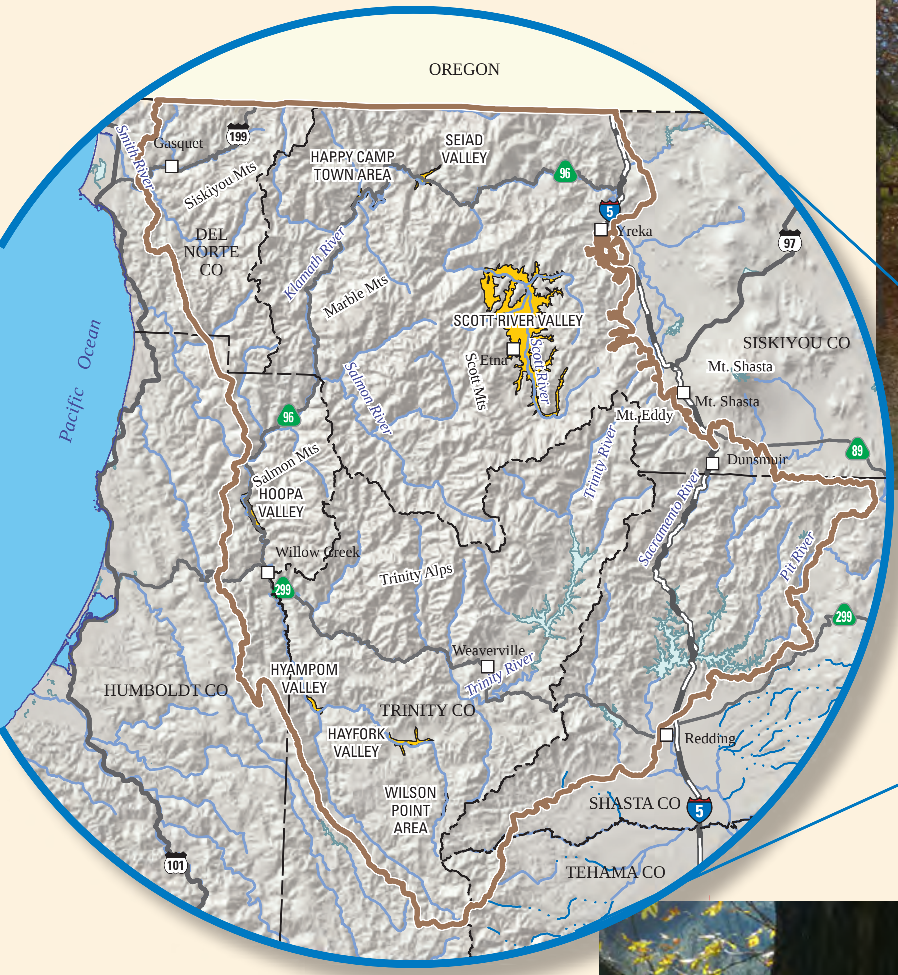

Data Series 803

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

Cover photographs:

Top photo: Well house near Lewiston, California. (Photograph by Tracy Davis, U.S. Geological Survey)

Bottom photo: Trinity River near Junction City, California. (Photograph by Dara Goldrath, U.S. Geological Survey)

Groundwater-Quality Data in the Klamath Mountains Study Unit, 2010: Results from the California GAMA Program

By Timothy M. Mathany and Kenneth Belitz

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Conversion Factors and Datums

Inch/Pound 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^2)	2.590	square kilometer (km^2)
quart (qt)	0.9464	liter (L)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

SI to Inch/Pound

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
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: °F=(1.8×°C)+32.

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

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

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

Concentrations of radioactive constituents in water (except uranium) 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).

Land-surface altitude, as used in this report, refers to distance above the vertical datum and is reported as feet above mean sea level (ft above msl).

Selected Terms and Symbols

α	significance level
x	activities of a radiochemical constituent in a groundwater sample
y	activities of a radiochemical constituent in a replicate sample
cm^3 STP/g	cubic centimeters of gas at standard temperature and pressure (0 degrees Celsius and 1 atmosphere of pressure) per gram of water
$\delta^{i}E$	delta notation, the ratio of a heavier isotope of an element (^{i}E) to the more common lighter isotope of that element, relative to a standard reference material, expressed as per mil
=	equal to
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
×	multiplied by
M	presence verified but not quantified
N	Normal (1-gram-equivalent per liter of solution)
—	not detected
p	p-value (probability)
pH	measure of the acidity of water
$pK_{1,2}$	acid dissociation constants of carbonic acid
pK_w	acid dissociation constant of water
R	ratio
σ	sigma (standard deviation)
±	plus or minus
*	concentration greater than benchmark level
**	concentration greater than upper benchmark level

Abbreviations and Acronyms

AL	action level
AL-US	action level (USEPA)
APE	Alternate Place Entry program designed for USGS sampling
CAS	Chemical Abstract Service
CASRN	Chemical Abstract Service (American Chemical Society) Registry Number®
CSU	combined standard uncertainty

Abbreviations and Acronyms—Continued

E	estimated or having a higher degree of uncertainty
GAMA	Groundwater Ambient Monitoring and Assessment Program
GPS	Global Positioning System
HAL	lifetime health advisory level
HAL-US	lifetime health advisory level (USEPA)
HPLC	high-performance liquid chromatography
IBSP	Inorganic Blind Sample Program (USGS)
KLAM	Klamath Mountains study unit
KLAM-U	Klamath Mountains study unit understanding (site)
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL	maximum contaminant 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
NELAP	National Environmental Laboratory Accreditation Program
NFM	National Field Manual (USGS)
NFQA	National Field Quality Assurance Program (USGS)
NL	notification level
NL-CA	notification level (CDPH)
np	no preference
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

Abbreviations and Acronyms—Continued

RPD	relative percent difference
RSD	relative standard deviation
RSD5-US	risk-specific dose at a risk factor of 10^{-5} (USEPA)
SD	standard deviation
SMCL	secondary maximum contaminant level
SMCL-CA	secondary maximum contaminant level (CDPH)
SMCL-US	secondary maximum contaminant level (USEPA)
SRL	study reporting level (concentration cutoff for applying the ≤ symbol in reporting results)
ssL_C	sample-specific critical level
TT-US	treatment technique (USEPA)
UV	ultraviolet
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

BQS	Branch of Quality Systems (USGS)
CDPH	California Department of Public Health
CDPR	California Department of Pesticide Regulation
CDWR	California Department of Water Resources
LLNL	Lawrence Livermore National Laboratory, Livermore, California
NAWQA	National Water-Quality Assessment Program (USGS)
NRP	National Research Program (USGS)
NWQL	National Water Quality Laboratory (USGS)
SITL	Stable Isotope and Tritium Laboratory, Menlo Park, California (USGS)
SWRCB	California State Water Resources Control Board
TML	Trace Metal Laboratory, Boulder, Colorado (USGS)
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
Weck	Weck Laboratories, Inc., City of Industry, California

Selected Chemical Names

$CaCO_3$	calcium carbonate
CO_3^{2-}	carbonate ion
H_2O	water
HCl	hydrochloric acid
HCO_3^-	bicarbonate ion
MEK	methyl ethyl ketone (2-butanone)
MTBE	methyl *tert*-butyl ether
PCE	perchloroethene (tetrachloroethene)
SiO_2	silicon dioxide
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound

Groundwater-Quality Data in the Klamath Mountains Study Unit, 2010: Results from the California GAMA Program

By Timothy M. Mathany and Kenneth Belitz

Abstract

Groundwater quality in the 8,806-square-mile Klamath Mountains (KLAM) study unit was investigated by the U.S. Geological Survey (USGS) from October to December 2010, 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 KLAM study unit was the thirty-third study unit to be sampled as part of the GAMA-PBP.

The GAMA Klamath Mountains study was designed to provide a spatially unbiased assessment of untreated-groundwater quality in the primary aquifer system and to facilitate statistically consistent comparisons of untreated-groundwater quality throughout California. The primary aquifer system is defined by the perforation intervals of wells listed in the California Department of Public Health (CDPH) database for the KLAM study unit. Groundwater quality in the primary aquifer system may differ from the quality in the shallower or deeper water-bearing zones; shallower groundwater may be more vulnerable to surficial contamination.

In the KLAM study unit, groundwater samples were collected from sites in Del Norte, Siskiyou, Humboldt, Trinity, Tehama, and Shasta Counties, California. Of the 39 sites sampled, 38 were selected by using a spatially distributed, randomized grid-based method to provide statistical representation of the primary aquifer system in the study unit (grid sites), and the remaining site was non-randomized (understanding site).

The groundwater samples were analyzed for basic field parameters, organic constituents (volatile organic compounds [VOCs] and pesticides and pesticide degradates), inorganic constituents (trace elements, nutrients, major and minor ions, total dissolved solids [TDS]), radon-222, gross alpha and gross beta radioactivity, and microbial indicators (total coliform and *Escherichia coli* [*E. coli*]). Isotopic tracers (stable isotopes of hydrogen and oxygen in water, isotopic ratios of dissolved strontium in water, and stable isotopes of carbon in dissolved inorganic carbon), dissolved noble gases, and age-dating tracers (tritium and carbon-14) were measured to help identify sources and ages of sampled groundwater.

Quality-control samples (field blanks, replicate sample pairs, and matrix spikes) were collected at 13 percent of the sites in the KLAM study unit, and the results were used to evaluate the quality of the data from the groundwater samples. Field blank samples rarely contained detectable concentrations of any constituent, indicating that contamination from sample collection or analysis was not a significant source of bias in the data for the groundwater samples. More than 99 percent of the replicate pair samples were within acceptable limits of variability. Matrix-spike sample recoveries were within the acceptable range (70 to 130 percent) for approximately 91 percent of the compounds.

This study did not evaluate the quality of water delivered to consumers. After withdrawal, groundwater typically is treated, disinfected, and (or) blended with other waters to maintain water quality. Regulatory benchmarks apply to water that is delivered to the consumer, not to untreated groundwater. However, 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 CDPH, and to non-health-based 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.

All concentrations of organic constituents from grid sites sampled in the KLAM study unit were less than health-based benchmarks. In total, VOCs were detected in 16 of the 38 grid sites sampled (approximately 42 percent), pesticides and pesticide degradates were detected in 8 grid sites (about 21 percent), and microbial indicators were detected in 14 grid sites (approximately 37 percent).

Inorganic constituents (trace elements, major and minor ions, nutrients, and uranium and other radioactive constituents) and microbial indicators were sampled for at 38 grid sites, and

all concentrations were less than health-based benchmarks, with the exception of one detection of boron greater than the CDPH notification level of 1,000 micrograms per liter (µg/L). Generally, concentrations of inorganic constituents with non-health-based benchmarks (iron, manganese, chloride, and TDS) were less than the CDPH secondary maximum contaminant level (SMCL-CA). Exceptions include three detections of iron greater than the SMCL-CA of 300 µg/L, four detections of manganese greater than the SMCL-CA of 50 µg/L, one detection of chloride greater than the recommended SMCL-CA of 250 µg/L, and one detection of TDS greater than the recommended SMCL-CA of 500 µg/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 aquifers used for public 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 in 2000 (California State Water Resources Control Board, 2011). 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, 2011a); (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 GAMA-PBP was initiated by the Groundwater Quality Monitoring Act of 2001 (State of California, 2001a, b; Sections 10780–10782.3 of the California Water Code, Assembly Bill 599). The USGS, in collaboration with the SWRCB, developed a monitoring plan to assess groundwater basins through direct and other statistically reliable sample approaches (Belitz and others, 2003; California State Water Resources Control Board, 2003). Additional partners in the GAMA-PBP include LLNL, the California Department of Public Health (CDPH), California Department of Water Resources (CDWR), California Department of Pesticide Regulation (CDPR), local water agencies, and well owners (Kulongoski and Belitz, 2004). The GAMA-PBP examines the part of the aquifer system used for public drinking-water supply, which typically is deeper than the part of the aquifer system used for domestic drinking-water supply. The GAMA Domestic Well Project generally focuses on the shallower aquifer systems, which may be particularly at risk as a result of surficial contamination. 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 interface serving all published and quality-assurance/quality-control (QA/QC) approved analytical data from the GAMA Program (California State Water Resources Control Board, 2009). GeoTracker GAMA also stores groundwater-quality data and related reports collected by other State agencies, such as the CDPH, CDWR, and CDPR, and data collected by the SWRCB and Regional Boards from groundwater monitoring wells at contaminated or remediated sites.

The GAMA-PBP is unique in California because it includes many chemical analyses that are not otherwise available in the statewide water-quality monitoring datasets. Groundwater samples collected for the GAMA-PBP are analyzed for approximately 300 chemical constituents by using methods with lower detection limits than required by the CDPH for regulatory monitoring of water from drinking-water wells. These analyses will be especially useful for providing an early indication of changes in groundwater quality. In addition, the GAMA-PBP analyzes samples for a suite of constituents more extensive than required by the CDPH and for a suite of chemical and isotopic tracers that can be used to further the understanding of hydrologic and geochemical processes. This 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.

In order to delineate areas for evaluation as part of the GAMA-PBP, the range of hydrologic, geologic, and climatic conditions in California needed to be considered. Belitz and others (2003) partitioned the State into 10 hydrogeologic provinces, each with distinctive hydrologic, geologic, and climatic 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 472 groundwater basins designated by the CDWR (California Department of Water Resources, 2003). Groundwater basins generally consist of relatively permeable, unconsolidated deposits of alluvial origin. Eighty percent of California’s approximately 16,000 active and standby drinking-water wells (and springs) listed in the statewide database maintained by the CDPH (hereinafter referred to as CDPH sites) are located in groundwater basins. Groundwater basins were prioritized for sampling on the basis of the number of CDPH wells in the basin, with secondary consideration given to municipal groundwater use, agricultural pumping, the number of formerly leaking underground fuel tanks, and the number of square-mile sections with registered pesticide applications (Belitz and others, 2003). Of the 472 basins designated by the CDWR, 116 contain approximately 95 percent of the CDPH wells located in basins. These 116 basins were defined as “priority basins,” and the

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

Provinces from Belitz and others, 2003

Figure 1. Hydrogeologic provinces of California and the location of the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit.

remaining 356 basins were defined as "low-use basins." All of the priority basins, selected low-use basins, and selected areas outside of groundwater basins were grouped into 35 GAMA Priority Basin Project study units that together represent approximately 95 percent of all CDPH wells.

The entire Klamath Mountains hydrogeologic province was defined as the Klamath Mountains (KLAM) study unit (fig. 1). The KLAM study unit includes seven priority basins and areas outside of groundwater basins. Groundwater is a major source of public drinking-water supply for many of the communities located in the KLAM study unit (Water Education Foundation, 2006; Dunsmuir Chamber of Commerce, 2012); therefore, the KLAM study unit was considered high priority for sampling to provide adequate representation of the Klamath Mountains hydrogeologic province.

The data collected in each study unit are used for three types of water-quality assessments: (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 are intended to characterize the quality of groundwater in the primary aquifer system of the study units, not the treated drinking water delivered to consumers by water purveyors. The primary aquifer system is defined as parts of aquifers corresponding to the perforation intervals of wells listed in the CDPH databases for the study units. The CDPH database lists wells and springs used for public drinking-water supplies and includes wells and springs from systems classified as community (such as those in cities, towns, and mobile-home parks), non-transient, non-community (such as those in schools, workplaces, and restaurants), and transient, non-community (such as those in campground and parks). Collectively, the CDPH refers to these as "public-supply" wells and springs (hereinafter referred to as CDPH sites). Groundwater quality in the primary aquifer system may differ from the quality in the shallow or deep parts of the aquifer system.

This USGS Data Series Report is one of a series of reports presenting the water-quality data collected by the USGS in the KLAM study unit for the GAMA-PBP. Data Series Reports for each of the GAMA-PBP study units are available from the U.S. Geological Survey (2011b) at http://ca.water.usgs.gov/projects/gama/includes/GAMA_publications.html.

Purpose and Scope

The purposes of this report are to describe (1) the hydrogeologic setting of the KLAM study unit, the study design, and the study methods; (2) the analytical results for groundwater samples collected in the KLAM study unit, and (3) the results of QC analyses. Groundwater samples were collected and analyzed for water-quality indicators; organic and inorganic constituents; isotopic and age-dating tracers; microbial indicators; and dissolved gases. The chemical data presented in this report were compared to State and Federal drinking-water standards. The health-based and non-health-based benchmarks considered are those established by the U.S. Environmental Protection Agency (USEPA) and (or) the CDPH. 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 KLAM study unit is located in a large region of northern California between the Northern Coast Ranges and the Cascades and Modoc Plateau hydrogeologic provinces (Belitz and others, 2003; fig. 1) and covers an area of 8,806 square miles (mi^2) in parts of Del Norte, Siskiyou, Humboldt, Trinity, Tehama, and Shasta Counties, California (fig. 2).

The study unit boundary extends from approximately 10 miles (mi) northwest of the city of Redding to the California/Oregon border (135 mi to the north) and from about 10 mi inland of the Pacific Ocean to the border of the Cascades and Modoc Plateau hydrogeologic province (about 125 mi to the east, fig. 1). The study unit is characterized by high peaks and continuous ridgelines separated by deep river gorges. These gorges separate the study unit into several distinct mountain ranges, including the Trinity Alps and the Siskiyou, Scott, Marble, and Salmon Mountains (fig. 2).

Land-surface altitudes in the study area range from about 400 feet above mean sea level (ft above msl) near the town of Gasquet, to over 9,000 ft above msl on Mount Eddy, located just west of the city of Mt. Shasta (figs. 2, 3A, 3B). The study unit includes parts of three major watersheds. Most of the study unit is drained by the Klamath River and its major tributaries, the Trinity and Salmon Rivers and their headwaters. The northwestern corner of the study unit is in the Smith River drainage basin (fig. 3A), and the southeastern corner of the study unit is drained by the Sacramento River and its tributary, the Pit River (fig. 3E). Shasta Lake on the Sacramento River and Trinity (Clair Engle) Lake on the upper Trinity River are large human-made reservoirs that supply water for the Federal Central Valley Project (fig. 3D). Water is diverted from the Trinity River to the Sacramento River through a tunnel in the Trinity Alps and the human-made Whiskeytown Lake reservoir (fig. 3D).

The climate in the study unit is typical of mountainous areas in northern California, with hot summers and cold winters (U.S. Department of Commerce, National Climatic Data Center, 2012). Generally, precipitation in the study unit

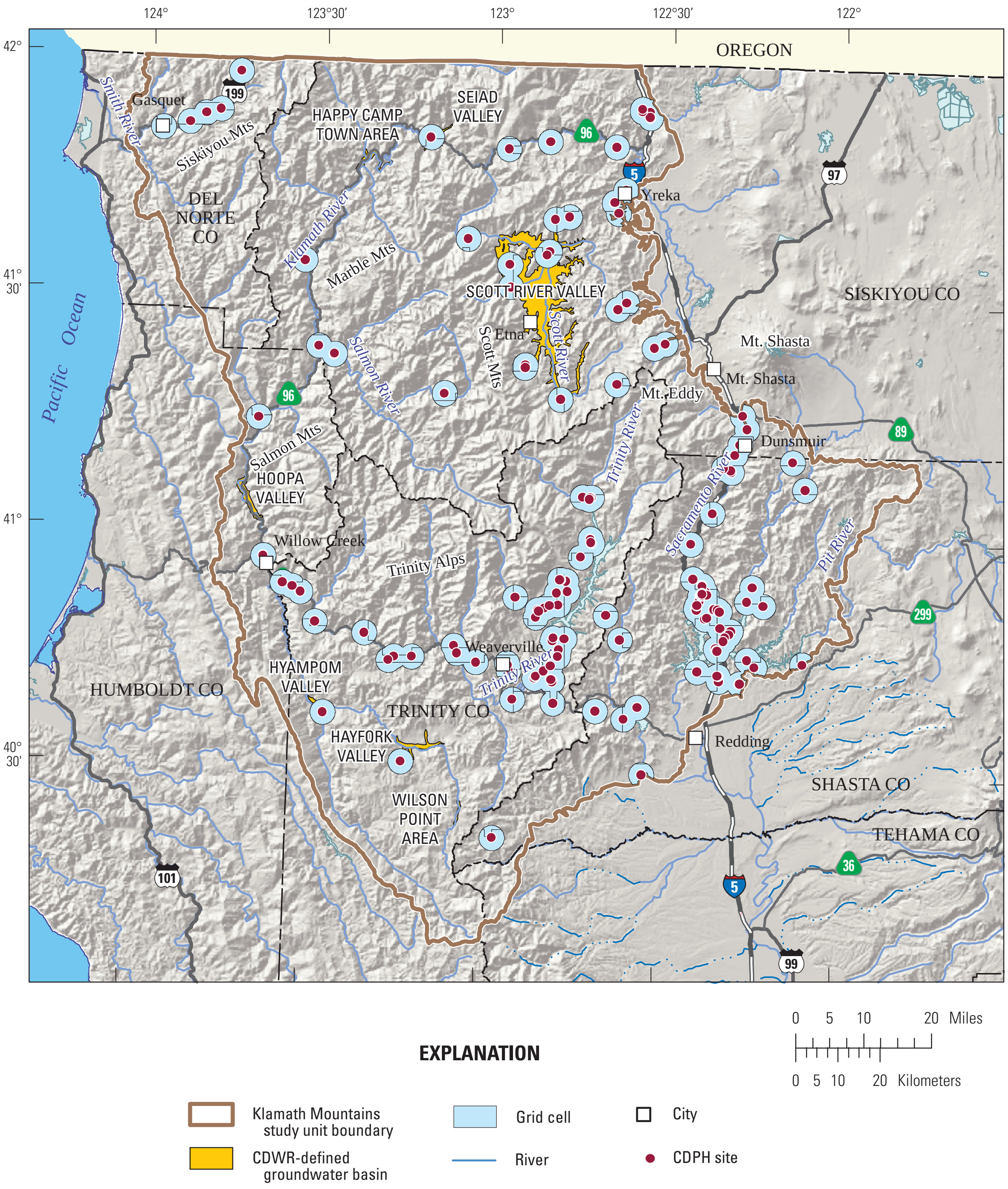


Figure 2. Boundaries of the Klamath Mountains (KLAM) study unit, topographic features, major cities, major roads, hydrologic features, the location of California Department of Public Health (CDPH) sites, and the distribution of the grid cells. [CDWR, California Department of Water Resources]

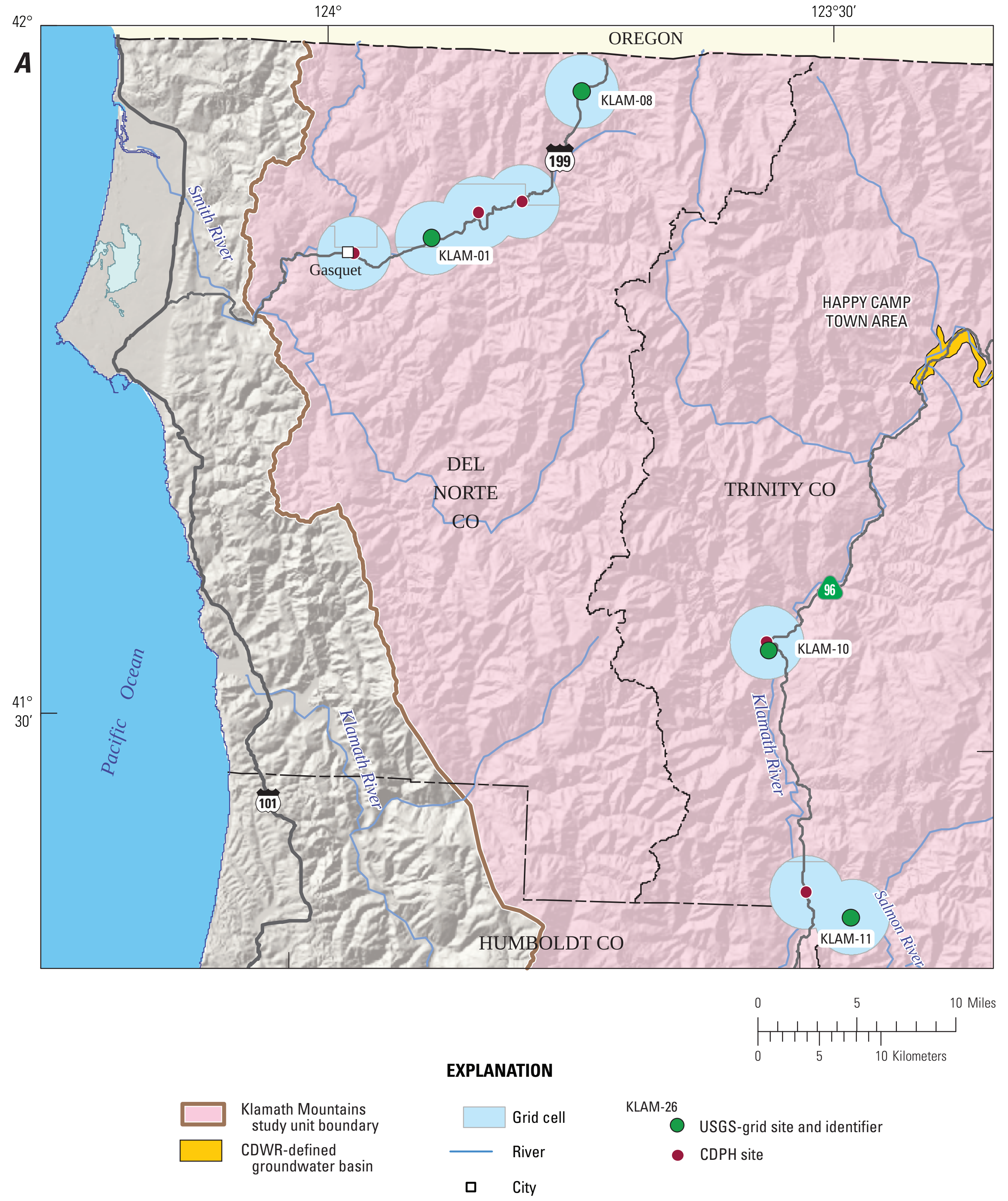


Figure 3*A*–*E*. Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, the distribution of the grid cells, sampled sites, the location of California Department of Public Health (CDPH) sites, major cities, and major roads. [CDWR, California Department of Water Resources]

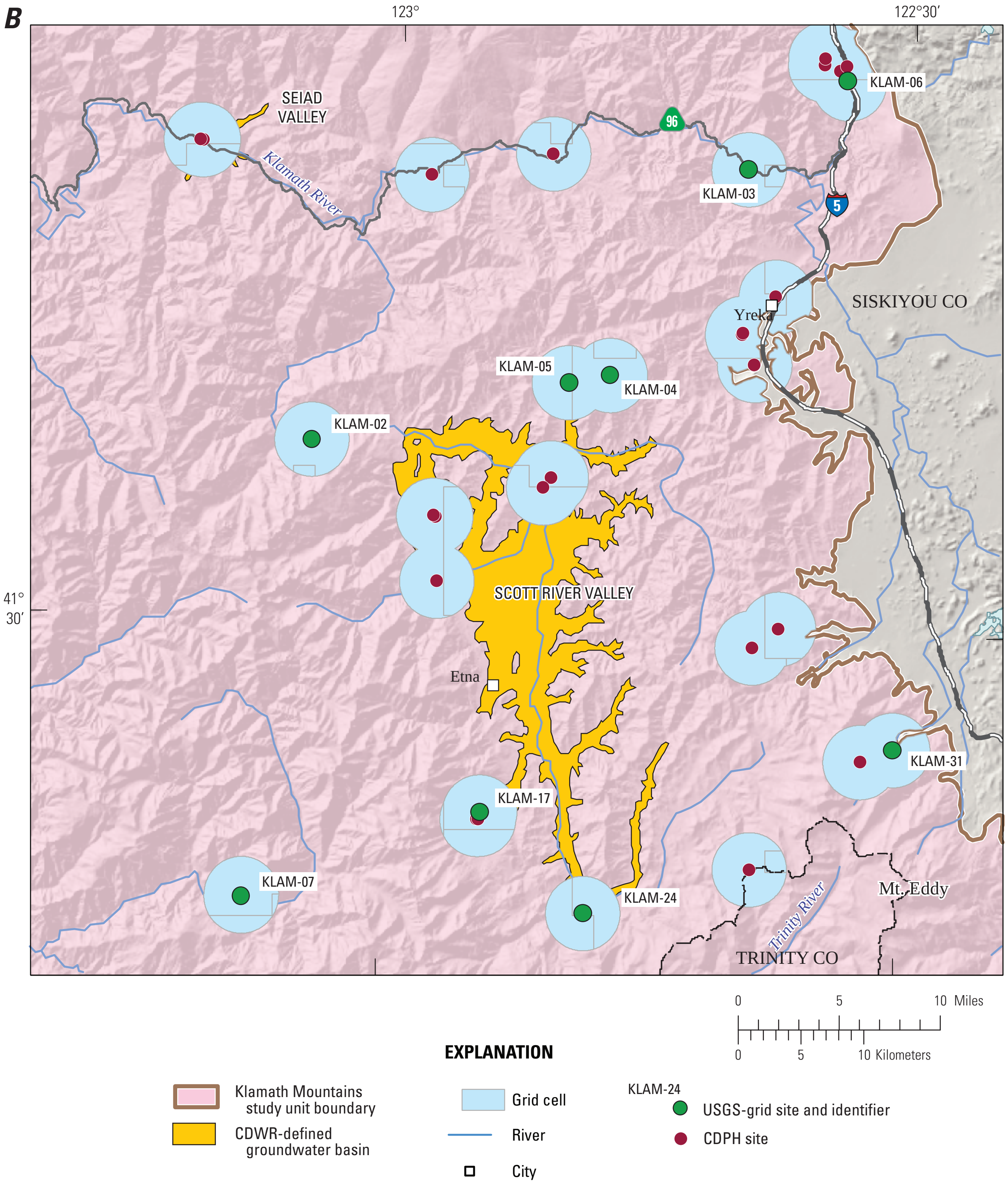


Figure 3*A*–*E*.—Continued

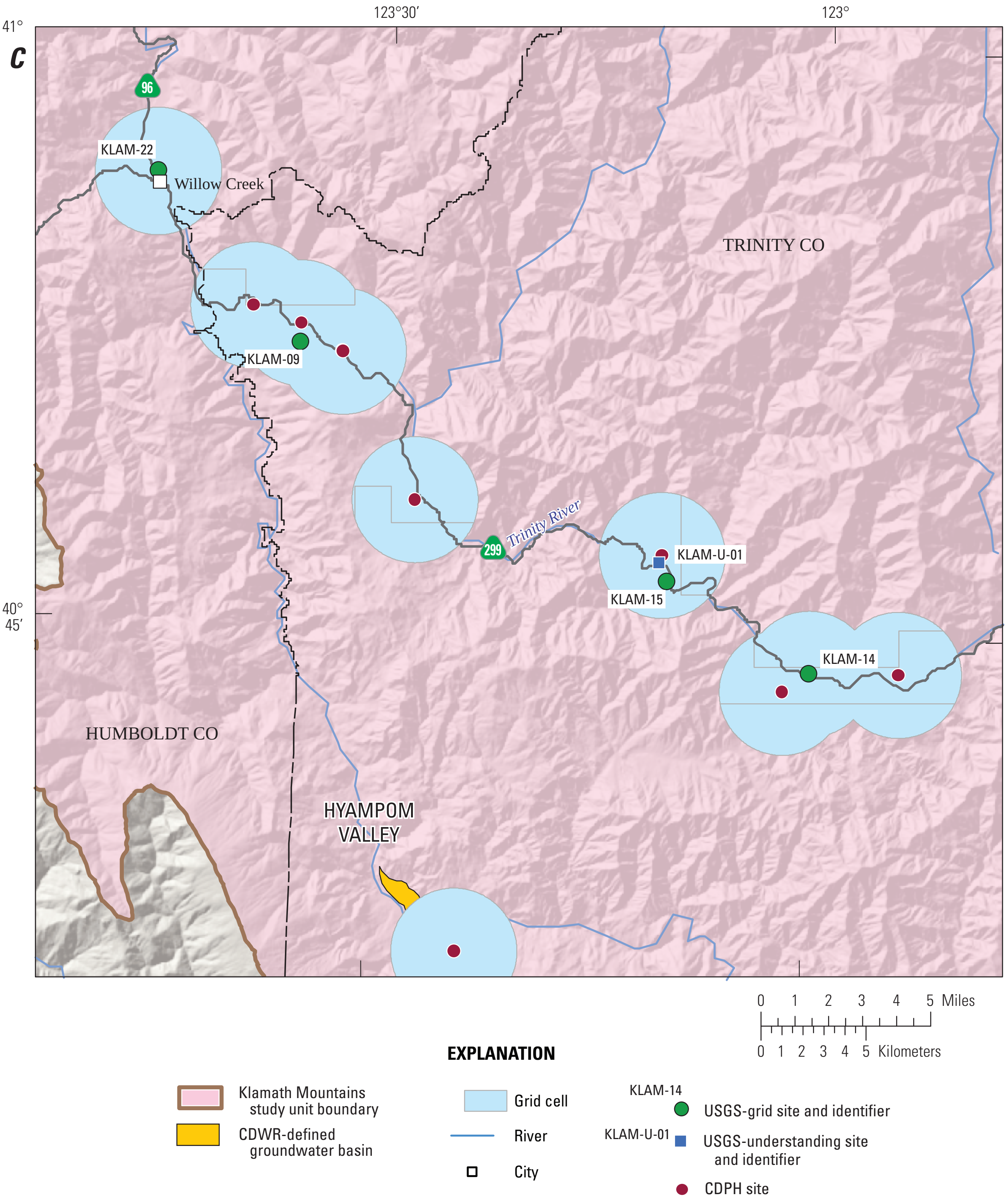


Figure 3*A*–*E*.—Continued

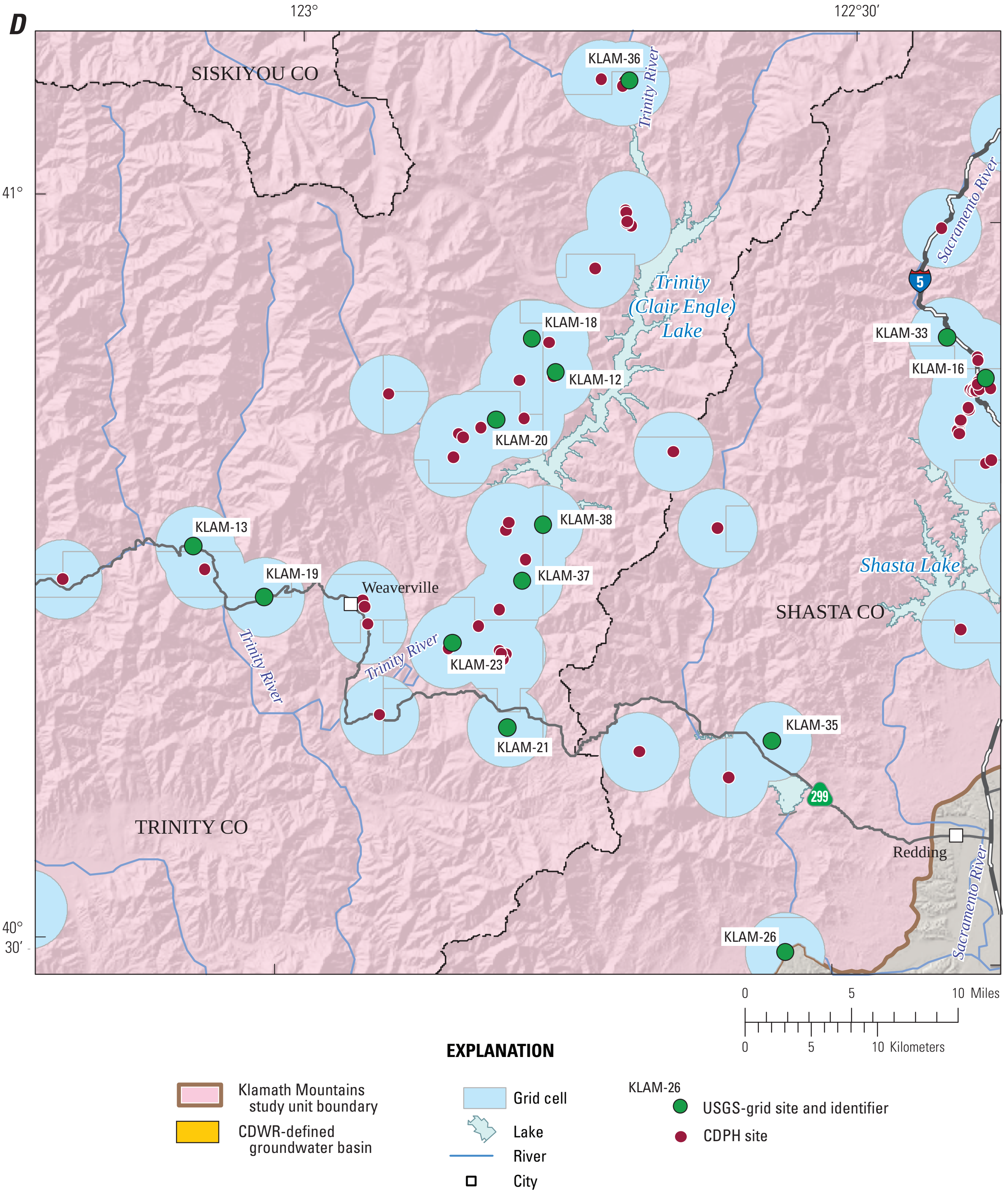


Figure 3*A–E*.—Continued

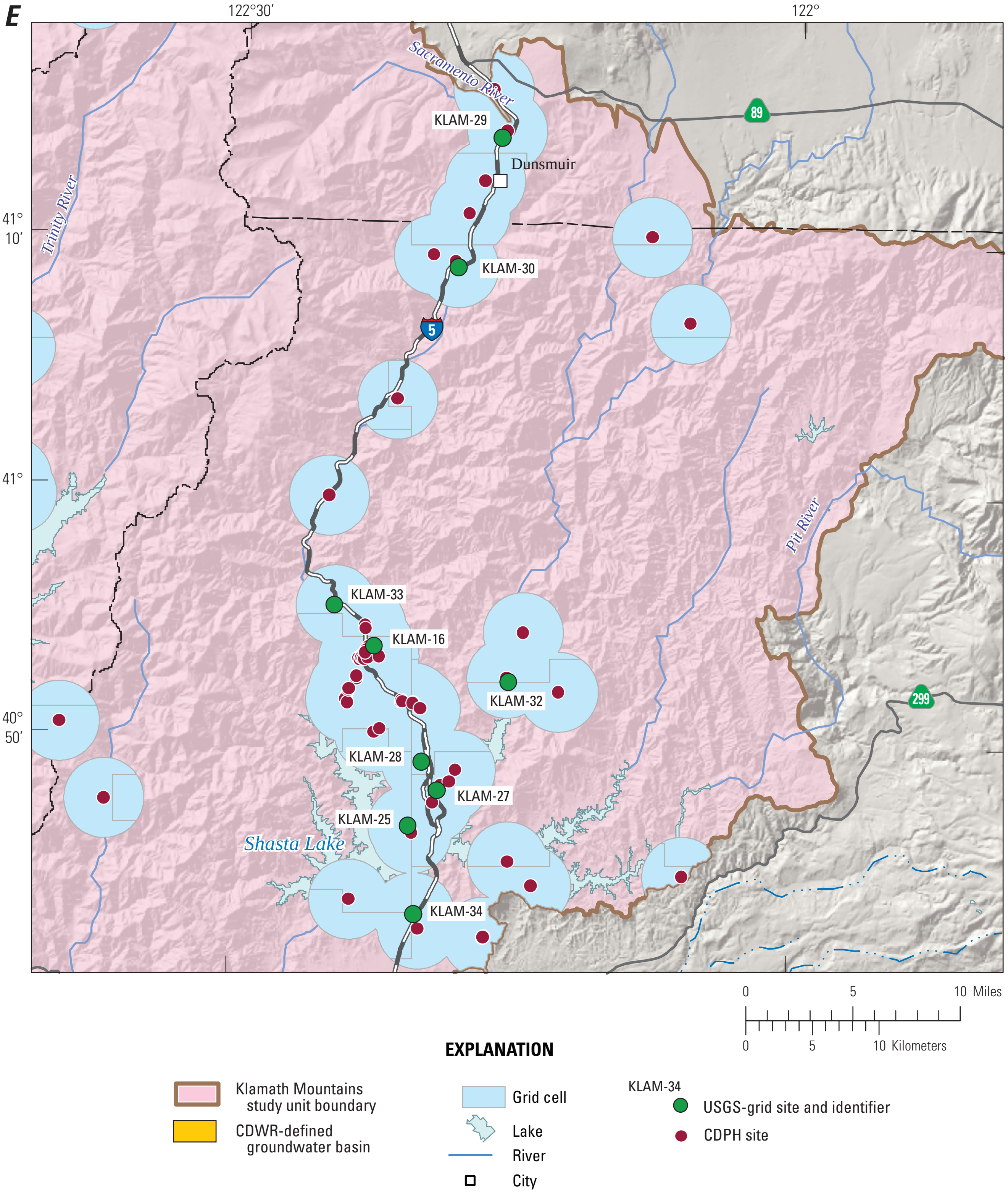
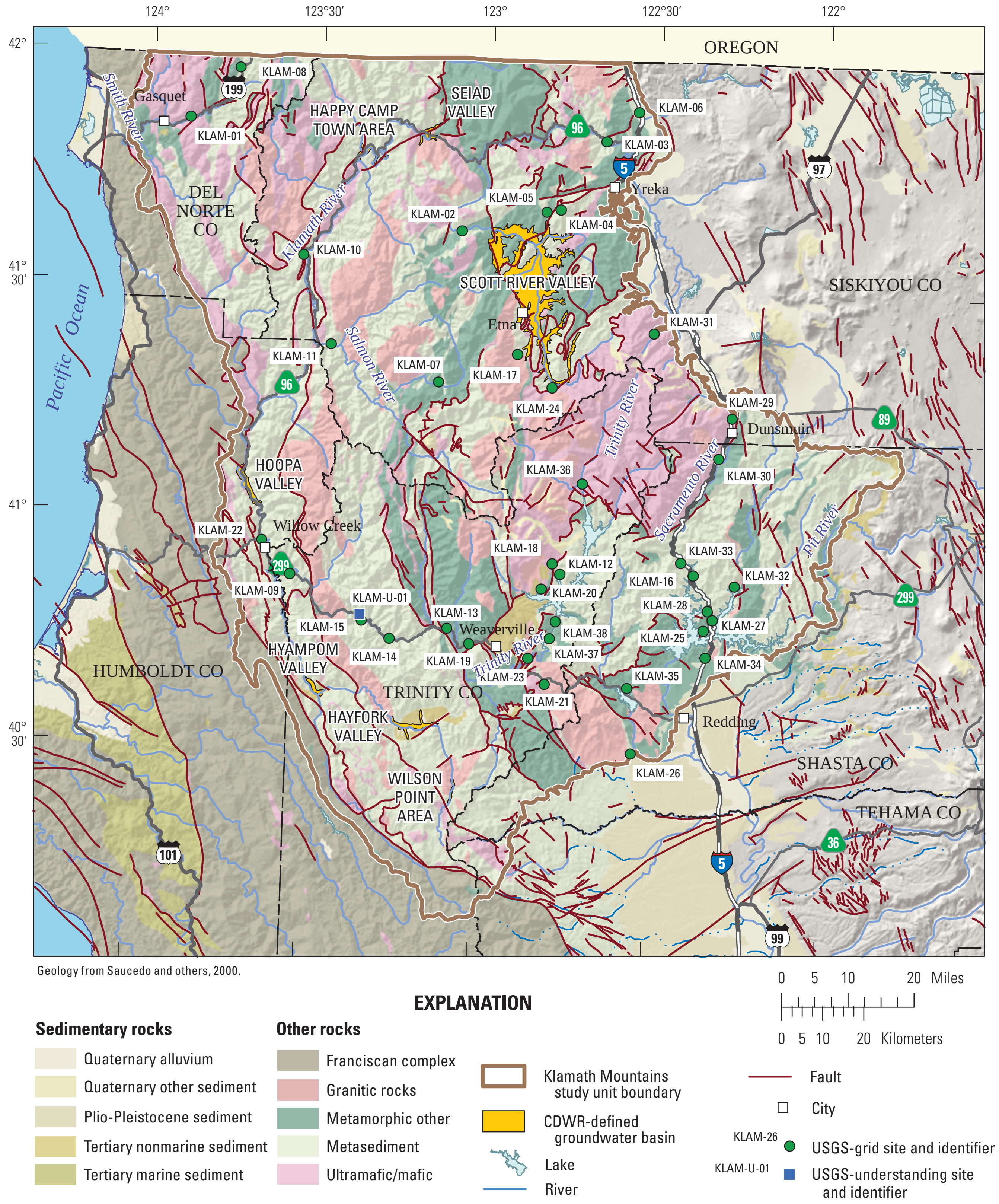


Figure 3*A*–*E*.—Continued



Geology from Saucedo and others, 2000.

EXPLANATION

Sedimentary rocks
- Quaternary alluvium
- Quaternary other sediment
- Plio-Pleistocene sediment
- Tertiary nonmarine sediment
- Tertiary marine sediment

Other rocks
- Franciscan complex
- Granitic rocks
- Metamorphic other
- Metasediment
- Ultramafic/mafic

- Klamath Mountains study unit boundary
- CDWR-defined groundwater basin
- Lake
- River
- Fault
- ☐ City
- KLAM-26 ● USGS-grid site and identifier
- KLAM-U-01 ■ USGS-understanding site and identifier

Figure 4. Geology of the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit. [CDWR, California Department of Water Resources]

reflects a rain shadow effect from west to east due to the repeated mountain ranges, whereas snowfall increases from south to north with elevation. Average annual precipitation in the study unit ranges from about 69 inches (in.) on the western edge of the study unit along the Northern Coast Ranges to about 40 in. in the central and eastern parts of the study unit (U.S. Department of Commerce, National Climatic Data Center, 2012; Western Regional Climate Center, 2012). Annual snow accumulation averages approximately 9 in. in the southern part of the study unit, 14 in. in the central part, and 22 in. in the northern reaches of the study unit (U.S. Department of Commerce, National Climatic Data Center, 2012; Western Regional Climate Center, 2012).

Geologically, the study unit is composed predominantly of Mesozoic volcanic rocks and Paleozoic to Mesozoic marine sedimentary and ophiolitic rocks (fig. 4). Regional studies conducted by the USGS and others have divided the Klamath Mountains geological region into nine terranes separated from each other by major east-dipping fault zones (Irwin and Wooden, 1999; Snoke and Barnes, 2006). The terranes are bounded by regional thrust faults that are older in eastern parts of the study unit and younger to the west. Additionally, granitic plutons of Mesozoic age were emplaced into the terranes in several areas of the study unit (Snoke and Barnes, 2006). Metamorphism occurred before and after accretion of these terranes along the edge of the North American plate during subduction of the Gorda plate (Wright, 1982).

For the purposes of this report, the sampled sites were classified by the general rock type in which they are located by use of a simplified ArcGIS geology layer modified by the GAMA Program (Saucedo and others, 2000). Within the KLAM study unit boundary, there are four dominant classifications of rock types: granitic (dark pink), metamorphic other (dark green), metasediment (light green), and ultramafic/mafic (light pink) (fig. 4). In summary, 4 sampling sites were located in granitic rock, 9 sites in metamorphic other rock, 19 sites in metasediment rock, and 7 sites in ultramafic/mafic rock.

The primary aquifer system in most of the study unit is made up of localized areas of fractured bedrock generally considered to be confined to semi-confined (Mack, 1960). In addition to production wells that are bored into the bedrock, numerous springs and horizontal wells are a significant source of water for many communities and campgrounds located within the study unit (Dunsmuir Chamber of Commerce, 2012; K. Stagg, U.S. Forest Service, Klamath National Forest, written commun., 2012). These springs and horizontal wells flow under artesian conditions for all or most of the year. The seven CDWR-defined groundwater basins (Scott River Valley, Hayfork Valley, Hoopa Valley, Happy Camp Town Area, Seiad Valley, Hyampom Valley, and Wilson Point Area) consist of alluvial fan, stream channel, and floodplain deposits of Quaternary age located within the study unit (California Department of Water Resources, 2004a–g: fig. 4). No sample sites were available during the period of study within these groundwater basins, and the connection between these alluvial deposits and the hard rock aquifer systems is unknown.

Groundwater recharge in the study unit consists of precipitation runoff, snowmelt, and streamflow that penetrate the bedrock through faults and fractures (California Department of Water Resources, 1984). Groundwater flow in the study unit is through numerous fracture systems related to local and regional faults. Unlike large groundwater basins which can develop regional-scale groundwater-flow patterns, the groundwater-flow patterns in steep mountainous terrains are controlled at much more localized scales that are dependent on local topography, faults and fracture systems, and the arrangement of discharge zones (Toth, 1963; Snoke and Barnes, 2006).

Methods

Methods used for the GAMA-PBP were selected to achieve the following objectives: (1) collect groundwater samples that are statistically representative of the primary aquifer system in each study unit; (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. The appendix contains detailed descriptions of the sample-collection protocols, analytical methods, and the QC data analysis.

Study Design

The wells and springs (hereinafter referred to as “sites”) selected for sampling in the KLAM study unit were selected to provide a statistically unbiased, spatially distributed assessment of the quality of groundwater used for public drinking-water supply.

The area of the KLAM study unit where groundwater is used for public drinking-water supply was divided into grid cells, and the objective was to sample one site in each cell (hereinafter referred to as “grid sites”). The KLAM study unit has 204 CDPH sites; however, these sites are not evenly distributed. To minimize the number of cells having no potential sampling sites, only the parts of the study unit near CDPH sites were included in the gridded area. A 1.86-mi (3-km) radius circle was drawn around each CDPH site, and the collective area encompassed by the circles was divided into forty 23-mi^2 (60-km^2) grid cells (Scott, 1990). A single grid cell may consist of non-contiguous pieces separated by non-gridded areas.

The CDPH sites all were assigned random rankings, and the highest ranking CDPH site in each cell that met basic sampling criteria (for example, sampling point located prior to treatment or capability to pump for several hours) and for which permission to sample could be obtained was sampled as the grid site. If a grid cell contained no accessible CDPH sites, then door-to-door canvassing and USGS databases were used to identify domestic, irrigation, and other wells appropriate for sampling. The non-CDPH wells selected as grid sites had depths and screened intervals similar to those in CDPH wells in the area. Grid sites were sampled in in 38 of the 40 grid cells; the other 2 cells contained no accessible sites. The 38 grid sites sampled were numbered in the order in which samples were collected with the prefix of "KLAM."

One additional off-grid site was sampled and hereinafter is referred to as the "understanding site" for consistency with the nomenclature used for non-grid sites in reports for other GAMA PBP study units. This site was not included in the statistical characterization of water quality in the KLAM study unit because inclusion of this site would have led to the overrepresentation of the previously sampled grid cells. This additional site was named with the prefix "KLAM-U" ("U" indicates "understanding") (fig. 3C). The GAMA site identification number for each sample, along with the date sampled, site type, land-surface altitude, and available construction information, is shown in table 1. Groundwater samples were collected from 32 production wells (30 CDPH wells, 1 domestic well, and 1 commercial well) and 7 CDPH springs during the time period from October to December 2010.

Site 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, and other sources of site information. Site and sample information were recorded in the field 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 entered into the USGS National Water Information System (NWIS) database. Site owner, site use, and site location are not published.

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 (Koterba and others, 1995) sampling protocols. These sampling protocols were followed so that samples representative of groundwater in the aquifer were collected at each site and so that the samples were collected and handled in ways that minimized the potential for contamination. Use of the sampling protocols also allows comparison with data collected by GAMA-PBP throughout California and with other USGS projects in California and the Nation.

All 39 sites in the KLAM study unit were sampled for the same set of constituents (table 2). Groundwater samples were analyzed for 85 VOCs (table 3A); 63 pesticides and pesticide degradates (table 3B); perchlorate (table 3C); 24 trace elements (table 3D); 5 nutrients (table 3E); 9 major and minor ions, silica, total dissolved solids (TDS), and alkalinity (table 3F); arsenic and iron species (table 3G); 6 isotopic tracers, uranium and 9 other radioactive constituents, and 5 dissolved noble gases (table 3H); and 2 microbial indicators (table 3I). The methods used for sample collection and analysis are described in the appendix section titled "Sample Collection and Analysis."

Data Reporting

Many of the constituents presented in this report have different laboratory reporting conventions; additionally, some of the constituents were analyzed by different analytical laboratories or methods. The appendix section titled "Data Reporting" gives details for the laboratory reporting conventions for all constituents and the method preferences for those constituents that were analyzed by multiple methods or by multiple laboratories in the KLAM study unit.

Quality-Assurance Methods

The QA/QC procedures used for this study followed the protocols described in the NFM (U.S. Geological Survey, variously dated) and used by the NAWQA Program (Koterba and others, 1995). The QA plan followed by the National Water Quality Laboratory (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 KLAM study unit were field blanks, replicate sample pairs, and matrix- and surrogate-spike samples. 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 appendix section titled "Quality-Assurance and Quality-Control Methods and Results."

Quality-Control Results

Results of QC analyses (field blank samples, replicate sample pairs, and matrix- and surrogate-spike samples) were used to evaluate the quality of the data for the groundwater samples. On the basis of detections in laboratory and field blank samples collected for this and for previous GAMA-PBP study units, the reporting levels (RLs) for three VOCs and nine trace elements were raised in this report (Olsen and others, 2010; Fram and others, 2012). The GAMA Program refers to these raised reporting levels as "study reporting levels" (SRLs). Detections of the three VOCs reported by the laboratory with concentrations less than the SRL were considered non-detections in this study to reduce the likelihood of reporting results that could be false positives. Data for perchlorate are not presented in this report because the data failed to meet the GAMA-PBP QC standards. Detections of the nine inorganic constituents with concentrations less than the SRL were flagged with a less than or equal to symbol (≤) in this report because the concentrations of these constituents could be less than or equal to the reported value (see table A3 and additional discussion in the appendix section titled "Field Blank Samples"). Variability for more than 99 percent of the replicate sample pairs for constituents detected in samples was within the acceptable limits. Results from the replicate sample pairs confirm that the procedures used to collect, process, and analyze the samples did not introduce unacceptable levels of variability (see tables A4A–D and additional discussion in the appendix section titled "Replicate Sample Pairs"). Median matrix-spike sample recoveries for 17 of the 148 organic constituents analyzed were less than the acceptable range of between 70 and 130 percent. Some constituents with low recoveries might not have been detected in some samples if they were present at concentrations near the laboratory reporting levels (LRLs). Exceptions include deethylatrazine (2-chloro-4-isopropylamino-6-amino-*s*-triazine) and hexazinone, both of which had low median matrix-spike recoveries and were detected in groundwater samples (see table A5B and additional discussion in the appendix section titled "Matrix-Spike Samples").

Comparison Benchmarks

Concentrations of constituents detected in groundwater samples were compared with USEPA and CDPH regulatory and non-regulatory drinking-water health-based benchmarks and benchmarks established for aesthetic purposes (U.S. Environmental Protection Agency, 2008b, 2009; California Department of Public Health, 2010a, b). The chemical data presented in this report are meant to characterize the quality of the untreated groundwater within the primary aquifer system of the KLAM study unit and are not intended to represent the treated drinking water delivered to consumers by water purveyors. 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 delivery to consumers. Comparisons of untreated groundwater to benchmarks are for illustrative purposes only and are not indicative of compliance or non-compliance with drinking-water regulations. Comparison benchmarks were selected in the following order of priority (for example, if a constituent had an MCL-CA and a HAL-US, the MCL-US was selected because it has higher priority).

1. **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; however, 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 concentration for a number of constituents. In this report, a benchmark set by the USEPA and adopted by the CDPH is labeled "MCL-US," and one set by CDPH that is more stringent than the MCL-US is labeled "MCL-CA." Site 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.

2. **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, the benchmarks are labeled "AL-US" in this report.

3. **TT–Treatment Technique.** A legally required process intended to reduce the level of a contaminant in drinking water. TT requires mandatory additional disinfection during water treatment when water delivered to consumers exceeds specified action levels. The action levels established by the USEPA and CDPH are the same, thus these benchmarks are labeled "TT-US" in this report.

4. **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 the CDPH are not required to be at least as stringent as those established by USEPA. SMCLs established by the CDPH are used in this report (SMCL-CA). 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 for these constituents corresponds to the recommended SMCL-CA. The SMCL-US is used for pH because no SMCL-CA has been defined.

5. **NL–Notification Level.** Health-based notification levels have been established by the CDPH (NL-CA) for some of the constituents in drinking water that lack MCLs. If a constituent is detected at concentrations greater than its NL-CA, California State law requires timely notification of local governing bodies and recommends consumer notification.

6. **HAL–Lifetime Health Advisory Level.** The maximum concentration of a constituent at which its presence in drinking water is not expected to cause any adverse carcinogenic effects for a lifetime of exposure. HALs are established by the USEPA (HAL-US) and are calculated assuming consumption of 2 liters (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.

7. **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. RSD5s are calculated by dividing the 10^{-4} cancer-risk concentration established by the USEPA by 10 (RSD5-US).

The comparison benchmarks used in this report are listed in tables 3A–I for all constituents and in tables 4–14 for constituents detected in groundwater samples from the KLAM study unit. Not all constituents analyzed for this study have established benchmarks available. Detections of constituents at concentrations greater than the selected comparison benchmark are marked with asterisk (*) in tables 4, 7, 9, and 10.

Water-Quality Results

Results from analyses of groundwater samples from the KLAM study unit are presented in tables 4–14. Groundwater samples collected in the KLAM study unit were analyzed for up to 220 unique constituents; 137 of those were not detected in any of the samples, and 83 constituents were detected (tables 3A–I, 4).

Water-quality indicators measured in the field and at the NWQL are summarized in table 4. The results of groundwater analyses organized by compound classes are presented in tables 5–14:

- Organic constituents
  - Volatile organic compounds (table 5)
  - Pesticides and pesticide degradates (table 6)
- Inorganic constituents
  - Trace elements (table 7)
  - Nutrients (table 8)
  - Major and minor ions, silica, and TDS (table 9)
- Arsenic and iron species (table 10)
- Isotopic tracers (table 11)
- Tritium, dissolved noble gases, and helium isotope ratios (table 12)
- Uranium and other radioactive constituents (table 13)
- Microbial indicators (table 14)

Water-Quality Indicators (Field and Laboratory)

Measurements of dissolved oxygen, pH, specific conductance, alkalinity, and associated parameters (water temperature and bicarbonate and carbonate concentrations) are presented in table 4. Dissolved oxygen, alkalinity, bicarbonate, and carbonate concentrations are used as indicators of natural processes that affect water chemistry.

The pH value indicates the acidity of the water. Low pH in water may contribute to corrosion of pipes, and high pH in water may contribute to scaling. Field pH values for 9 of the 38 of the grid sites sampled in the KLAM study unit were outside of the SMCL-US range for pH (< 6.5 or > 8.5) (table 4). Laboratory pH values for three of the grid sites were outside of the SMCL-US range for pH. Laboratory pH values may be dissimilar to field pH values because the pH of groundwater may change upon removal from the ambient environment and exposure to the atmosphere; therefore, the field measurements are preferred over the laboratory results.

Specific conductance is the measure of electrical conductivity of the water and is proportional to the amount of dissolved solids in the water. Field and laboratory specific-conductance values for 1 of the 38 grid sites sampled were greater than the upper SMCL-CA benchmark of 1,600 microsiemens per centimeter at 25 degrees Celsius (µS/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 in the KLAM study unit, 10 were detected in groundwater samples; all concentrations were less than health-based benchmarks (table 5). One or more VOCs were detected in 16 of the 38 grid sites sampled (about 42 percent detection frequency). Chloroform (trichloromethane) was the only VOC detected in more than 10 percent of the grid sites in the KLAM study unit. Chloroform is among the most commonly detected VOCs in groundwater nationally (Zogorski and others, 2006).

Pesticides (herbicides, insecticides, and fungicides) are chemicals used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. Pesticide degradates are the product of the environmental transformations of the parent pesticide, and they can have similar properties to the parent pesticide (Andreu and Pico, 2004).

Of the 83 pesticides and pesticide degradates analyzed in the KLAM study unit, 4 were detected in groundwater samples (deethylatrazine, atrazine, simazine, and hexazinone); all concentrations were less than health-based benchmarks (table 6). One or more pesticide compounds were detected in 8 of the 39 grid sites sampled (about 21 percent detection frequency). Deethylatrazine, a degradate of atrazine, was detected in more than 10 percent of the grid sites in the KLAM study unit. Deethylatrazine, simazine, and atrazine are among the Nation's most commonly detected pesticide compounds in groundwater (Gilliom and others, 2006).

Inorganic Constituents

Health-based or non-health-based benchmarks have been established for 22 of 25 trace elements analyzed in this study (tables 3D, F). Of the 18 trace elements with health-based benchmarks, all detected concentrations at the sites sampled in the KLAM study unit were less than established benchmarks, with the exception of one detection of boron that was greater than the NL-CA of 1,000 micrograms per liter (µg/L) (KLAM-06; table 7).

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. All concentrations of nutrients measured in the KLAM study unit were less than health-based benchmarks (table 8).

The CDPH has established non-health-based secondary benchmarks (SMCL-CAs) that are based on aesthetic properties (such as taste, color, and odor) and technical properties (such as scaling and staining) of water, rather than on human-health concerns for iron, manganese, silver, zinc, chloride, sulfate, and TDS.

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 samples from three grid sites, and manganese concentrations greater than the SMCL-CA of 50 µg/L were detected in samples from four grid sites. Chloride and TDS were both detected at a concentration greater than their recommended SMCL-CA benchmarks (250 mg/L and 500 mg/L, respectively) in a sample from one grid site (table 9). Additionally, all silver and zinc concentrations detected in samples from KLAM study unit sites were less than the corresponding SMCL-CA benchmarks (table 7).

Arsenic and iron occur as different species depending on the oxidation–reduction state of the groundwater. The characterization of oxidized and reduced species of each of these elements in groundwater and the relative proportions of the oxidized and reduced species of each element can be used in the interpretation of the oxidation–reduction conditions of the aquifer.

Concentrations of total arsenic and total iron reported by the NWQL in table 7 are considered to be more accurate than the concentrations reported by the USGS National Research Program (NRP) Trace Metal Laboratory (TML), Boulder, Colorado, in table 10 (see the appendix section titled "Constituents Determined by Multiple Methods or Laboratories"). Total iron concentrations (reported from the USGS NRP-TML) greater than the SMCL-CA of 300 µg/L were detected in samples from three grid sites (table 10).

Isotopic Tracers and Dissolved Noble Gases

The isotopic ratios, activities, and concentrations of many elements are used as tracers of hydrologic processes. Stable isotope ratios of hydrogen (δ^2H) and oxygen (δ^{18}O) in water aid in the interpretation of the sources of groundwater recharge. These stable-isotope ratios reflect the altitude, latitude, and signature precipitation and can also be used to evaluate the extent of evaporation of water (Clark and Fritz, 1997). In the KLAM study unit, the stable-isotope ratios of hydrogen ranged from –104 to –57.8 per mil, and the stable isotope ratios of oxygen ranged from –14.41 to –8.75 per mil (table 11).

Isotopic ratios of strontium (^{87}Sr/^{86}Sr) in water reflect the amounts of strontium (and other inorganic constituents) the aquifer materials are contributing to the groundwater system. In regions that have diverse geology, isotopic ratios of strontium may aid in identifying groundwater-flow paths (Clark and Fritz, 1997). The isotopic ratios of strontium ranged from 0.70405 to 0.71348 (table 11).

Tritium activities 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 levels generally indicate the presence of water recharged since the early 1950s. Helium isotope ratios can be used in conjunction with tritium concentrations to estimate ages for young groundwater (Clark and Fritz, 1997). Of the isotopic tracer constituents analyzed for this study, tritium is the only one with a health-based benchmark. All measured tritium activities in samples from the sites in the KLAM study unit were more than three orders of magnitude less than the MCL-CA benchmark (tables 12 and 13).

Carbon-14, a radioactive isotope of carbon, is an age-dating tracer. Low levels of carbon-14 are produced continuously by interaction of cosmic radiation with the Earth's atmosphere and are 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 thousands of years old or more (Clark and Fritz, 1997). Carbon-14 activities ranged from 38.86 to 110.6 percent modern carbon, and the stable isotopes of carbon ($\delta^{13}C$) in dissolved inorganic carbon ranged from –21.74 to –11.15 per mil (table 11).

Gases dissolve in water that is in contact with the atmosphere, and the solubilities of the different gas species vary with temperature. Concentrations of dissolved noble gases are used to estimate the conditions of groundwater recharge, particularly the temperature of the water at the time of recharge (Clark and Fritz, 1997). Dissolved noble gas concentrations and the estimated temperature of the water at the time of recharge are presented in table 12.

Uranium and Other 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 such as 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). Radon-222 is a radioactive isotope formed during the uranium or thorium decay series. In each step in the decay series, one radioactive element turns into a different radioactive element by emitting an alpha or a beta particle from its nucleus. For example, radium-226 emits an alpha particle and therefore turns into radon-222. Radium-228 decays to form actinium-228 by emission of a beta particle. The alpha and beta particles emitted during radioactive decay are hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA may increase the risk of getting cancer.

All measured activities of uranium, radon-222, and gross alpha and gross beta radioactivity in samples from the sites in the KLAM study unit were less than health-based benchmarks (table 13).

Microbial Indicators

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

The presence of total coliform (a bacterial indicator) was detected in 14 of the 38 grid sites in the KLAM study unit. In addition, *Escherichia coli* (*E. coli*) (a bacterial indicator) was detected in samples from 2 of these 14 grid sites (table 14).

Future Work

Subsequent reports for the KLAM study unit will be focused on assessment of the data presented in this report by using statistical, qualitative, and quantitative approaches to evaluate the natural and human factors affecting groundwater quality in the KLAM study unit. Water-quality data contained in the CDPH databases will be used in combination with the data that are presented in this report.

Summary

Groundwater quality in the 8,806-square-mile Klamath Mountains (KLAM) study unit was investigated by the U.S. Geological Survey (USGS) from October to December 2010, as part of the Priority Basin Project (PBP) of the California State Water Resources Control Board (SWRCB) Groundwater Ambient Monitoring and Assessment (GAMA) Program. 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 Klamath Mountains study was designed to provide a spatially unbiased assessment of untreated-groundwater quality in the primary aquifer system and to facilitate statistically consistent comparisons of untreated-groundwater quality throughout California. The primary aquifer system is defined by the perforation intervals of wells listed in the California Department of Public Health (CDPH) database for the KLAM study unit. The quality of groundwater in the primary aquifer system may differ from shallow or deep water-bearing zones; shallow groundwater may be more vulnerable to surficial contamination.

This study did not evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, and blended with other waters to maintain acceptable water quality. The benchmarks used in this report apply to treated water that is served to the consumer, not to untreated groundwater. However, to provide context for the results, concentrations of constituents measured in these groundwater samples were compared with benchmarks established by the U.S. Environmental Protection Agency (USEPA) and the CDPH.

The KLAM study unit is located within the Klamath Mountains hydrologic province and included assessment of the groundwater quality from 39 sites in Del Norte, Humboldt, Siskiyou, Tehama, Trinity, and Shasta Counties, California. A total of 38 sites were selected by using a randomized grid approach to achieve statistically unbiased representation of groundwater used for public drinking-water supplies (grid sites). In addition, one non-randomized site was sampled (understanding site).

Groundwater samples were analyzed for water-quality indicators, organic constituents, inorganic constituents, and uranium and other radioactive constituents. Isotopic tracers and dissolved gases also were measured to provide a dataset that will be used to interpret the sources and ages of groundwater. In total, 213 unique constituents and 7 water-quality indicators were measured. This report describes the sampling, analytical, and quality-assurance methods used in the study, and presents the results of the chemical analyses of the groundwater samples.

Quality-control samples (field blanks, replicate sample pairs, and matrix spikes) were collected at 13 percent of the sites in the KLAM study unit, and the results for these samples were used to evaluate the quality of the data for the groundwater samples. Field blank samples rarely contained detectable concentrations of any constituent. Replicate pair samples were generally within acceptable limits of variability, and matrix-spike sample recoveries were largely within the acceptable range.

All detections of organic constituents, inorganic constituents, uranium and other radioactive constituents, and microbial indicators from the 39 sites sampled in the KLAM study unit were less than health-based benchmarks, with the exception of one detection of boron greater than the CDPH notification level of 1,000 micrograms per liter (µg/L).

Chloride and total dissolved solids (TDS) concentrations did not exceed the upper non-health-based benchmarks in groundwater sampled as part of this study; however, concentrations of iron and manganese were measured at concentrations greater than the corresponding CDPH secondary maximum contaminant levels (SMCL-CAs).

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Table 1. Identification, sampling, and construction information for sites sampled for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[Sampling schedule is described in table 2. 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 of 1988 (NAVD 88). **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. **Other abbreviations**: ft, feet; na, not available]

GAMA site identification number	Sampling information			Construction information		
	Date sampled (mm/dd/yyyy)	Site 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)
KLAM grid sites (38 sites sampled)						
KLAM-01	10/18/2010	Spring	723	at LSD	at LSD	at LSD
KLAM-02	10/19/2010	Spring	3,043	at LSD	at LSD	at LSD
KLAM-03	10/19/2010	Production	1,977	32	24	32
KLAM-04	10/20/2010	Spring	4,745	at LSD	at LSD	at LSD
KLAM-05	10/20/2010	Production	2,989	80	57	80
KLAM-06	10/21/2010	Production	2,324	270	170	270
KLAM-07	10/21/2010	Production	2,235	na	na	na
KLAM-08	11/1/2010	Production	2,152	180	0	180
KLAM-09	11/1/2010	Production	713	48	36	48
KLAM-10	11/2/2010	Spring	1,063	at LSD	at LSD	at LSD
KLAM-11	11/2/2010	Production	647	89	49	89
KLAM-12	11/3/2010	Spring	2,655	at LSD	at LSD	at LSD
KLAM-13	11/3/2010	Production	1,412	45	na	na
KLAM-14	11/4/2010	Production	1,270	na	na	na
KLAM-15	11/4/2010	Production	1,140	na	na	na
KLAM-16	11/15/2010	Production	1,120	278	55	278
KLAM-17	11/15/2010	Production	3,321	na	na	na
KLAM-18	11/16/2010	Production	3,301	300	240	300
KLAM-19	11/16/2010	Production	1,788	80	na	na
KLAM-20	11/17/2010	Spring	2,465	at LSD	at LSD	at LSD
KLAM-21	11/17/2010	Production	2,620	225	na	na
KLAM-22	11/18/2010	Production	457	44	na	na
KLAM-23	11/18/2010	Production	1,794	305	160	305
KLAM-24	11/29/2010	Production	3,436	na	na	na
KLAM-25	11/30/2010	Production	1,085	125	na	na
KLAM-26	11/30/2010	Production	1,093	90	70	90
KLAM-27	12/1/2010	Production	1,143	320	300	320
KLAM-28	12/1/2010	Production	1,091	112	68	112
KLAM-29	12/2/2010	Spring	2,611	at LSD	at LSD	at LSD
KLAM-30	12/2/2010	Production	2,008	120	60	120

Table 1. Identification, sampling, and construction information for sites sampled for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[Sampling schedule is described in table 2. 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 of 1988 (NAVD 88). **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. **Other abbreviations**: ft, feet; na, not available]

GAMA site identification number	Sampling information			Construction information		
	Date sampled (mm/dd/yyyy)	Site 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)
KLAM grid sites (38 sites sampled)—Continued						
KLAM-31	12/6/2010	Production	3,971	na	na	na
KLAM-32	12/7/2010	Production	1,416	227	187	227
KLAM-33	12/7/2010	Production	1,250	249	201	249
KLAM-34	12/8/2010	Production	903	177	77	177
KLAM-35	12/8/2010	Production	1,331	na	na	na
KLAM-36	12/9/2010	Production	2,479	25	na	na
KLAM-37	12/13/2010	Production	1,926	na	na	na
KLAM-38	12/14/2010	Production	1,970	na	na	na
KLAM understanding site						
KLAM-U-01	12/14/2010	Production	1,185	na	na	na

Table 2. Classes of chemical constituents and field water-quality indicators collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[**Abbreviations:** VOC, volatile organic compound; TDS, total dissolved solids; LLNL, Lawrence Livermore National Laboratory, Livermore, California]

Constituent classes	Constituent list table	Results table
Field water-quality indicators		
Dissolved oxygen, temperature, pH, and specific conductance	no table	4
Field alkalinity, bicarbonate, and carbonate	no table	4
Organic constituents		
VOCs	3A	5
Pesticides and pesticide degradates	3B	6
Constituent of special interest		
Perchlorate	3C	none [1]
Inorganic constituents		
Trace elements	3D	7
Nutrients	3E	8
Major and minor ions, silica, and TDS	3F	9
Laboratory alkalinity, bicarbonate, and carbonate	3F	4
Arsenic and iron species	3G	10
Isotopic tracers and dissolved noble gases		
Stable isotopes of hydrogen and oxygen in water	3H	11
Isotopic ratios of strontium in water	3H	11
Stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance	3H	11
Dissolved noble gases and helium isotope ratios	3H	12
Uranium and other radioactive constituents		
Uranium	3H	13
Radon-222	3H	13
Gross alpha and gross beta radioactivity (72-hour and 30-day counts)	3H	13
Tritium (LLNL)	3H	12
Tritium	3H	13
Microbial constituents		
Escherichia coli (*E.coli*) and total coliform	3I	14

[1] Perchlorate data did not meet quality-control standards as required by the GAMA Program; therefore, data are not presented. Please see the appendix section titled “Other Quality-Control Results” for more information.

Table 3A. Volatile organic compounds, 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 October 1, 2010. **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; NL-CA, CDPH notification level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CAS, Chemical Abstracts Service; CASRN, Chemical Abstract 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 [1]	LRL or SRL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
Acetone	Solvent	81552	67-64-1	3.4	na	na	—
Acrylonitrile	Organic synthesis	34215	107-13-1	0.8	RSD5-US	0.6	—
tert-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	—
Bromobenzene	Solvent	81555	108-86-1	0.022	na	na	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.06	HAL-US	90	—
Bromodichloromethane	Disinfection byproduct (THM)	32101	75-27-4	0.034	MCL-US	[3] 80	D
Bromoform (Tribromomethane)	Disinfection byproduct (THM)	32104	75-25-2	0.1	MCL-US	[3] 80	—
Bromomethane (Methyl bromide)	Fumigant	34413	74-83-9	0.2	HAL-US	10	—
n-Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.08	NL-CA	260	—
sec-Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.034	NL-CA	260	—
tert-Butylbenzene	Gasoline hydrocarbon	77353	98-06-6	0.06	NL-CA	260	—
Carbon disulfide	Organic synthesis	77041	75-15-0	0.08	NL-CA	160	D
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.06	MCL-CA	0.5	—
Chlorobenzene	Solvent	34301	108-90-7	0.026	MCL-CA	70	—
Chloroethane	Solvent	34311	75-00-3	0.06	na	na	—
Chloroform (Trichloromethane)	Disinfection byproduct (THM)	32106	67-66-3	0.03	MCL-US	[3] 80	D
Chloromethane	Solvent	34418	74-87-3	0.14	HAL-US	30	—
3-Chloropropene	Organic synthesis	78109	107-05-1	0.08	na	na	—
2-Chlorotoluene	Solvent	77275	95-49-8	0.028	NL-CA	140	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.042	NL-CA	140	—
Dibromochloromethane	Disinfection byproduct (THM)	32105	124-48-1	0.12	MCL-US	[3] 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	—
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.028	MCL-CA	600	—
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.024	HAL-US	600	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.026	MCL-CA	5	—
trans-1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	0.36	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.1	NL-CA	1,000	—

Table 3A. Volatile organic compounds, 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 October 1, 2010. **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; NL-CA, CDPH notification level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CAS, Chemical Abstracts Service; CASRN, Chemical Abstract 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 [1]	LRL or SRL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
1,1-Dichloroethane (1,1-DCA)	Solvent	34496	75-34-3	0.044	MCL-CA	5	—
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	—
cis-1,2-Dichloroethene (*cis*-1,2-DCE)	Solvent	77093	156-59-2	0.022	MCL-CA	6	—
trans-1,2-Dichloroethene (*trans*-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	—
cis-1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.1	RSD5-US	[4] 4	—
trans-1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.14	RSD5-US	[4] 4	—
Diethyl ether	Solvent	81576	60-29-7	0.1	na	na	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.06	na	na	—
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.036	MCL-CA	300	—
Ethyl *tert*-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	—
o-Ethyl toluene (1-Ethyl-2-methyl benzene)	Gasoline hydrocarbon	77220	611-14-3	0.032	na	na	—
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.08	RSD5-US	9	—
Hexachloroethane	Solvent	34396	67-72-1	0.22	HAL-US	1	—
2-Hexanone (*n*-Butyl methyl ketone)	Solvent	77103	591-78-6	0.4	na	na	—
Iodomethane (Methyl iodide)	Organic synthesis	77424	74-88-4	0.26	na	na	—
Isopropylbenzene	Gasoline hydrocarbon	77223	98-82-8	0.042	NL-CA	770	—
4-Isopropyl-1-methyl benzene	Gasoline hydrocarbon	77356	99-87-6	0.06	na	na	—
Methyl acrylate	Organic synthesis	49991	96-33-3	0.22	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.26	na	na	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.1	MCL-CA	13	D
Methyl *iso*-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	HAL-US	4,000	D

Table 3A. Volatile organic compounds, 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 October 1, 2010. **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; NL-CA, CDPH notification level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CAS, Chemical Abstracts Service; CASRN, Chemical Abstract 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 [1]	LRL or SRL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.22	na	na	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.18	NL-CA	17	—
Perchloroethene (PCE, Tetrachloroethene)	Solvent	34475	127-18-4	0.026	MCL-US	5	D
n-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	HAL-US	70	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.14	MCL-CA	1	—
Tetrahydrofuran	Solvent	81607	109-99-9	all data [2]	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	[2] 0.69	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-CA	200	—
1,1,2-Trichloroethane (1,1,2-TCA)	Solvent	34511	79-00-5	0.028	MCL-CA	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	—
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.12	HAL-US	40	—
Trichlorotrifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.034	MCL-CA	1,200	—
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.06	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	[2] 0.56	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	—
m- plus *p*-Xylene	Gasoline hydrocarbon	85795	108-38-3 / 106-42-3	0.08	MCL-CA	[5] 1,750	—
o-Xylene	Gasoline hydrocarbon	77135	95-47-6	0.032	MCL-CA	[5] 1,750	—

[1] 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℠.

[2] The SRL was defined by Fram and others (2012).

[3] The MCL-US benchmark for trihalomethanes is the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

[4] The RSD5 benchmark for 1,3-dichloropropene is the sum of its isomers (*cis* and *trans*).

[5] The MCL-CA benchmarks 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 October 1, 2010. **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 maximum contaminant level; MCL-US, USEPA maximum contaminant level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CASRN, Chemical Abstract 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	Benchmark level (µg/L)	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.01	na	na	—
Alachlor	Herbicide	46342	15972-60-8	0.008	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.007	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.12	na	na	—
Azinphos-methyl oxon	Insecticide degradate	61635	961-22-8	0.042	na	na	—
Benfluralin	Herbicide	82673	1861-40-1	0.014	na	na	— (1)
Carbaryl	Insecticide	82680	63-25-2	0.06	RSD5-US	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	0.0046	na	na	—
Chlorpyrifos	Insecticide	38933	2921-88-2	0.0036	HAL-US	2	—
Chlorpyrifos oxon	Insecticide degradate	61636	5598-15-2	0.06	na	na	— (1)
Cyfluthrin	Insecticide	61585	68359-37-5	0.016	na	na	— (1)
Cypermethrin	Insecticide	61586	52315-07-8	0.02	na	na	— (1)
Dacthal (DCPA)	Herbicide	82682	1861-32-1	0.0076	HAL-US	70	—
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-*s*-triazine)	Herbicide degradate	04040	6190-65-4	0.006	na	na	D (1)
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	HAL-US	1	—
3,4-Dichloroaniline	Herbicide degradate	61625	95-76-1	0.0042	na	na	—
Dichlorvos	Insecticide	38775	62-73-7	0.04	na	na	— (1)
Dicrotophos	Insecticide	38454	141-66-2	0.08	na	na	— (1)
Dieldrin	Insecticide	39381	60-57-1	0.008	RSD5-US	0.02	—
2,6-Diethylaniline	Herbicide degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.006	na	na	— (1)
Ethion	Insecticide	82346	563-12-2	0.008	na	na	— (1)
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	HAL-US	0.7	—

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 October 1, 2010. **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 maximum contaminant level; MCL-US, USEPA maximum contaminant level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CASRN, Chemical Abstract 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	Benchmark level (µg/L)	Detection
Fenamiphos sulfone	Insecticide degradate	61645	31972-44-8	0.054	na	na	—
Fenamiphos sulfoxide	Insecticide degradate	61646	31972-43-7	0.08	na	na	— (1)
Fipronil	Insecticide	62166	120068-37-3	0.018	na	na	—
Fipronil sulfide	Insecticide degradate	62167	120067-83-6	0.012	na	na	—
Fipronil sulfone	Insecticide degradate	62168	120068-36-2	0.024	na	na	—
Fonofos	Insecticide	04095	944-22-9	0.0048	HAL-US	10	—
Hexazinone	Herbicide	04025	51235-04-2	0.008	HAL-US	400	D (1)
Iprodione	Fungicide	61593	36734-19-7	0.014	na	na	— (1)
Isofenphos	Insecticide	61594	25311-71-1	0.006	na	na	—
Malaoxon	Insecticide degradate	61652	1634-78-2	0.022	na	na	—
Malathion	Insecticide	39532	121-75-5	0.016	HAL-US	100	—
Metalaxyl	Fungicide	61596	57837-19-1	0.014	na	na	—
Methidathion	Insecticide	61598	950-37-8	0.012	na	na	—
Metolachlor	Herbicide	39415	51218-45-2	0.014	HAL-US	700	—
Metribuzin	Herbicide	82630	21087-64-9	0.012	HAL-US	70	—
Myclobutanil	Fungicide	61599	88671-89-0	0.01	na	na	—
1-Naphthol	Insecticide degradate	49295	90-15-3	0.036	na	na	— (1)
Paraoxon-methyl	Insecticide degradate	61664	950-35-6	0.014	na	na	— (1)
Parathion-methyl	Insecticide	82667	298-00-0	0.008	HAL-US	1	—
Pendimethalin	Herbicide	82683	40487-42-1	0.012	na	na	—
cis-Permethrin	Insecticide	82687	54774-45-7	0.01	na	na	— (1)
Phorate	Insecticide	82664	298-02-2	0.02	na	na	—
Phorate oxon	Insecticide degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.14	na	na	— (1)
Phosmet oxon	Insecticide degradate	61668	3735-33-9	0.0511	na	na	— (1)
Prometon	Herbicide	04037	1610-18-0	0.012	HAL-US	100	—
Prometryn	Herbicide	04036	7287-19-6	0.006	na	na	—
Pronamide (Propyzamide)	Herbicide	82676	23950-58-5	0.0036	RSD5-US	20	—

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 October 1, 2010. **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 maximum contaminant level; MCL-US, USEPA maximum contaminant level; RSD5-US, USEPA risk-specific dose at a risk factor of 10^{-5}. **Other abbreviations**: CASRN, Chemical Abstract 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	Benchmark level (µg/L)	Detection
Simazine	Herbicide	04035	122-34-9	0.006	MCL-US	4	D
Tebuthiuron	Herbicide	82670	34014-18-1	0.028	HAL-US	500	—
Terbufos	Insecticide	82675	13071-79-9	0.018	HAL-US	0.4	—
Terbufos oxon sulfone	Insecticide degradate	61674	56070-15-6	0.045	na	na	—
Terbuthylazine	Herbicide	04022	5915-41-3	0.006	na	na	—
Tribufos	Defoliant	61610	78-48-8	0.018	na	na	— (1)
Trifluralin	Herbicide	82661	1582-09-8	0.018	HAL-US	10	—

[1] 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.

Table 3C. Perchlorate, primary uses or source, comparison benchmark, and reporting information for Weck Laboratories, Inc. (Weck), City of Industry, California, analyses.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. MRL, benchmark type, and benchmark level as of October 1, 2010. **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**: CASRN, Chemical Abstract Service Registry Number; MRL, minimum reporting level; µg/L, micrograms per liter; na, not available]

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	63790	14797-73-0	0.10	MCL-CA	6	na [1]

[1] Perchlorate data did not meet quality-control standards as required by the GAMA Program; therefore, data are not presented. Please see the appendix section titled “Other Quality-Control Results” for more information.

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 October 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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**: CASRN, Chemical Abstract Service Registry Number; LT-MDL, long-term method detection limit; SRL, study reporting level; D, detected in groundwater samples (table 7); na, not available; µg/L, micrograms per liter; —, not detected; KLAM, Klamath Mountains study unit]

Constituent	USGS parameter code	CASRN	LT-MDL or SRL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
Aluminum	01106	7429-90-5	[1] 1.6	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.054	MCL-US	6	D
Arsenic	01000	7440-38-2	0.044	MCL-US	10	D
Barium	01005	7440-39-3	[1] 0.36	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.012	MCL-US	4	D
Boron	01020	7440-42-8	2.8	NL-CA	1,000	D
Cadmium	01025	7440-43-9	0.02	MCL-US	5	D
Chromium	01030	7440-47-3	[1] 0.42	MCL-CA	50	D
Cobalt	01035	7440-48-4	[2] 0.23	na	na	D
Copper	01040	7440-50-8	[1] 1.7	AL-US	1,300	D
Iron	01046	7439-89-6	[1] 6	SMCL-CA	300	D
Lead	01049	7439-92-1	[1] 0.65	AL-US	15	D
Lithium	01130	7439-93-2	0.44	na	na	D
Manganese	01056	7439-96-5	[2] 0.36	SMCL-CA	50	D
Mercury	71890	7439-97-6	0.005	MCL-US	2	—
Molybdenum	01060	7439-98-7	0.028	HAL-US	40	D
Nickel	01065	7440-02-0	[1] 0.36	MCL-CA	100	D
Selenium	01145	7782-49-2	0.040	MCL-US	50	D
Silver	01075	7440-22-4	0.005	SMCL-CA	100	D
Strontium	01080	7440-24-6	0.40	HAL-US	4,000	D
Thallium	01057	7440-28-0	0.020	MCL-US	2	D
Tungsten	01155	7440-33-7	[1] 0.11	na	na	D
Vanadium	01085	7440-62-2	0.16	NL-CA	50	D
Zinc	01090	7440-66-6	[1] 4.8	SMCL-CA[3]	5,000	D

[1] The SRL was defined by Olsen and others (2010).

[2] The SRL was defined based on the highest concentration detected in the KLAM field blank samples.

[3] Zinc also has a HAL-US benchmark of 2,000 µg/L.

Table 3E. Nutrients, comparative 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 October 1, 2010. **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**: CASRN, Chemical Abstract Service Registry Number; LT-MDL, long-term method detection limit; D, detected in groundwater samples (table 8); 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	[1] 24.7	D
Nitrite (as nitrogen)	00613	14797-65-0	0.001	MCL-US	1	D
Nitrate plus nitrite (as nitrogen)	00631	na	0.02	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	0.006	na	na	D

[1] 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 3F. Major and minor ions, silica, total dissolved solids (TDS), and alkalinity, comparative 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 October 1, 2010. **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; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations**: CASRN, Chemical Abstract 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; SiO_2, silicon dioxide; $CaCO_3$, 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	0.02	na	na	D
Calcium	00915	7440-70-2	0.044	na	na	D
Chloride	00940	16887-00-6	0.12	SMCL-CA	[1] 250 (500)	D
Fluoride	00950	16984-48-8	0.08	MCL-CA	2	D
Iodide	71865	7553-56-2	0.002	na	na	D
Magnesium	00925	7439-95-4	0.016	na	na	D
Potassium	00935	7440-09-7	0.064	na	na	D
Sodium	00930	7440-23-5	0.10	na	na	D
Sulfate	00945	14808-79-8	0.18	SMCL-CA	[1] 250 (500)	D
Silica (as SiO_2)	00955	7631-86-9	0.058	na	na	D
Total dissolved solids (TDS)	70300	na	10	SMCL-CA	[1] 500 (1,000)	D
Laboratory alkalinity (as $CaCO_3$) [2]	29801	na	1	na	na	D

[1] The SMCL-CA for chloride, sulfate, and TDS have recommended and upper benchmark values. The upper benchmark value is shown in parentheses.

[2] Laboratory alkalinity results are presented in table 4.

Table 3G. Arsenic and iron species, comparison benchmarks, and reporting information for the U.S. Geological Survey (USGS) National Research Laboratory (NRP) Trace Metal Laboratory (TML), Boulder, Colorado, analyses.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. MDL, benchmark type, and benchmark level as of October 1, 2010. **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; SMCL-CA, California Department of Public Health secondary maximum contaminant level. **Other abbreviations**: CASRN, Chemical Abstract Service Registry Number; MDL, method detection limit; na, not available; µg/L, micrograms per liter; D, detected in groundwater samples (table 10); —, not detected]

Constituent	USGS parameter code	CASRN	MDL (µg/L)	Benchmark type	Benchmark level (µg/L)	Detection
Arsenic (total)	99033	7440-38-2	0.5	MCL-US	10	D
Arsenic-III	99034	22569-72-8	1	na	na	—
Iron (total)	01046	7439-89-6	2	SMCL-CA	300	D
Iron-II	01047	7439-89-6	2	na	na	D

Table 3H. Dissolved noble gases, isotopic tracers, and uranium and other 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. 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. Benchmark type and benchmark value as of October 1, 2010. **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; Sr, strontium; C, carbon. **Reporting units**: µg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; cm^3 STP/g, cubic centimeters of gas at standard temperature and pressure per gram of water. **Other abbreviations**: USGS, U.S. Geological Survey; CASRN, Chemical Abstract Service Registry Number; %, percent; na, not available; pmc, percent modern carbon; D, detected in groundwater samples (tables 11, 12, and 13); ssL_C, sample-specific critical level; NRP, National Research Program]

Constituent	USGS parameter code	CASRN	Method uncertainty	Reporting units	Benchmark type	Benchmark level (pCi/L)	Detection
Dissolved noble gases [1]							
Argon	85563	7440-37-1	2%	cm^3 STP/g	na	na	D
Helium-4	85561	7440-59-7	2%	cm^3 STP/g	na	na	D
Krypton	85565	7439-90-9	2%	cm^3 STP/g	na	na	D
Neon	61046	7440-01-09	2%	cm^3 STP/g	na	na	D
Xenon	85567	7440-63-3	2%	cm^3 STP/g	na	na	D
Isotopic tracers							
Helium-3 / Helium-4 [1]	61040	na / 7440-59-7	0.75%	atom ratio	na	na	D
$\delta^{2}H$ in water [2]	82082	na	2	per mil	na	na	D
$\delta^{18}O$ in water [2]	82085	na	0.20	per mil	na	na	D
Strontium isotope ratio in water ($^{87}Sr/^{86}Sr$) [3]	75978	na	0.00005	atom ratio	na	na	D
$\delta^{13}C$ in dissolved inorganic carbon [4]	82081	na	0.05	per mil	na	na	D
Uranium and other radioactive constituents							
Uranium [6]	22703	7440-61-1	LT-MDL	µg/L	MCL-US	30	D
C-14 [4]	49933	14762-75-5	0.0015	pmc	na	na	D
Tritium [1]	07000	10028-17-8	ssL_C	pCi/L	MCL-CA	20,000	D
Tritium [5]	07000	10028-17-8	ssL_C	pCi/L	MCL-CA	20,000	D
Radon-222 [6]	82303	14859-67-7	ssL_C	pCi/L	MCL-US (Proposed)	4,000	D
Gross alpha radioactivity, 72-hour and 30-day counts [7]	62636, 62639	12587-46-1	ssL_C	pCi/L	MCL-US	[8] 15	D
Gross beta radioactivity, 72-hour and 30-day counts [7]	62642, 62645	12587-47-2	ssL_C	pCi/L	MCL-CA	50	D

[1] Lawrence Livermore National Laboratory, Livermore, California (CA-LLNL).

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

[3] USGS-NRP Metals Isotope Research Laboratory, Menlo Park, California (USGSMICA).

[4] Woods Hole Oceanographic Institution, National Ocean Sciences Accelerator Mass Spectrometry Facility [NOMAS], Woods Hole, Massachusetts (MA-WHAMS).

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

[6] USGS NWQL Denver, Colorado.

[7] Eberline Analytical Services, Richmond, California (CA-EBERL).

[8] 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 3I. Microbial indicators, comparison benchmarks, and reporting information for the IDEXX Colilert® field test kit analyses.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. MDL, benchmark type, and benchmark level as of October 1, 2010. **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. TT-US, U.S. Environmental Protection Agency (USEPA) treatment technique—a required process intended to reduce the level of contamination in drinking water; MCL-US, USEPA maximum contaminant level. **Other abbreviations**: USGS, U.S. Geological Survey; MDL, method detection limit; %, percent; D, detected in groundwater samples (table 14)]

Constituent	USGS parameter code	Primary source	MDL	Benchmark type	Benchmark value	Detection
Total coliform (including fecal coliform and *Escherichia coli* [*E. coli*])	99595	Sewage and animal waste indicator	presence / absence	MCL-US	5% of samples positive per month	D
E. coli	99596	Sewage and animal waste indicator	presence / absence	TT-US	No fecal coliforms are allowed	D

Table 4. Water-quality indicators in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and RL as of October 1, 2010. **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; $CaCO_3$, calcium carbonate; E, estimated or having a higher degree of uncertainty; *, concentration greater than the benchmark level; **, concentration greater than the upper benchmark level; —, not detected]

GAMA site 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 $CaCO_3$) (29802)	Alkalinity, laboratory (mg/L as $CaCO_3$) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory [2] (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory [2] (mg/L)
Benchmark type	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**	**SMCL-CA**	**na**	**na**	**na**	**na**	**na**	**na**
Benchmark level	**na**	**na**	**<6.5 or >8.5**	**<6.5 or >8.5**	**[1] 900 (1,600)**	**[1] 900 (1,600)**	**na**	**na**	**na**	**na**	**na**	**na**
[RL]	**[0.2]**	**[0.0–38.5]**	**[0–14]**	**[0–14]**	**[5]**	**[5]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**
KLAM grid sites (38 sites sampled)												
KLAM-01	10.1	13.0	8.2	8.3	190	194	nc	104	nc	124	nc	1.1
KLAM-02	10.6	9.0	*6.1	7.0	167	172	69.8	78.0	85.0	95.1	—	—
KLAM-03	3.2	15.0	6.9	7.2	391	400	167	183	204	223	0.1	0.2
KLAM-04	7.9	13.0	*6.3	E7.0	87	E91	nc	43.9	nc	53.5	nc	—
KLAM-05	8.7	11.0	7.2	7.7	372	374	nc	197	nc	239	nc	0.6
KLAM-06	0.5	16.5	8.3	8.3	**1,690	**1,690	nc	140	nc	168	nc	1.5
KLAM-07	8.4	13.0	7.1	7.3	338	343	nc	189	nc	230	nc	0.2
KLAM-08	0.9	11.5	7.3	7.5	295	292	nc	130	nc	158	nc	0.2
KLAM-09	2.9	12.5	6.5	7.0	269	271	nc	121	nc	147	nc	0.1
KLAM-10	nc	13.0	*6.0	E7.4	62	E62	nc	32.8	nc	39.9	nc	—
KLAM-11	9.4	13.0	6.9	7.4	207	207	nc	112	nc	136	nc	0.2
KLAM-12	7.5	10.5	6.6	7.4	144	145	70.4	76.7	85.7	93.3	—	0.1
KLAM-13	7.8	12.5	6.7	7.0	245	247	114	129	139	157	—	0.1
KLAM-14	6.9	13.0	7.2	7.1	459	463	nc	246	nc	300	nc	0.2
KLAM-15	9.3	11.0	6.8	7.2	337	344	nc	181	nc	220	nc	0.2

Table 4. Water-quality indicators in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and RL as of October 1, 2010. **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; $CaCO_3$, calcium carbonate; E, estimated or having a higher degree of uncertainty; *, concentration greater than the benchmark level; **, concentration greater than the upper benchmark level; —, not detected]

GAMA site 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 $CaCO_3$) (29802)	Alkalinity, laboratory (mg/L as $CaCO_3$) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory [2] (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory [2] (mg/L)
Benchmark type	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**	**SMCL-CA**	**na**	**na**	**na**	**na**	**na**	**na**
Benchmark level	**na**	**na**	**<6.5 or >8.5**	**<6.5 or >8.5**	**[1] 900 (1,600)**	**[1] 900 (1,600)**	**na**	**na**	**na**	**na**	**na**	**na**
[RL]	**[0.2]**	**[0.0–38.5]**	**[0–14]**	**[0–14]**	**[5]**	**[5]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-16	4.5	14.0	*5.9	*E6.2	77	E80	nc	38.2	nc	46.6	nc	—
KLAM-17	2.2	12.0	*6.2	6.5	220	227	nc	115	nc	140	nc	—
KLAM-18	6.1	9.5	*6.1	E6.5	86	E90	nc	48.0	nc	58.6	nc	—
KLAM-19	2.0	14.0	7.2	7.5	195	197	98.1	103	119	125	0.1	0.2
KLAM-20	7.5	10.0	7.6	7.8	226	230	nc	131	nc	159	nc	0.5
KLAM-21	7.2	12.0	7.2	7.3	326	326	172	184	209	224	0.2	0.2
KLAM-22	10.7	13.5	7.0	7.2	207	210	nc	100	nc	122	nc	0.1
KLAM-23	2.5	15.0	7.4	8.4	289	292	nc	130	nc	155	nc	1.8
KLAM-24	0.4	11.0	7.5	7.5	506	526	nc	221	nc	269	nc	0.4
KLAM-25	2.4	16.5	7.0	7.0	401	385	167	174	203	212	0.1	0.1
KLAM-26	1.4	17.0	6.8	7.0	296	303	124	134	151	163	0.1	0.1
KLAM-27	6.1	15.0	*6.2	6.5	261	259	nc	75.5	nc	92.1	nc	—
KLAM-28	3.4	11.5	6.5	6.9	137	140	nc	62.0	nc	75.6	nc	—
KLAM-29	11.8	7.5	6.6	7.0	114	115	nc	56.5	nc	68.9	nc	—
KLAM-30	<0.2	12.0	6.8	7.1	340	342	nc	151	nc	184	nc	0.1

Table 4. Water-quality indicators in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and RL as of October 1, 2010. **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; $CaCO_3$, calcium carbonate; E, estimated or having a higher degree of uncertainty; *, concentration greater than the benchmark level; **, concentration greater than the upper benchmark level; —, not detected]

GAMA site 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 $CaCO_3$) (29802)	Alkalinity, laboratory (mg/L as $CaCO_3$) (29801)	Bicarbonate, field (mg/L) (63786)	Bicarbonate, laboratory [2] (mg/L)	Carbonate, field (mg/L) (63788)	Carbonate, laboratory [2] (mg/L)
Benchmark type	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**	**SMCL-CA**	**na**	**na**	**na**	**na**	**na**	**na**
Benchmark level	**na**	**na**	**<6.5 or >8.5**	**<6.5 or >8.5**	**[1] 900 (1,600)**	**[1] 900 (1,600)**	**na**	**na**	**na**	**na**	**na**	**na**
[RL]	**[0.2]**	**[0.0–38.5]**	**[0–14]**	**[0–14]**	**[5]**	**[5]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**	**[1]**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-31	2.6	10.0	*9.4	*9.3	555	572	nc	379	nc	389	nc	35.7
KLAM-32	4.2	13.5	6.9	7.1	225	231	108	121	132	147	0.1	0.1
KLAM-33	0.9	14.0	7.6	7.7	186	189	66.3	80.4	80.4	97.6	0.2	0.2
KLAM-34	5.6	16.0	7.3	7.6	460	464	nc	177	nc	215	nc	0.4
KLAM-35	4.1	14.0	6.7	7.1	225	227	nc	119	nc	145	nc	0.1
KLAM-36	7.0	11.0	6.6	7.0	142	143	nc	77.5	nc	94.5	nc	—
KLAM-37	2.3	14.5	*6.1	*6.3	192	195	nc	57.7	nc	70.4	nc	—
KLAM-38	7.3	10.0	6.9	7.2	180	184	nc	80.1	nc	97.6	nc	0.1
KLAM understanding site												
KLAM-U-01	7.4	13.0	7.2	7.5	435	438	194	197	236	240	0.3	0.3

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

[2] Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values by using the advanced speciation method (http://or.water.usgs.gov/alk/methods.html) with $pK_1 = 6.35$, $pK_2 = 10.33$, and $pK_W = 14$.

Table 5. Volatile organic compounds (VOCs) detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites 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 38 grid sites. All constituents are listed in table 3A. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LRL as of October 1, 2010. **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 (CDPH) maximum contaminant level; NL-CA, CDPH notification level. **Other abbreviations**: USGS, U.S. Geological Survey; ≤, less than or equal to; LRL, laboratory reporting level; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected]

Primary use or source	**Trihalomethanes**			**Solvents**			**Hydrocarbons**		**Natural**	**Gasoline oxygenate**		
GAMA site identification number	**Chloroform (Trichloro-methane) (µg/L) (32106)**	**Bromodi-chloro-methane (µg/L) (32101)**	**Dibromo-chloro-methane (µg/L) (32105)**	**Methyl ethyl ketone (2-butanone, MEK) (µg/L) (81595)**	**Perchloroethene (PCE, Tetrachloro-ethene) (µg/L) (34475)**	**Trichloro-ethene (TCE) (µg/L) (39180)**	**Toluene (µg/L) (34010)**	**Styrene (µg/L) (77128)**	**Carbon disulfide (µg/L) (77041)**	**Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)**	**Detections per site**	**VOC detection summary [1]**
Benchmark type	**MCL-US**	**MCL-US**	**MCL-US**	**HAL-US**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-CA**		
Benchmark level	**[2] 80**	**[2] 80**	**[2] 80**	**4,000**	**5**	**5**	**150**	**100**	**160**	**13**		
[LRL or SRL]	**[0.03]**	**[0.034]**	**[0.12]**	**[1.6]**	**[0.026]**	**[0.018]**	**[0.69] [1]**	**[0.03]**	**[0.03]**	**[0.1]**		
KLAM grid sites (38 sites sampled)												
KLAM-07	0.19	—	—	—	—	—	—	—	—	—	1	—
KLAM-08	0.03	—	—	—	—	—	—	—	—	—	1	—
KLAM-09	0.03	—	—	—	—	—	—	—	—	—	1	—
KLAM-12	—	—	—	1.0	—	—	—	—	—	—	1	—
KLAM-17	—	—	—	—	—	—	—	—	—	0.76	1	—
												—
KLAM-18	0.02	—	—	—	—	—	—	—	—	—	1	—
KLAM-22	0.01	—	—	—	—	—	—	—	—	—	1	—
KLAM-23	0.08	—	—	—	—	—	—	—	—	—	1	—
KLAM-25	—	—	—	—	—	—	≤0.01	0.12	—	—	1	—
KLAM-26	0.03	—	—	—	—	—	—	—	—	—	1	—
												—
KLAM-27	0.02	—	—	—	—	—	—	—	—	—	1	—
KLAM-28	0.02	—	—	1.7	—	—	—	—	—	—	2	—
KLAM-30	—	—	—	—	—	—	—	—	0.10	—	1	—
KLAM-31	0.12	—	—	—	—	—	—	—	—	—	1	—
KLAM-34	0.66	0.082	—	—	0.012	0.026	—	—	—	—	4	—

Table 5. Volatile organic compounds (VOCs) detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites 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 38 grid sites. All constituents are listed in table 3A. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LRL as of October 1, 2010. **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 (CDPH) maximum contaminant level; NL-CA, CDPH notification level. **Other abbreviations**: USGS, U.S. Geological Survey; ≤, less than or equal to; LRL, laboratory reporting level; SRL, study reporting level; µg/L, micrograms per liter; na, not available; —, not detected]

Primary use or source	Trihalomethanes			Solvents			Hydrocarbons		Natural	Gasoline oxygenate		
GAMA site identification number	Chloroform (Trichloromethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Dibromochloromethane (µg/L) (32105)	Methyl ethyl ketone (2-butanone, MEK) (µg/L) (81595)	Perchloroethene (PCE, Tetrachloroethene) (µg/L) (34475)	Trichloroethene (TCE) (µg/L) (39180)	Toluene (µg/L) (34010)	Styrene (µg/L) (77128)	Carbon disulfide (µg/L) (77041)	Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)	Detections per site	VOC detection summary [1]
Benchmark type	**MCL-US**	**MCL-US**	**MCL-US**	**HAL-US**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-CA**		
Benchmark level	**[2] 80**	**[2] 80**	**[2] 80**	**4,000**	**5**	**5**	**150**	**100**	**160**	**13**		
[LRL or SRL]	**[0.03]**	**[0.034]**	**[0.12]**	**[1.6]**	**[0.026]**	**[0.018]**	**[0.69] [1]**	**[0.03]**	**[0.03]**	**[0.1]**		
KLAM grid sites (38 sites sampled)—Continued												
KLAM-37	2.3	0.534	0.17	—	—	—	—	—	—	—	3	—
Number of sites with detections	12	2	1	2	1	1	0	1	1	1	—	16
Detection frequency (percent)	31.6	5.3	2.6	5.3	2.6	2.6	0	2.6	2.6	2.6	—	42
Total detections (number)	—	—	—	—	—	—	—	—	—	—	—	22
KLAM understanding site [3]												
KLAM-U-01	0.02	—	—	—	—	—	1.0	—	—	—	2	—

[1] The SRLs for toluene, tetrahydrofuran, and 1,2,4-trimethylbenzene were defined by Fram and others (2012). All detections of tetrahydrofuran (KLAM-12: 6 µg/L; KLAM-28: 8 µg/L) and 1,2,4-trimethylbenzene (KLAM-02: 0.02 µg/L; KLAM-04: 0.02 µg/L; KLAM-05: 0.03 µg/L; KLAM-06: 0.06 µg/L; KLAM-07: 0.04 µg/L; KLAM-08: 0.11 µg/L; KLAM-09: 0.06 µg/L; KLAM-10: 0.25 µg/L; KLAM-12: 0.06 µg/L; KLAM-13: 0.26 µg/L; KLAM-14: 0.38 µg/L; KLAM-15: 0.30 µg/L; KLAM-16: 0.08 µg/L; KLAM-18: 0.09 µg/L; KLAM-19: 0.10 µg/L; KLAM-21: 0.02 µg/L; KLAM-22: 0.01 µg/L; KLAM-23: 0.02 µg/L; KLAM-24: 0.04 µg/L; KLAM-25: 0.05 µg/L; KLAM-26: 0.03 µg/L; KLAM-27: 0.04 µg/L; KLAM-28: 0.13 µg/L; KLAM-29: 0.03 µg/L; KLAM-30: 0.04 µg/L; KLAM-31: 0.11 µg/L; KLAM-32: 0.02 µg/L; KLAM-33: 0.02 µg/L; KLAM-34: 0.05 µg/L; KLAM-35: 0.04 µg/L; KLAM-38: 0.06 µg/L) have been reclassified as non-detections and are not presented in this report. Please see the appendix section titled "Quality-Assurance and Quality-Control Methods and Results" for more information.

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

[3] The understanding site was not included in statistical calculations.

Table 6. Pesticides and pesticide degradates detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites 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 38 grid sites. All constituents are listed in table 3B. **GAMA site identification number**: KLAM, Klamath Mountains study unit. Benchmark type, benchmark level, and LRL as of October 1, 2010. **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 (USEPA) maximum contaminant level; HAL-US, USEPA lifetime health advisory 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; —, not detected]

Primary use or source	**Herbicide degradate**	**Herbicide**				
GAMA site identification number	**Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-*s*-triazine) (µg/L) (04040)**	**Atrazine (µg/L) (39632)**	**Simazine (µg/L) (04035)**	**Hexazinone (µg/L) (04025)**	**Pesticide detections per site**	**Pesticide detection summary**
Benchmark type	**na**	**MCL-CA**	**MCL-US**	**HAL-US**		
Benchmark level	**na**	**1**	**4**	**400**		
[LRL]	**[0.014]**	**[0.007]**	**[0.006]**	**[0.008]**		
KLAM grid sites (38 sites sampled)						
KLAM-03	—	—	0.011	—	1	—
KLAM-13	—	—	0.007	—	1	—
KLAM-16	E0.007	—	—	—	1	—
KLAM-26	E0.042	—	—	—	1	—
KLAM-28	E0.007	0.006	—	—	2	—
KLAM-29	E0.008	—	—	0.065	2	—
KLAM-32	E0.010	—	—	—	1	—
KLAM-34	E0.009	0.009	—	—	2	—
Number of sites with detections	6	2	2	1	—	8
Detection frequency (percent)	15.8	5.3	5.3	2.6	—	21
Total detections (number)	—	—	—	—	—	11

Table 7. Trace elements detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of mercury, which was sampled for at KLAM-19 per owner's request. Information about the constituents given in table 3D. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of March 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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 site 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)
Benchmark type	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Benchmark level	**1,000**	**6**	**10**	**1,000**	**4**	**1,000**	**5**	**50**	**na**	**1,300**	**300**	**15**
[LT-MDL or SRL]	**[1.7]**	**[0.027]**	**[0.022]**	**[0.36] [1]**	**[0.006]**	**[3]**	**[0.016]**	**[0.42] [1]**	**[0.23] [2]**	**[1.7] [1]**	**[6.0] [1]**	**[0.65] [1]**
KLAM grid sites (38 sites sampled)												
KLAM-01	—	—	—	0.47	—	—	—	1.5	≤0.02	≤1.3	6.7	≤0.23
KLAM-02	2.7	—	0.15	51.6	—	—	—	0.43	≤0.04	8.2	12.3	≤0.49
KLAM-03	4.6	0.028	0.19	15.4	—	26	—	≤0.25	≤0.05	≤0.99	32.4	≤0.19
KLAM-04	—	—	—	70.6	—	—	0.020	≤0.15	≤0.03	26.0	—	≤0.45
KLAM-05	—	0.051	0.52	30.2	—	7	—	0.49	≤0.04	3.6	11.9	≤0.13
KLAM-06	—	—	0.17	39.2	0.052	*2,230	—	—	—	—	29.9	≤0.03
KLAM-07	7.3	0.097	1.30	1.5	—	94	—	6.3	≤0.04	4.0	—	2.6
KLAM-08	—	0.229	0.43	82.6	—	29	—	—	≤0.06	—	244	≤0.02
KLAM-09	—	0.055	0.08	65.8	—	11	—	≤0.17	≤0.10	—	170	—
KLAM-10	2.7	—	0.12	9.2	—	3	0.018	0.73	≤0.18	3.2	—	≤0.31
KLAM-11	2.8	0.061	0.36	1.5	—	44	—	0.43	—	≤0.80	—	≤0.34
KLAM-12	24.7	—	0.13	1.0	—	3	—	≤0.08	—	≤1.3	48.3	≤0.05
KLAM-13	—	—	0.08	7.3	—	37	—	≤0.40	≤0.02	2.8	≤4.5	≤0.24
KLAM-14	—	—	0.27	51.4	—	93	—	≤0.36	≤0.02	≤1.6	—	1.1
KLAM-15	—	0.028	0.10	9.6	—	20	—	≤0.39	≤0.04	4.1	—	0.78
KLAM-16	2.2	—	0.06	81.1	—	8	0.053	0.97	—	—	—	≤0.10
KLAM-17	1.9	—	0.29	12.3	—	13	—	≤0.18	≤0.04	≤1.6	—	≤0.30
KLAM-18	1.9	—	—	≤0.15	—	—	—	1.0	≤0.07	≤1.0	*385	—
KLAM-19	—	0.057	4.2	50.7	—	32	—	—	≤0.03	≤1.3	6.5	0.81
KLAM-20	2.1	—	0.05	8.9	—	—	—	6.9	—	—	—	≤0.18

Table 7. Trace elements detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of mercury, which was sampled for at KLAM-19 per owner's request. Information about the constituents given in table 3D. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of March 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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 site 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)
Benchmark type	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Benchmark level	**1,000**	**6**	**10**	**1,000**	**4**	**1,000**	**5**	**50**	**na**	**1,300**	**300**	**15**
[LT-MDL or SRL]	**[1.7]**	**[0.027]**	**[0.022]**	**[0.36] [1]**	**[0.006]**	**[3]**	**[0.016]**	**[0.42] [1]**	**[0.23] [2]**	**[1.7] [1]**	**[6.0] [1]**	**[0.65] [1]**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-21	—	—	0.65	16.1	—	4	—	0.79	—	≤1.7	—	≤0.04
KLAM-22	1.9	0.077	0.37	20.4	—	41	—	2.0	≤0.06	2.3	34.2	≤0.54
KLAM-23	15.7	—	0.88	6.5	—	—	—	≤0.23	≤0.05	≤1.2	11.6	≤0.30
KLAM-24	2.0	—	0.12	11.1	—	10	—	—	≤0.08	—	*472	≤0.05
KLAM-25	3.0	0.193	0.43	38.4	—	114	—	≤0.24	≤0.11	—	152	≤0.02
KLAM-26	3.9	—	0.07	1.5	—	64	—	≤0.13	≤0.03	≤0.67	14.7	≤0.28
KLAM-27	4.4	0.276	0.08	35.5	—	17	—	—	0.72	1.9	52.9	≤0.15
KLAM-28	—	—	0.16	8.8	—	4	—	≤0.07	—	—	9.6	≤0.38
KLAM-29	8.2	—	0.29	2.9	0.009	17	—	≤0.42	—	≤1.2	7.8	≤0.23
KLAM-30	1.8	—	0.06	18.9	0.030	590	—	—	≤0.02	—	*2,950	—
KLAM-31	—	0.032	0.05	0.84	—	177	—	1.4	≤0.04	—	≤5.5	—
KLAM-32	—	—	0.12	45.9	—	13	—	≤0.23	≤0.02	≤1.6	22.0	0.76
KLAM-33	12.0	0.049	0.89	244	0.008	381	—	—	—	—	9.2	≤0.29
KLAM-34	3.5	0.055	0.26	19.0	—	13	0.019	≤0.41	≤0.07	≤0.79	63.5	≤0.20
KLAM-35	2.9	0.036	0.25	0.71	—	—	0.076	≤0.07	≤0.02	8.9	—	1.4
KLAM-36	3.1	0.036	0.13	3.3	—	13	—	1.2	≤0.10	≤1.5	7.3	≤0.41
KLAM-37	9.7	—	0.16	24.6	—	49	0.027	0.76	≤0.15	2.8	33.0	≤0.10
KLAM-38	8.9	0.031	0.13	1.9	—	—	—	≤0.10	—	3.6	≤4.1	≤0.38

Table 7. Trace elements detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of mercury, which was sampled for at KLAM-19 per owner's request. Information about the constituents given in table 3D. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of March 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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 site 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)
Benchmark type	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-US**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Benchmark level	**1,000**	**6**	**10**	**1,000**	**4**	**1,000**	**5**	**50**	**na**	**1,300**	**300**	**15**
[LT-MDL or SRL]	**[1.7]**	**[0.027]**	**[0.022]**	**[0.36] [1]**	**[0.006]**	**[3]**	**[0.016]**	**[0.42] [1]**	**[0.23] [2]**	**[1.7] [1]**	**[6.0] [1]**	**[0.65] [1]**
KLAM understanding site												
KLAM-U-01	—	0.08	0.98	29.1	—	6	—	0.45	≤0.06	≤0.87	8.8	0.85

GAMA site identification number	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Mercury (µg/L) (71890)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Silver (µg/L) (01075)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Benchmark type	**na**	**SMCL-CA**	**MCL-US**	**HAL-US**	**MCL-CA**	**MCL-US**	**SMCL-CA**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**
Benchmark level	**na**	**50**	**2**	**40**	**100**	**50**	**100**	**4,000**	**2**	**na**	**50**	**5,000**
[LT-MDL or SRL]	**[0.22]**	**[0.36] [2]**	**[0.005]**	**[0.014]**	**[0.36] [1]**	**[0.03]**	**[0.005]**	**[0.2]**	**[0.01]**	**[0.11] [1]**	**[0.08]**	**[4.8] [1]**
KLAM grid sites (38 sites sampled)												
KLAM-01	—	—	nc	0.040	2.3	0.04	—	3.24	—	—	—	9.8
KLAM-02	2.43	2.4	nc	0.224	24.4	0.38	—	40.7	—	—	0.42	20.3
KLAM-03	0.69	6.6	nc	0.781	0.43	0.73	—	494	—	—	0.89	≤3.0
KLAM-04	1.84	1.3	nc	—	0.43	0.04	—	55.8	—	—	—	35.8
KLAM-05	—	0.57	nc	0.479	≤0.17	0.22	—	197	—	—	1.2	47.2
KLAM-06	138	25.2	nc	0.279	—	—	—	806	—	≤0.07	0.46	≤1.6
KLAM-07	—	≤0.14	nc	0.243	≤0.34	0.09	—	48.4	—	0.56	2.9	36.8
KLAM-08	7.55	21.3	nc	1.96	0.61	0.15	—	1,600	—	≤0.02	—	108
KLAM-09	3.64	30.8	nc	0.889	4.4	0.74	—	321	—	≤0.01	0.17	11.1
KLAM-10	—	—	nc	0.117	6.9	0.07	—	87.7	—	—	0.18	—

Table 7. Trace elements detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of mercury, which was sampled for at KLAM-19 per owner's request. Information about the constituents given in table 3D. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of March 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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 site identification number	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Mercury (µg/L) (71890)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Silver (µg/L) (01075)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Benchmark type	**na**	**SMCL-CA**	**MCL-US**	**HAL-US**	**MCL-CA**	**MCL-US**	**SMCL-CA**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**
Benchmark level	**na**	**50**	**2**	**40**	**100**	**50**	**100**	**4,000**	**2**	**na**	**50**	**5,000**
[LT-MDL or SRL]	**[0.22]**	**[0.36] [2]**	**[0.005]**	**[0.014]**	**[0.36] [1]**	**[0.03]**	**[0.005]**	**[0.2]**	**[0.01]**	**[0.11] [1]**	**[0.08]**	**[4.8] [1]**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-11	—	—	nc	0.513	≤0.33	0.28	—	94.0	—	≤0.01	3.6	19.0
KLAM-12	0.79	≤0.15	nc	—	≤0.32	—	—	17.0	—	—	1.7	≤1.5
KLAM-13	—	0.40	nc	0.304	1.7	0.06	—	45.4	—	—	1.8	22.1
KLAM-14	1.91	—	nc	0.599	0.43	0.36	—	208	—	≤0.02	1.2	7.7
KLAM-15	0.54	≤0.21	nc	0.188	≤0.25	0.21	—	240	—	—	0.94	≤4.2
KLAM-16	5.44	≤0.22	nc	0.049	2.5	0.36	—	36.0	—	—	0.14	≤1.8
KLAM-17	17.8	≤0.30	nc	0.555	0.45	0.05	—	125	—	≤0.01	3.0	≤1.7
KLAM-18	0.43	36.1	nc	—	0.95	—	—	27.8	—	—	1.2	14.3
KLAM-19	—	1.2	—	0.189	≤0.26	0.09	0.012	26.2	0.01	—	2.3	—
KLAM-20	0.44	—	nc	—	2.1	—	—	55.7	—	—	0.90	40.7
KLAM-21	8.90	—	nc	0.892	—	0.10	—	60.4	—	≤0.04	11.9	≤1.6
KLAM-22	0.63	5.2	nc	0.364	13.7	0.31	—	143	—	—	0.36	66.0
KLAM-23	10.6	1.7	nc	2.92	0.42	1.0	—	208	—	0.17	12.4	≤2.3
KLAM-24	10.5	*146	nc	0.347	0.67	—	—	303	—	0.13	0.13	6.9
KLAM-25	12.2	*121	nc	0.443	0.42	—	—	198	—	≤0.08	—	≤3.5

Table 7. Trace elements detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of mercury, which was sampled for at KLAM-19 per owner's request. Information about the constituents given in table 3D. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of March 1, 2010. **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; HAL-US, USEPA lifetime health advisory 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 site identification number	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Mercury (µg/L) (71890)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Silver (µg/L) (01075)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)
Benchmark type	**na**	**SMCL-CA**	**MCL-US**	**HAL-US**	**MCL-CA**	**MCL-US**	**SMCL-CA**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**
Benchmark level	**na**	**50**	**2**	**40**	**100**	**50**	**100**	**4,000**	**2**	**na**	**50**	**5,000**
[LT-MDL or SRL]	**[0.22]**	**[0.36] [2]**	**[0.005]**	**[0.014]**	**[0.36] [1]**	**[0.03]**	**[0.005]**	**[0.2]**	**[0.01]**	**[0.11] [1]**	**[0.08]**	**[4.8] [1]**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-26	3.12	0.94	nc	0.754	0.48	0.16	—	70.4	—	≤0.02	9.1	≤2.3
KLAM-27	10.1	*66.5	nc	0.101	0.57	—	—	119	—	≤0.02	—	≤4.0
KLAM-28	0.32	1.4	nc	0.041	≤0.14	0.08	—	39.8	—	—	—	11.8
KLAM-29	3.93	—	nc	0.126	—	—	0.005	68.3	—	≤0.02	7.9	≤2.4
KLAM-30	13.0	*104	nc	0.941	5.6	—	—	137	—	0.52	—	≤2.1
KLAM-31	4.67	31.9	nc	0.107	0.62	0.04	—	5.71	—	1.0	0.12	—
KLAM-32	0.33	1.8	nc	2.11	≤0.31	0.22	—	57.3	—	—	2.5	≤3.8
KLAM-33	19.2	8.8	nc	1.10	—	0.50	0.006	364	—	0.16	0.60	21.4
KLAM-34	1.07	4.2	nc	0.097	≤0.28	0.54	—	79.6	—	—	1.1	5.7
KLAM-35	—	—	nc	0.164	≤0.10	0.11	—	15.4	—	0.18	1.4	43.6
KLAM-36	0.38	≤0.36	nc	0.078	18.6	—	—	16.5	—	—	0.54	10.8
KLAM-37	0.35	1.0	nc	0.066	9.2	0.09	0.005	78.6	—	—	0.49	5.9
KLAM-38	—	≤0.14	nc	0.101	≤0.10	0.13	—	29.7	—	—	0.50	≤4.1
KLAM understanding site												
KLAM-U-01	4.82	7.6	nc	1.11	0.61	0.89	—	274	—	—	0.67	12.4

[1] The SRL was defined by Olsen and others (2010).

[2] The SRL was defined based on the highest concentration detected in KLAM field blank samples.

Table 8. Nutrients detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, but only samples with detections are listed. Information about the constituents given in table 3E. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of October 1, 2010. **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; na, not available; —, not detected]

GAMA site identification number	Ammonia (as nitrogen) (mg/L) (00608)	Nitrite (as nitrogen) (mg/L) (00613)	Nitrite plus nitrate (as nitrogen) [1] (mg/L) (00631)	Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen) (mg/L) (62854)	Phosphate, orthophosphate (as phosphorus) (mg/L) (00671)
Benchmark type	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**
Benchmark level	**[2] 24.7**	**1**	**10**	**na**	**na**
[LT-MDL]	**[0.01]**	**[0.001]**	**[0.02]**	**[0.05]**	**[0.006]**
KLAM grid sites (38 sites sampled)					
KLAM-01	—	—	—	—	0.006
KLAM-02	—	—	—	—	0.011
KLAM-03	—	—	0.27	0.26	0.025
KLAM-04	—	—	0.07	—	0.014
KLAM-05	—	—	0.06	—	0.036
KLAM-06	0.29	—	—	0.25	0.010
KLAM-07	—	—	0.17	0.15	0.018
KLAM-08	0.06	0.002	0.03	0.06	0.007
KLAM-09	—	—	0.08	0.07	0.012
KLAM-10	—	—	0.03	—	0.035
KLAM-11	—	—	0.06	0.05	0.016
KLAM-12	—	—	0.03	—	0.022
KLAM-13	0.01	—	0.08	0.07	0.018
KLAM-14	—	—	0.35	0.35	0.037
KLAM-15	—	—	0.19	0.17	0.015
KLAM-16	—	—	0.11	0.10	0.024
KLAM-17	—	—	0.58	0.61	0.024
KLAM-18	0.01	—	—	—	0.017
KLAM-19	0.01	—	0.08	0.12	0.029
KLAM-20	—	—	0.04	—	0.026
KLAM-21	—	—	0.05	—	0.022
KLAM-22	—	—	0.20	0.20	0.017
KLAM-23	—	—	0.17	0.18	0.028
KLAM-25	0.03	—	—	—	0.029
KLAM-26	—	—	2.56	2.57	0.035

Table 8. Nutrients detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, but only samples with detections are listed. Information about the constituents given in table 3E. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of October 1, 2010. **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; na, not available; —, not detected]

GAMA site identification number	Ammonia (as nitrogen) (mg/L) (00608)	Nitrite (as nitrogen) (mg/L) (00613)	Nitrite plus nitrate (as nitrogen) [1] (mg/L) (00631)	Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen) (mg/L) (62854)	Phosphate, orthophosphate (as phosphorus) (mg/L) (00671)
Benchmark type	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**
Benchmark level	**[2] 24.7**	**1**	**10**	**na**	**na**
[LT-MDL]	**[0.01]**	**[0.001]**	**[0.02]**	**[0.05]**	**[0.006]**
KLAM grid sites (38 sites sampled)—Continued					
KLAM-27	—	—	—	—	0.026
KLAM-28	—	—	0.03	—	0.015
KLAM-29	—	—	0.23	0.23	0.075
KLAM-30	0.06	—	—	—	0.025
KLAM-31	0.02	—	0.03	—	0.010
KLAM-32	—	—	0.05	—	0.030
KLAM-33	0.04	0.002	0.06	0.07	0.073
KLAM-34	—	—	1.85	1.95	0.020
KLAM-35	—	—	0.04	—	0.016
KLAM-36	—	—	0.04	0.07	0.011
KLAM-37	—	—	1.57	1.69	0.039
KLAM-38	—	—	—	—	0.012
KLAM understanding site					
KLAM-U-01	—	—	0.05	—	0.018

[1] Nitrite plus nitrate (as nitrogen) is referred to as nitrate in the text for clarity.

[2] 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 9. Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed. Information about the constituents given in table 3F. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of October 1, 2010. **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_2, silicon dioxide; na, not available; —, not detected; *, concentration greater than the recommended benchmark level]

GAMA site 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_2) (mg/L) (00955)	TDS (mg/L) (70300)
Benchmark type	**na**	**na**	**SMCL-CA**	**MCL-CA**	**na**	**na**	**na**	**na**	**SMCL-CA**	**na**	**SMCL-CA**
Benchmark level	**na**	**na**	**250 (500)**	**2**	**na**	**na**	**na**	**na**	**250 (500)**	**na**	**500 (1,000)**
[LT-MDL]	**[0.01]**	**[0.022]**	**[0.06]**	**[0.04]**	**[0.002]**	**[0.008]**	**[0.022]**	**[0.06]**	**[0.09]**	**[0.029]**	**[12]**
KLAM grid sites (38 sites sampled)											
KLAM-01	—	1.15	2.59	—	—	23.2	0.05	1.56	1.07	9.74	101
KLAM-02	—	14.9	0.53	0.06	—	8.67	2.79	3.27	11.5	19.2	108
KLAM-03	0.02	59.1	7.22	0.09	—	8.77	0.58	12.4	21.0	23.6	263
KLAM-04	—	5.36	0.57	—	—	5.53	0.60	3.61	3.71	13.1	52
KLAM-05	—	58.5	0.35	0.11	—	12.1	0.69	3.98	13.5	14.6	222
KLAM-06	0.73	22.6	*454	0.23	0.094	2.27	0.63	303	22.1	15.1	*926
KLAM-07	—	36.0	0.90	0.09	—	20.1	0.29	7.59	3.36	25.5	208
KLAM-08	—	41.7	2.35	0.08	—	6.13	0.73	10.7	20.6	12.0	169
KLAM-09	0.01	44.1	2.02	0.12	—	3.96	1.35	5.65	18.0	16.9	169
KLAM-10	—	5.08	0.90	—	—	3.05	0.29	2.85	1.56	13.5	52
KLAM-11	—	28.9	1.00	0.07	—	6.74	0.36	3.55	9.20	24.3	139
KLAM-12	—	16.1	0.39	0.05	—	6.34	0.20	4.60	0.24	23.7	108
KLAM-13	—	29.0	1.80	0.07	—	13.3	0.30	4.17	4.96	25.8	158
KLAM-14	0.01	72.4	1.66	0.16	—	15.1	0.84	6.99	16.7	18.7	285
KLAM-15	—	58.8	1.78	0.08	—	6.14	0.94	4.98	13.5	18.2	213

Table 9. Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed. Information about the constituents given in table 3F. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of October 1, 2010. **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_2, silicon dioxide; na, not available; —, not detected; *, concentration greater than the recommended benchmark level]

GAMA site 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_2) (mg/L) (00955)	TDS (mg/L) (70300)
Benchmark type	**na**	**na**	**SMCL-CA**	**MCL-CA**	**na**	**na**	**na**	**na**	**SMCL-CA**	**na**	**SMCL-CA**
Benchmark level	**na**	**na**	**250 (500)**	**2**	**na**	**na**	**na**	**na**	**250 (500)**	**na**	**500 (1,000)**
[LT-MDL]	**[0.01]**	**[0.022]**	**[0.06]**	**[0.04]**	**[0.002]**	**[0.008]**	**[0.022]**	**[0.06]**	**[0.09]**	**[0.029]**	**[12]**
KLAM grid sites (38 sites sampled)—Continued											
KLAM-16	—	5.82	0.66	0.11	—	3.12	0.23	5.59	4.25	33.9	73
KLAM-17	—	24.6	1.63	0.11	—	8.69	1.05	9.07	4.54	29.1	142
KLAM-18	—	9.52	0.42	—	—	3.77	0.45	3.28	0.18	33.7	80
KLAM-19	—	21.1	0.84	0.08	—	10.9	0.28	3.18	2.23	16.6	94
KLAM-20	—	6.80	0.50	—	—	26.3	0.44	2.63	0.22	36.3	135
KLAM-21	—	26.0	1.06	0.07	—	25.7	4.12	4.73	2.29	27.0	187
KLAM-22	—	20.5	2.57	—	—	13.9	0.43	3.17	10.7	18.1	137
KLAM-23	—	32.7	3.61	0.07	0.001	11.9	4.18	9.73	21.2	31.0	213
KLAM-24	—	59.0	1.76	0.11	0.002	25.8	2.70	16.3	68.3	33.8	334
KLAM-25	—	60.4	2.72	0.23	0.001	7.85	0.35	11.9	27.6	35.7	255
KLAM-26	0.01	30.0	6.20	—	0.002	15.3	1.13	9.07	10.8	45.4	203
KLAM-27	—	29.0	2.04	0.16	—	8.01	0.52	11.3	50.7	44.4	197
KLAM-28	—	17.3	0.80	0.04	—	3.63	0.17	4.75	7.43	21.7	94
KLAM-29	—	9.90	2.62	0.04	—	4.54	1.95	6.27	0.78	45.9	109
KLAM-30	0.06	26.9	15.7	0.07	0.007	18.3	1.09	17.5	9.41	52.5	226

Table 9. Major and minor ions, silica, and total dissolved solids (TDS) detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed. Information about the constituents given in table 3F. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and LT-MDL as of October 1, 2010. **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_2, silicon dioxide; na, not available; —, not detected; *, concentration greater than the recommended benchmark level]

GAMA site 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_2) (mg/L) (00955)	TDS (mg/L) (70300)
Benchmark type	**na**	**na**	**SMCL-CA**	**MCL-CA**	**na**	**na**	**na**	**na**	**SMCL-CA**	**na**	**SMCL-CA**
Benchmark level	**na**	**na**	**250 (500)**	**2**	**na**	**na**	**na**	**na**	**250 (500)**	**na**	**500 (1,000)**
[LT-MDL]	**[0.01]**	**[0.022]**	**[0.06]**	**[0.04]**	**[0.002]**	**[0.008]**	**[0.022]**	**[0.06]**	**[0.09]**	**[0.029]**	**[12]**
KLAM grid sites (38 sites sampled)—Continued											
KLAM-31	—	2.60	4.05	—	0.006	93.3	0.34	4.80	3.93	12.5	308
KLAM-32	—	29.5	0.73	0.14	—	7.81	0.40	8.49	4.19	28.4	153
KLAM-33	0.02	8.55	7.89	0.12	0.013	2.45	0.33	28.6	7.12	18.1	118
KLAM-34	0.03	83.8	8.43	0.06	—	6.42	0.32	7.66	53.0	24.3	300
KLAM-35	—	20.6	0.74	0.09	—	14.5	0.09	7.15	6.12	20.2	130
KLAM-36	—	5.43	1.36	—	—	14.5	0.23	2.15	1.16	20.3	78
KLAM-37	—	10.4	13.6	0.08	—	9.72	0.98	11.5	14.4	21.4	122
KLAM-38	—	19.0	0.61	—	—	8.84	0.24	5.77	13.0	17.2	118
KLAM understanding site											
KLAM-U-01	—	73.1	1.26	0.14	—	8.86	2.97	5.56	38.6	20.6	276

Table 10. Arsenic and iron species detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Information about the constituents given in table 3G. Samples from all 39 sites were analyzed, but only samples with detections are listed. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type, benchmark level, and MDL as of October 1, 2010. **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; SMCL-CA, CDPH secondary maximum contaminant level. **Other abbreviations**: USGS, U.S. Geological Survey; MDL, method detection limit; na, not available; µg/L, micrograms per liter; E, estimated or having a higher degree of uncertainty; *, concentration greater than the benchmark level; —, not detected]

GAMA site identification number	Arsenic (total) (99033) (µg/L)	Arsenic-III (99034) (µg/L)	Iron (total) (01046) (µg/L)	Iron-II (01047) (µg/L)
Benchmark type	**MCL-US**	**na**	**SMCL-CA**	**na**
Benchmark level	**10**	**na**	**300**	**na**
[MDL]	**[0.5]**	**[1]**	**[2]**	**[2]**
KLAM grid sites (38 sites sampled)				
KLAM-01	—	—	3	—
KLAM-02	—	—	10	9
KLAM-03	E0.2	—	36	32
KLAM-05	0.5	—	—	—
KLAM-06	—	—	31	31
KLAM-07	1.0	—	—	—
KLAM-08	E0.4	—	259	238
KLAM-09	—	—	178	175
KLAM-11	E0.4	—	—	—
KLAM-12	—	—	11	6
KLAM-13	—	—	6	5
KLAM-14	E0.3	—	—	—
KLAM-17	E0.3	—	—	—
KLAM-18	—	—	*394	380
KLAM-19	4.3	—	6	6
KLAM-21	0.6	—	—	—
KLAM-22	E0.3	—	38	31
KLAM-23	0.8	—	9	4
KLAM-24	—	—	*490	463
KLAM-25	0.5	—	245	234
KLAM-26	—	—	14	11
KLAM-27	—	—	55	47
KLAM-28	—	—	10	10
KLAM-29	E0.2	—	7	4
KLAM-30	—	—	*2,940	2,890
KLAM-32	—	—	24	19
KLAM-33	0.8	—	6	3
KLAM-34	—	—	56	33
KLAM-36	—	—	5	4
KLAM-37	—	—	37	25
KLAM-38	—	—	3	3
KLAM understanding site				
KLAM-U-01	1.0	—	8	—

Table 11. Isotopic tracers detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[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 3H. Samples from all 39 sites were analyzed. Stable isotope ratios of hydrogen, oxygen, and carbon are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. Isotopic ratios of strontium in water are reported as the abundance of atoms of the heavier isotope to the lighter isotope of the element. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. **Other abbreviations**: USGS, U.S. Geological Survey; H, hydrogen; O, oxygen; Sr, strontium; ^{14}C, carbon-14; na, not available]

GAMA site identification number	δ^{2}H in water (per mil) (82082)	δ^{18}O in water (per mil) (82085)	Isotopic ratio of Sr in water (^{87}Sr/^{86}Sr) (atom ratio) (75978)	δ^{13}C in dissolved inorganic carbon (per mil) (82081)	^{14}C in water (percent modern) (49933)
Benchmark type	**na**	**na**	**na**	**na**	**na**
Benchmark level	**na**	**na**	**na**	**na**	**na**
KLAM grid sites (38 sites sampled)					
KLAM-01	–57.8	–8.75	0.70626	–11.15	90.37
KLAM-02	–88.1	–12.17	0.70720	–20.85	104.2
KLAM-03	–93.3	–12.01	0.70554	–15.19	85.06
KLAM-04	–104	–14.41	0.71327	–19.28	103.4
KLAM-05	–98.1	–13.52	0.70511	–12.63	98.45
KLAM-06	–103	–13.24	0.70615	–16.31	38.86
KLAM-07	–82.2	–11.30	0.70532	–16.55	94.33
KLAM-08	–59.2	–9.10	0.70541	–13.36	48.36
KLAM-09	–66.9	–9.62	0.70551	–18.40	75.52
KLAM-10	–70.0	–10.17	0.70600	–20.61	95.41
KLAM-11	–69.3	–10.08	0.70406	–17.84	106.7
KLAM-12	–84.3	–11.94	0.70730	–19.79	95.10
KLAM-13	–79.5	–11.27	0.70446	–15.56	104.2
KLAM-14	–73.4	–10.33	0.71348	–14.79	100.3
KLAM-15	–74.3	–10.61	0.71306	–14.19	100.7
KLAM-16	–65.7	–9.78	0.70738	–21.74	96.63
KLAM-17	–87.8	–11.51	0.70606	–20.05	104.2
KLAM-18	–85.3	–12.10	0.70692	–21.08	95.53
KLAM-19	–72.9	–9.21	0.70692	–13.38	102.6
KLAM-20	–87.2	–12.15	0.70482	–21.34	94.60
KLAM-21	–86.9	–12.00	0.70717	–17.22	95.14
KLAM-22	–64.3	–9.40	0.70576	–13.80	96.17
KLAM-23	–85.6	–11.81	0.70513	–18.32	96.74
KLAM-24	–94.9	–12.27	0.71048	–14.38	78.07
KLAM-25	–63.9	–9.60	0.70796	–19.28	77.21
KLAM-26	–66.2	–9.61	0.70547	–18.12	110.6
KLAM-27	–63.6	–9.56	0.70663	–20.32	103.9
KLAM-28	–64.9	–9.90	0.70623	–16.40	97.17
KLAM-29	–90.8	–12.98	0.70405	–13.53	63.98
KLAM-30	–77.8	–11.28	0.70431	–17.19	56.22
KLAM-31	–99.7	–13.05	0.70518	–14.62	75.63
KLAM-32	–65.5	–9.72	0.70538	–18.80	88.25
KLAM-33	–72.4	–10.64	0.71107	–15.84	47.02
KLAM-34	–63.7	–9.59	0.70665	–13.75	71.40
KLAM-35	–64.0	–9.68	0.70608	–18.71	96.61
KLAM-36	–91.9	–12.97	0.70449	–14.92	104.5
KLAM-37	–77.7	–10.77	0.70651	–19.97	100.7
KLAM-38	–79.8	–11.24	0.70519	–13.57	101.6
KLAM understanding site					
KLAM-U-01	–76.7	–10.56	0.71309	–14.53	88.39

Table 12. Results for the Lawrence Livermore National Laboratory (LLNL) analyses of tritium, dissolved noble gases, and helium isotope ratios in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit number in parentheses below the constituent name is the USGS parameter code used to uniquely identify a specific constituent or property. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. **Measurement errors**: Helium-3/helium-4 ratios, helium-4, krypton, neon, and xenon have 2-percent errors; argon has 3-percent errors; errors for modeled recharge temperature are less than 1 °C for 82 percent of the samples. Benchmark type and benchmark level as of October 1, 2010. **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. **Abbreviations**: cm^3 STP/g, cubic centimeters at standard temperature and pressure per gram of water; °C, degrees Celsius; na, not available; pCi/L, picocuries per liter; CSU, 1-sigma combined standard uncertainty; —, not detected; ±, plus or minus; nc, not collected]

GAMA site identification number	Tritium (pCi/L) (07000)	Helium-3/ Helium-4 (atom ratio) (61040)	Helium-4 (cm^3 STP/g) (85561)	Neon (cm^3 STP/g) (61046)	Argon (cm^3 STP/g) (85563)	Krypton (cm^3 STP/g) (85565)	Xenon (cm^3 STP/g) (85567)	Modeled recharge temperature (°C)
Benchmark type	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**na**	**na**
Benchmark level	**20,000**	**na**	**na**	**na**	**na**	**na**	**na**	**na**
[RL]	**result ± CSU**	**$x\ 10^{-7}$**	**$x\ 10^{-7}$**	**$x\ 10^{-7}$**	**$x\ 10^{-4}$**	**$x\ 10^{-8}$**	**$x\ 10^{-8}$**	**0.1**
KLAM grid sites (38 sites sampled)								
KLAM-01	2.2 ± 0.18	13.44	0.69	2.29	3.58	8.05	1.17	14.1
KLAM-02	2.4 ± 0.18	13.45	0.78	3.58	6.44	14.85	2.45	11.5
KLAM-03	1.9 ± 0.18	7.24	0.98	2.08	3.42	7.86	1.14	13.1
KLAM-04	2.9 ± 0.18	13.73	0.79	3.39	4.41	9.89	1.35	5.7
KLAM-05	2.5 ± 0.18	13.37	0.69	2.78	3.35	8.43	1.20	11.5
KLAM-06	0.40 ± 0.18	10.17	51.41	3.61	4.52	10.04	1.50	6.8
KLAM-07	2.0 ± 0.18	11.82	0.83	2.77	3.95	8.60	1.17	13.0
KLAM-08	2.1 ± 0.18	13.18	0.67	2.74	4.17	9.45	1.20	12.4
KLAM-09	2.3 ± 0.18	3.93	3.01	2.16	3.61	8.24	1.26	12.2
KLAM-10	2.4 ± 0.18	13.72	0.63	2.79	4.78	11.28	1.62	3.2
KLAM-11	2.6 ± 0.18	13.68	0.63	2.63	3.70	8.34	1.10	15.2
KLAM-12	3.5 ± 0.18	nc	nc	nc	nc	nc	nc	nc
KLAM-13	2.9 ± 0.18	13.68	0.47	2.04	3.48	8.18	1.13	13.0
KLAM-14	2.8 ± 0.18	9.84	0.65	2.23	3.82	7.10	1.09	11.5
KLAM-15	2.4 ± 0.18	8.91	1.88	2.77	4.23	9.44	1.29	11.0
KLAM-16	3.4 ± 0.18	15.64	0.72	3.03	4.30	9.28	1.26	11.9
KLAM-17	1.9 ± 0.18	9.09	0.79	2.25	3.77	8.84	1.24	8.4
KLAM-18	2.3 ± 0.18	14.55	0.80	3.40	4.43	9.42	1.34	7.9
KLAM-19	2.7 ± 0.18	13.81	0.57	2.39	3.57	7.94	1.09	14.3
KLAM-20	1.4 ± 0.18	14.10	0.43	1.90	3.60	8.51	1.24	11.5
KLAM-21	1.8 ± 0.18	13.79	0.49	1.90	3.18	7.47	1.06	14.3
KLAM-22	2.0 ± 0.18	13.87	1.49	6.03	7.84	15.06	1.91	6.4
KLAM-23	1.4 ± 0.18	10.84	0.88	2.71	3.89	8.37	1.16	12.7
KLAM-24	1.5 ± 0.18	5.72	3.78	5.77	5.87	11.52	1.59	5.0
KLAM-25	2.8 ± 0.18	11.08	0.80	2.78	3.89	8.59	1.26	12.1

Table 12. Results for the Lawrence Livermore National Laboratory (LLNL) analyses of tritium, dissolved noble gases, and helium isotope ratios in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit number in parentheses below the constituent name is the USGS parameter code used to uniquely identify a specific constituent or property. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. **Measurement errors**: Helium-3/helium-4 ratios, helium-4, krypton, neon, and xenon have 2-percent errors; argon has 3-percent errors; errors for modeled recharge temperature are <1 °C for 82 percent of the samples. Benchmark type and benchmark level as of October 1, 2010. **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. **Abbreviations**: cm^3 STP/g, cubic centimeters at standard temperature and pressure per gram of water; °C, degrees Celsius; na, not available; pCi/L, picocuries per liter; CSU, 1-sigma combined standard uncertainty; —, not detected; ±, plus or minus; nc, not collected]

GAMA site identification number	Tritium (pCi/L) (07000)	Helium-3/ Helium-4 (atom ratio) (61040)	Helium-4 (cm^3 STP/g) (85561)	Neon (cm^3 STP/g) (61046)	Argon (cm^3 STP/g) (85563)	Krypton (cm^3 STP/g) (85565)	Xenon (cm^3 STP/g) (85567)	Modeled recharge temperature (°C)
Benchmark type	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**na**	**na**
Benchmark level	**20,000**	**na**	**na**	**na**	**na**	**na**	**na**	**na**
[RL]	**result ± CSU**	**x 10^{-7}**	**x 10^{-7}**	**x 10^{-7}**	**x 10^{-4}**	**x 10^{-8}**	**x 10^{-8}**	**0.1**
KLAM grid sites (38 sites sampled)—Continued								
KLAM-26	2.4 ± 0.18	14.34	6.68	14.83	8.47	14.25	1.67	11.5
KLAM-27	2.4 ± 0.18	13.54	0.45	1.84	3.36	7.86	1.04	14.7
KLAM-28	2.8 ± 0.18	14.10	0.51	2.15	3.65	8.46	1.24	11.5
KLAM-29	2.4 ± 0.18	24.73	0.52	1.92	3.65	8.71	1.26	8.5
KLAM-30	0.25 ± 0.18	44.85	2.61	2.91	4.29	9.74	1.39	7.5
KLAM-31	2.8 ± 0.18	6.02	18.06	2.09	4.31	8.72	1.23	11.5
KLAM-32	3.4 ± 0.18	14.89	0.88	3.70	4.67	9.71	1.25	14.2
KLAM-33	1.6 ± 0.18	9.86	2.64	3.24	4.35	9.24	1.10	18.0
KLAM-34	2.9 ± 0.18	13.68	1.44	5.16	5.38	9.73	1.25	14.5
KLAM-35	2.5 ± 0.18	13.95	0.67	2.97	4.22	9.17	1.22	13.3
KLAM-36	3.0 ± 0.18	13.27	0.45	2.03	3.94	9.07	1.36	6.6
KLAM-37	2.5 ± 0.18	13.91	0.48	2.16	3.28	7.63	1.11	14.2
KLAM-38	2.6 ± 0.18	13.87	0.48	2.11	3.58	8.39	1.24	10.4
KLAM understanding site								
KLAM-U-01	2.6 ± 0.18	12.50	0.49	1.94	3.43	8.07	1.11	13.5

Table 13. Uranium and other radioactive constituents detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of radon-222 at site KLAM-12. Information about the constituents given in table 3H. 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 site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type and benchmark level as of October 1, 2010. **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; µg/L, micrograms per liter; —, not detected; ±, plus or minus; nc, not collected]

GAMA site identification number	Uranium (µg/L) (22703)	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	**MCL-US**	**Proposed MCL-US**		**MCL-US**		**MCL-US**		**MCL-CA**		**MCL-CA**		**MCL-CA**
Benchmark level	**30**	**4,000**		**15**		**15**		**50**		**50**		**20,000**
[RL]	**[0.004]**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**
KLAM grid sites (38 sites sampled)												
KLAM-01	—	—	13	—	0.28	—	0.37	—	0.40	—	0.90	7.0 ± 0.38
KLAM-02	0.033	500 ± 31	11	—	0.27	—	0.24	2.82 ± 0.34	0.42	1.7 ± 0.41	0.60	7.6 ± 0.42
KLAM-03	0.226	420 ± 27	14	0.84 ± 0.44	0.56	1.02 ± 0.56	0.63	—	0.84	—	0.82	6.2 ± 0.41
KLAM-04	0.012	460 ± 29	12	0.71 ± 0.22	0.23	—	0.66	—	0.42	1.19 ± 0.55	0.83	9.1 ± 0.44
KLAM-05	0.183	270 ± 20	13	—	0.44	1.06 ± 0.43	0.50	—	0.57	—	0.91	8.0 ± 0.48
KLAM-06	0.013	280 ± 20	12	2.29 ± 0.83	0.73	—	1.0	1.26 ± 0.75	1.2	—	0.92	1.3 ± 0.32
KLAM-07	0.026	71 ± 13	17	—[1]	0.41	0.76 ± 0.51	0.65	[1] 0.58 ± 0.34	0.53	1.84 ± 0.61	0.92	6.3 ± 0.44
KLAM-08	0.023	152 ± 15	15	[1] 0.73 ± 0.48	0.58	—	1.0	—[1]	0.63	—	1.4	6.6 ± 0.44
KLAM-09	0.126	420 ± 28	14	—[1]	0.66	2.28 ± 0.88	0.74	[1] 0.88 ± 0.44	0.67	—	1.4	7.3 ± 0.47
KLAM-10	—	450 ± 29	13	—	0.33	—	0.55	—	0.92	0.93 ± 0.55	0.83	7.5 ± 0.46
KLAM-11	0.034	590 ± 36	13	—	0.52	—	0.91	—	0.60	—	0.83	8.4 ± 0.44
KLAM-12	0.005	nc		—	0.43	—	0.61	—	0.74	—	1.3	11.3 ± 0.54
KLAM-13	0.030	199 ± 16	14	—	0.54	—	0.65	—	0.65	—	0.87	9.4 ± 0.48
KLAM-14	0.497	450 ± 28	12	1.36 ± 0.52	0.57	—	0.88	0.70 ± 0.43	0.66	—	0.95	8.8 ± 0.48
KLAM-15	0.339	410 ± 26	12	—	0.45	—	0.88	—	0.71	—	0.84	7.6 ± 0.43

Table 13. Uranium and other radioactive constituents detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of radon-222 at site KLAM-12. Information about the constituents given in table 3H. 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 site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type and benchmark level as of October 1, 2010. **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; µg/L, micrograms per liter; —, not detected; ±, plus or minus; nc, not collected]

GAMA site identification number	Uranium (µg/L) (22703)	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	**MCL-US**	**Proposed MCL-US**		**MCL-US**		**MCL-US**		**MCL-CA**		**MCL-CA**		**MCL-CA**
Benchmark level	**30**	**4,000**		**15**		**15**		**50**		**50**		**20,000**
[RL]	**[0.004]**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**	**ssL_C**	**Result ± CSU**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-16	—	2,670 ± 150	13	—	0.35	—	0.18	0.67 ± 0.27	0.42	0.78 ± 0.37	0.57	10.7 ± 0.50
KLAM-17	0.923	1,630 ± 91	13	0.67 ± 0.35	0.48	—	0.6	1.08 ± 0.28	0.41	1.1 ± 0.40	0.61	6.1 ± 0.43
KLAM-18	—	79 ± 11	13	—	0.36	—	0.38	0.62 ± 0.27	0.42	—	0.59	7.3 ± 0.42
KLAM-19	0.054	85 ± 11	13	—	0.40	—	0.65	—	0.52	—	0.66	8.5 ± 0.45
KLAM-20	0.099	340 ± 23	13	0.25 ± 0.18	0.23	—	0.39	—	0.45	—	0.72	4.5 ± 0.47
KLAM-21	3.22	1,830 ± 100	12	2.08 ± 0.48	0.42	1.84 ± 0.63	0.59	4.31 ± 0.41	0.42	4.93 ± 0.57	0.66	5.7 ± 0.48
KLAM-22	0.005	149 ± 17	18	—	0.31	—	0.46	0.52 ± 0.26	0.41	—	0.62	6.3 ± 0.46
KLAM-23	0.349	600 ± 38	18	—	0.48	—	0.47	3.64 ± 0.39	0.44	3.7 ± 0.50	0.61	4.5 ± 0.40
KLAM-24	0.252	1,660 ± 92	11	9.6 ± 1.4	0.72	1.84 ± 0.53	0.51	5.07 ± 0.53	0.61	3.9 ± 0.46	0.55	4.8 ± 0.41
KLAM-25	0.020	65 ± 9.1	11	—	0.58	—	0.59	—	0.72	—	1.0	8.9 ± 0.54
KLAM-26	0.037	59 ± 8.7	11	—	0.52	—	0.74	1.03 ± 0.32	0.48	—	0.67	7.7 ± 0.48
KLAM-27	0.004	38 ± 9.3	13	—	0.52	—	0.67	—	0.41	—	0.66	7.8 ± 0.46
KLAM-28	0.007	212 ± 17	14	—	0.3	—	0.44	—	0.41	—	0.56	8.9 ± 0.52
KLAM-29	0.074	1,240 ± 70	12	—	0.42	—	0.49	1.55 ± 0.28	0.40	1.88 ± 0.45	0.66	7.5 ± 0.45
KLAM-30	0.011	237 ± 17	12	—	0.95	—	0.56	1.58 ± 0.66	0.94	0.93 ± 0.43	0.69	0.80 ± 0.38

Table 13. Uranium and other radioactive constituents detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, with the exception of radon-222 at site KLAM-12. Information about the constituents given in table 3H. 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 site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type and benchmark level as of October 1, 2010. **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; µg/L, micrograms per liter; —, not detected; ±, plus or minus; nc, not collected]

GAMA site identification number	Uranium (µg/L) (22703)	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	**MCL-US**	**Proposed MCL-US**		**MCL-US**		**MCL-US**		**MCL-CA**		**MCL-CA**		**MCL-CA**
Benchmark level	**30**	**4,000**		**15**		**15**		**50**		**50**		**20,000**
[RL]	**[0.004]**	**Result ± CSU**	**ssL$_C$**	**Result ± CSU**	**ssL$_C$**	**Result ± CSU**	**ssL$_C$**	**Result ± CSU**	**ssL$_C$**	**Result ± CSU**	**ssL$_C$**	**Result ± CSU**
KLAM grid sites (38 sites sampled)—Continued												
KLAM-31	—	—	14	—	0.42	—	0.59	—	0.47	—	0.66	8.9 ± 0.43
KLAM-32	0.039	410 ± 26	12	—	0.44	0.46 ± 0.35	0.44	—	0.69	—	0.76	10.8 ± 0.43
KLAM-33	0.022	1,200 ± 67	12	0.42 ± 0.28	0.37	—	0.54	—	0.42	—	0.57	5.2 ± 0.31
KLAM-34	0.130	320 ± 23	14	—	0.67	—	0.98	—	0.86	—	0.80	9.2 ± 0.41
KLAM-35	0.004	68 ± 10	13	—	0.35	—	0.50	—	0.67	—	0.65	7.9 ± 0.37
KLAM-36	—	54 ± 9.0	12	—	0.21	0.41 ± 0.27	0.33	—	0.42	—	0.62	9.6 ± 0.42
KLAM-37	0.008	1,330 ± 76	15	— [1]	0.38	—	0.46	[1] 0.76 ± 0.26	0.40	—	0.65	7.9 ± 0.39
KLAM-38	0.010	91 ± 12	14	—	0.35	—	0.51	—	0.45	—	0.73	8.3 ± 0.42
KLAM understanding site												
KLAM-U-01	0.662	630 ± 38	13	—	0.75	—	0.66	2.76 ± 0.46	0.63	1.73 ± 0.47	0.70	8.2 ± 0.55

[1] Counted 4-6 days after sample collection.

Table 14. Microbial indicators detected in samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[The five-digit USGS parameter code below the constituent name is used to uniquely identify a specific constituent or property. Samples from all 39 sites were analyzed, but only samples with detections are listed. Information about the constituents given in table 3I. **GAMA site identification number**: KLAM, Klamath Mountains study unit; KLAM-U, Klamath Mountains study unit understanding site. Benchmark type and benchmark level as of October 1, 2010. **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. TT-US, U.S. Environmental Protection Agency (USEPA) treatment technique; MCL-US, USEPA maximum contaminant level. **Other abbreviations**: USGS, U.S. Geological Survey; %, percent; M, presence verified but not quantified; —, not detected]

GAMA site identification number	Total coliform (including fecal coliform and *E. coli*) (99595)	*Escherichia coli* (*E. coli*) (99596)
Benchmark type	**MCL-US**	**TT-US**
Benchmark level	**5% of samples positive per month**	**No fecal coliforms are allowed**
KLAM grid sites (38 sites sampled)		
KLAM-01	M	—
KLAM-02	M	—
KLAM-04	M	—
KLAM-08	M	M
KLAM-12	M	—
KLAM-20	M	—
KLAM-22	M	—
KLAM-23	M	—
KLAM-25	M	—
KLAM-26	M	—
KLAM-34	M	M
KLAM-36	M	—
KLAM-37	M	—
KLAM-38	M	—
KLAM understanding site		
KLAM-U-01	M	—

Appendix

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 site 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 KLAM study unit, groundwater samples were collected and QA/QC procedures were implemented using standard and modified USGS protocols from the NFM (U.S. Geological Survey, variously dated; Wilde and others, 1999, 2004) and the NAWQA Program (Koterba and others, 1995). 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 system to land surface and into a distribution system. Sites were classified as springs if groundwater discharged naturally at land surface from the aquifer without a drilled hole or if a well was drilled horizontally. A few springs had pumps to transport groundwater from the spring site to a storage tank at a higher elevation.

Prior to sampling, each well was pumped continuously to purge at least three casing volumes of water from the well (Wilde and others, 1999). Wells were sampled using Teflon® tubing with brass and stainless-steel fittings attached to a sampling point (usually a hose-bib fitting) on the well discharge pipe as close to the wellhead as possible. The sampling point was located upstream from water-storage tanks or wellhead treatment systems (if present). 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. The mobile laboratory could not be parked within 50 ft of the sampling point at most of the sampling sites; therefore, 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).

Most of the springs were plumbed and had sampling points on the discharge pipes similar to the sampling points found on discharge pipes from wells. Field water-quality indicators were measured and samples were collected using the same protocols as used for wells.

One spring (KLAM-12) was not plumbed and discharged into a pool from which the water was then pumped into the distribution system. For this spring, field water-quality parameters were measured by dipping the multi-probe meter directly into the water as close to the spring discharge point as possible. Groundwater samples were collected by dipping bottles into the water as close to the spring discharge point as possible. This method was used because the alternative—pumping water from the pool with a portable peristaltic pump through the filtration apparatus—was not logistically possible at most of the unplumbed spring sites. In all cases, turbidity (measured with a calibrated turbidity meter) was less than 0.5 nephelometric turbidity units (NTU) and the samples were collected unfiltered, but marked as filtered for analysis.

For the field measurements, groundwater was pumped through a flow-through chamber (attached to the sampling point) 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 USGS 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 5-minute (min) intervals, and when these values remained stable for a minimum of 30 min, samples for laboratory analyses then were collected.

Field measurements and instrument calibrations were recorded on field record sheets and electronically on field laptop computers using the Personal Computer Field Form (PCFF) program. Analytical service requests for the NWQL were generated 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 database 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 by using ampoules of certified, traceable concentrated acids obtained from the NWQL.

VOC samples were collected in three 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_2O) solution was added as a preservative to the VOC samples. Tritium samples 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 60-mL clear glass bottles filled with unfiltered groundwater, sealed with a conical cap, and secured with electrical tape to prevent leakage and evaporation.

Pesticides and pesticide degradate samples were collected in 1-L baked amber glass bottles. Samples were filtered through a 0.7-micrometer (µm) nominal pore-size glass fiber filter during collection.

Groundwater samples for analysis of trace elements, major and minor ions, silica, and TDS 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. The 250-mL filtered sample then was preserved with 7.5-N nitric acid. Samples for analyses of nutrients were filtered into 125-mL brown polyethylene bottles. Samples for analyses of arsenic and iron species were filtered into 250-mL polyethylene bottles that were covered with tape to prevent light exposure and preserved with 6-N hydrochloric acid. Samples for analyses of isotopic ratios of dissolved strontium were filtered into 250-mL polyethylene bottles and secured with electrical tape to prevent leakage and evaporation. Samples for stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance 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. Samples for field alkalinity titrations were collected by filtering groundwater into 500-mL polyethylene bottles.

For the collection of groundwater samples for analysis of radon-222, a stainless-steel and Teflon® valve assembly was attached to the sampling port at the wellhead (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 shaken. The vial was placed in an insulated cardboard tube to protect the sample during shipping.

Samples for analyses of dissolved noble gases were collected in ⅜-inch-diameter copper tubes by using reinforced nylon tubing connected to the hose bib at the wellhead. Groundwater was flushed through the tubing to dislodge any bubbles before the flow was restricted with a back pressure valve. Clamps on either side of the copper tube then were tightened, trapping a sample of groundwater for analyses of dissolved noble gases (Weiss, 1968).

Samples for analysis of the presence or absence of microbial indicators were collected at the wellhead using the IDEXX Colilert® test kit (Standard Method 9223; American Public Health Association, 1998). Prior to the collection of samples, the sampling port was sterilized with isopropyl alcohol and then was flamed or left to air dry. Groundwater was run through the sampling port for at least 2 minutes to remove any traces of the sterilizing agent. A 100-mL IDEXX Colilert® sterile sample bottle containing sodium thiosulfate (to neutralize chlorine when present) was filled directly from the sampling port. After a reagent was added, the sample bottle was inverted gently to mix the reagent with the sample. The sample was incubated for 24 hours at 35 ºC ± 0.5 ºC. Sample results were viewed against a comparator and interpreted as follows: if the sample was (1) less yellow than the comparator, then the presence of total coliform and *E. coli* were not detected; (2) more yellow than or the same as the comparator, then the presence of total coliform was detected; (3) more yellow and more fluorescent than or the same as the comparator, then the presence of *E. coli* was detected.

Field alkalinity was measured in the mobile laboratory at 25 percent of the field sites. Field alkalinity was measured in filtered groundwater samples by Gran's titration method (Gran, 1952). Titration data were entered directly into PCFF, and the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) automatically were 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_3^- and CO_3^{2-} also were calculated for all field sites from the laboratory alkalinity and laboratory pH measurements.

Temperature-sensitive samples were stored on ice prior to and during daily shipping to the various laboratories. The non-temperature- or non-time-sensitive samples for analyses of tritium, stable isotopes of hydrogen and oxygen in water, isotopic ratios of dissolved strontium, and dissolved noble gases were shipped monthly. Temperature- or time-sensitive samples for analyses of VOCs, pesticides and pesticide degradates, perchlorate, trace elements, nutrients, major and minor ions, silica, and TDS were shipped daily. The temperature-sensitive samples for analyses of arsenic and iron species were stored on ice and shipped weekly. Samples for analyses of stable isotopes of carbon in dissolved inorganic carbon and carbon-14 abundance were stored on ice, archived in a laboratory refrigerator, and shipped after results for alkalinity were received from the NWQL.

Nine 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 the National Environmental Laboratory Accreditation Program (NELAP) and other certifications. In addition, 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 and evaluation of equipment used to collect these measurements (http://qadata.cr.usgs.gov/nfqa/). Results for analyses made at the NWQL or by laboratories contracted by the NWQL are uploaded directly into the USGS NWIS database. Results of analyses made at other laboratories are compiled in a project database and uploaded from there into the USGS NWIS database. Some laboratory QC data are stored in the USGS NWIS database also.

Data Reporting

Laboratory Reporting Conventions

The USGS NWQL uses different conventions for reporting results for organic, inorganic, and radioactive constituents. For organic constituents (VOCs and pesticides), an 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 level (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 a 1-percent chance of a false positive) (Childress and others, 1999; U.S. Environmental Protection Agency, 2002).

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 KLAM study unit (October to December 2010). Concentrations less than the LRL and the LT-MDL are reported as non-detections with a dash (—) in the data tables.

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 methods that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection, such as those methods used to analyze VOCs and pesticides, detections less than the LT-MDL have high certainty of presence, but the precise concentration is uncertain. These values are also E-coded. 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).

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

Results for most constituents are given by using the LRL, LT-MDL, MDL, or MRL values provided by the analyzing laboratories. Results for some organic and inorganic constituents are presented using SRLs derived from assessing results from QC samples associated with groundwater samples collected as part of the GAMA-PBP [see the appendix section titled “Methods of Determining Study Reporting Levels (SRLs)”]. The SRLs are raised reporting levels with concentrations greater than the concentrations of the reporting level used by the laboratory.

The methods used for analysis of the radiochemical constituents (tritium, radon-222, and gross alpha and gross beta radioactivity) measure activities by counting techniques (table A1). Activity often is used instead of concentration for reporting the presence of radioactive constituents. Activity of these 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.

The reporting limits for the radiochemical constituents 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 radioactive 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 also are 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).

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

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

where i is the atomic mass of the heavier isotope of the element;

E is the element (H for hydrogen, O for oxygen, and C for carbon);

R_{sample} is the ratio of the abundance of the heavier isotope of the element (^{2}H, ^{18}O, ^{13}C) to the lighter isotope of the element (^{1}H, ^{16}O, ^{12}C) in the sample; and

$R_{reference}$ 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 δ^{18}O and δ^{2}H values of 0 per mil (note than δ^{2}H is sometimes written as δD because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium). The reference material for carbon is Vienna Pee Dee Belemnite (VPDB), which is assigned a δ^{13}C value of 0 per mil. Positive values indicate enrichment of the heavier isotope, and negative values indicate depletion of the heavier isotope, compared to the ratios observed in the standard reference material. Isotopic ratios of strontium in water are presented as the abundance of atoms of the heavier isotope (^{87}Sr) to the lighter isotope (^{86}Sr) of the element.

Constituents Determined by Multiple Methods or Laboratories

Six constituents were measured by more than one analytical method or by more than one laboratory (table A2). The preferred methods for these constituents were selected on the basis of the procedure recommended by the NWQL (http://wwwnwql.cr.usgs.gov/dyn.shtml?Preferred_method_selection_procedure).

The water-quality indicators—alkalinity, pH, and specific conductance—were measured in the field and at the NWQL. The field measurements are the preferred method for all three constituents; however, both measurements are reported (table 4). Field values are generally preferred because field conditions are considered more representative of groundwater conditions (Hem, 1985).

For total arsenic and total iron concentrations, the approved method, Schedule 1948 (table 3G), used by the NWQL is preferred over the research methods used by the USGS NRP-TML (table 3D); however, both measurements are reported (tables 7 and 10). The concentrations of arsenic and iron measured by the USGS NRP-TML only are used to calculate ratios of redox species (table 10).

For example,

$$Fe(III) = Fe(T) - Fe(II) \, , \qquad \text{(A2)}$$

where

$Fe(T)$ is the total iron concentration (measured),

$Fe(II)$ is the concentration of ferrous iron (measured), and

$Fe(III)$ is the concentration of ferric iron (calculated).

Tritium also was measured at two laboratories: LLNL and USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (SITL) (table 3H). There was no preferred laboratory for the reporting of tritium, and only tritium data from the SITL were available for reporting at the time of this publication (table 12).

Quality-Assurance and Quality-Control Methods and Results

The purpose of QA/QC is to identify which data best represent groundwater conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, and (or) laboratory analyses. 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 for organic constituents, and (4) surrogate compounds were added to samples analyzed for organic constituents to assess potential bias from laboratory analytical methods. Results that were found to have significant contamination bias, on the basis of the QC data collected from this and previous studies, were flagged with an appropriate remark code (described in subsequent sections) and rejected from subsequent use, including calculations of detection frequency.

Field Blank Samples

The primary purposes of collecting field blank samples are to evaluate potential contamination of samples with compounds of interest during sample handling or analysis and to identify and mitigate the sources of sample contamination (if present).

Methods of Field Blank Sample Collection and Analysis

Field blank samples were collected by using blank water certified by the NWQL to contain less than the reporting levels for selected constituents investigated in the study (http://wwwnwql.cr.usgs.gov/USGS/OBW/obw.html). Nitrogen-purged, organic-free water was used to process blanks analyzed for organic constituents, and inorganic-free water was used to process blanks for inorganic constituents.

Field blank samples were collected to assess whether contamination of samples was introduced during collection, processing, transport, and analysis. To collect field blanks, blank water either was pumped or poured through the same sampling equipment used to collect groundwater samples, then processed and transported by using the same protocols used for the groundwater samples. Typically, 12 L 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, perchlorate, trace elements, nutrients, major and minor ions, silica, TDS, arsenic and iron species, and microbial indicators.

Field blank samples were not collected for radon and gross alpha and gross beta particle activities 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. Stated another way, it is the amount of radionuclide that is statistically significantly greater than the amount in a blank. In addition, blanks were not collected for tritium or dissolved noble gases. Tritium and dissolved noble gases are 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 hydrogen, oxygen, boron, strontium, and carbon are an intrinsic property of any of these elements; therefore, the concept of a blank does not apply to these ratios.

Methods of Determining Study Reporting Levels (SRLs)

The SRLs for selected VOCs were defined by Fram and others (2012) on the basis of the assessment of results from field blank samples, source-solution blank samples, laboratory instrument blank samples, and groundwater samples from the first 32 GAMA-PBP study units (May 2004 through September 2010). SRLs were established for those VOCs that had evidence of potential contamination due to field or laboratory processes. Detections of VOCs in groundwater samples at concentrations less than the SRLs were reported with a ≤ symbol preceding the measured value from the laboratory and considered non-detections.

The SRLs for trace elements were defined by Olsen and others (2010) on the basis of statistical assessment of results from the field blank samples from the first 20 GAMA-PBP study units (May 2004 through January 2008). 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, processed, transported, and analyzed. Detections of trace elements having concentrations less than or equal to the SRLs were reported with a ≤ symbol preceding the measured value from the laboratory to indicate that the true value may be less than or equal to the reported value (including the possibility of being a non-detection).

The SRLs for two other constituents collected for the KLAM study unit (cobalt and manganese) were defined as equal to the highest concentration measured in the field blank samples. Detections of constituents in groundwater samples at concentrations less than or equal to the SRLs defined by the field blank samples were reported with a ≤ symbol preceding the measured value from the laboratory (for inorganic constituents) as described by Olsen and others (2010).

In the USGS NWIS database, data affected by SRLs are accompanied with the following comment: “Result is < or = reported value, based on QC data.”

Detections in Field Blank Samples and Application of SRLs

Table A3 presents a summary of detections in the field blank samples and the SRLs applied for the KLAM study unit. Field blanks samples were collected at 13 percent of the sites sampled in the KLAM study unit.

Five field blank samples were collected in the KLAM study unit for the analysis of VOCs. 1,2,4-Trimethylbenzene was detected in two field blank samples. Toluene and tetrahydrofuran have SRLs defined by Fram and others (2012). A summary of the VOC field blank sample detections and (or) concentration ranges and SRL applications is listed here:

- 1,2,4-Trimethylbenzene was detected in two field blank samples at concentrations of 0.096 µg/L and 0.024 µg/L. 1,2,4-Trimethylbenzene has an SRL of 0.56 µg/L as defined by Fram and others (2012), and 31 groundwater samples had detections with concentrations less than the SRL (table 5, footnote 1).
- Toluene has an SRL of 0.69 µg/L as defined by Fram and others (2012), and one groundwater sample had a detected concentration less than the SRL (table 5).
- Tetrahydrofuran has an SRL defined by Fram and others (2012) that consists of coding all detected concentrations in groundwater as “reviewed and rejected” in the USGS NWIS database. This is equivalent to saying no data are available for tetrahydrofuran for two groundwater samples in the KLAM study unit (table 5, footnote 1).

Five field blank samples were collected in the KLAM study unit for the analysis of trace elements. Seven trace elements (cobalt, copper, iron, lead, manganese, molybdenum, and tungsten) were detected in one or more of the field blank samples collected. An additional three trace elements (chromium, nickel, and zinc) were detected in groundwater samples at concentrations less than or equal to the SRLs defined by Olsen and others (2010). A summary of the trace element field blank sample detections and (or) concentration ranges and SRL applications is listed here:

- Cobalt was detected in four field blank samples, at concentrations ranging from 0.04 µg/L to 0.23 µg/L (table A3). Cobalt has an SRL of 0.23 µg/L as defined by the blank results, and 28 groundwater samples had detections with concentrations less than the SRL (table 7).

- Copper was detected in one field blank sample at a concentration of 1.0 µg/L (table A3). Copper has an SRL of 1.7 µg/L as defined by Olsen and others (2010), and 16 groundwater samples had detections with concentrations less than the SRL (table 7).

- Iron was detected in one field blank sample at a concentration of 4.9 µg/L (table A3). Iron has an SRL of 6.0 µg/L as defined by Olsen and others (2010), and three groundwater samples had detections with concentrations less than the SRL (table 7).

- Lead was detected in two field blank samples at concentrations of 0.12 µg/L and 0.28 µg/L (table A3). Lead has an SRL of 0.65 µg/L as defined by Olsen and others (2010), and 28 groundwater samples had detections with concentrations less than the SRL (table 7).

- Manganese was detected in two field blank samples at concentrations of 0.16 µg/L and 0.36 µg/L (table A3). Manganese has an SRL of 0.36 µg/L as defined by the blank results, and seven groundwater samples had detections with concentrations less than the SRL (table 7).

- Molybdenum was detected in one field blank sample at a concentration of 0.02 µg/L (table A3). Molybdenum was not detected in groundwater samples at concentrations ≤ 0.02 µg/L; therefore, application of an SRL was not necessary.

- Tungsten was detected in one field blank sample at a concentration of 0.02 µg/L (table A3). Tungsten has an SRL of 0.11 µg/L as defined by Olsen and others (2010), and 11 groundwater samples had detections with concentrations less than the SRL (table 7).

- Chromium has an SRL of 0.42 µg/L as defined by Olsen and others (2010), and 17 groundwater samples had detections with concentrations less than the SRL (table 7).

- Nickel has an SRL of 0.36 µg/L as defined by Olsen and others (2010), and 11 groundwater samples had detections with concentrations less than the SRL (table 7).

- Zinc has an SRL of 4.8 µg/L as defined by Olsen and others (2010), and 15 groundwater samples had detections with concentrations less than the SRL (table 7).

Four field blank samples were collected in the KLAM study unit for the analysis of the major and minor ions, silica, and TDS. Silica (as SiO_2) was detected in one field blank at a concentration of 0.030 mg/L (table A3). Silica (as SiO_2) was not detected in groundwater samples at concentrations ≤0.030 mg/L (table 9); therefore, application of an SRL was not necessary. Pesticides were not detected in field blank samples.

Replicate Sample Pairs

Sequential replicate sample pairs 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.

Methods of Assessment of Replicate Sample Pairs

Three methods for measuring replicate pair variability were used to assess precision over the range of measured concentrations in groundwater samples. The variability between results in the pairs of replicate samples was represented by the absolute 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 pair of samples expressed as a percentage. The boundary between concentrations for each metric was defined as five times (×) the reporting level (RL) for each constituent: pairs with mean concentrations ≤ 5×RL used the SD, and pairs with mean concentrations > 5×RL used the RSD. As discussed in the section "Laboratory Reporting Conventions," the RL for most constituents was an LRL or LT-MDL, and some constituents are reported with an SRL, MDL, or MRL.

Replicate pairs of analyses for all constituents except for radioactive constituents were evaluated as follows.

- If both values were reported as detections, the SD or RSD was calculated. Acceptable variability is defined as an SD of < ½ RL or an RSD of < 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 < RL, then a value of zero was substituted for the non-detection, and the SD was calculated. Zero was selected as substitution value because substituting zero for the non-detection yields the maximum possible value for the SD for the replicate pair.

- If one value for a sample pair was reported as a non-detection and the other value was flagged with a ≤ symbol, or if both values were flagged with a ≤ symbol, the SD was not calculated because the values may be analytically identical. The ≤ symbol indicates that the value is a maximum potential concentration and the true concentration could be < RL for the other sample in the pair.

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

Replicate pairs for analyses of radioactive constituents were evaluated by using the following equation (Parr and Porterfield, 1997; McCurdy and others, 2008) to calculate the normalized absolute difference (*NAD*):

$$NAD \leq \frac{|x-y|}{\sqrt{CSU_X^2 + CSU_y^2}}, \qquad \text{(A3)}$$

where x = activities of a radiochemical constituent in the groundwater sample,

y = activities of the same radiochemical constituent in the replicate sample,

CSU_x = combined standard uncertainty of x at the 1σ confidence level, and

CSU_y = combined standard uncertainty of y at the 1σ confidence level.

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

Variability in Replicate Sample Pairs

If results from replicate sample pairs indicate that variability is unacceptable for a constituent, 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 less than that benchmark. Similarly, if measured concentrations are less than a water-quality benchmark, then actual concentrations could be greater than a benchmark. If a constituent has high variability in replicate sample pairs, then a larger difference between concentrations measured in two samples is required to conclude that the two samples have significantly different concentrations.

Tables A4A–D summarize the results of replicate pair analyses for groundwater samples collected in the KLAM study unit. Replicate sample pairs were collected for 13 percent of the samples collected.

Five replicate pairs of samples were analyzed for VOCs, and all pairs were composed of two values reported as non-detections with the exception of one replicate pair for chloroform. The replicate pair yielded two values reported as detections, and the replicate pair analysis resulted in an SD within acceptable precision.

Six replicate pairs of samples were analyzed for pesticide and pesticide degradate compounds, and all pairs were composed of two values reported as non-detections with the exception of one replicate pair analyzed for simazine. The replicate pair yielded two values reported as detections, and the replicate pair analysis resulted in an SD within acceptable precision.

Five replicate pairs of samples were analyzed for inorganic constituents. All replicate pairs were either composed of two values reported as non-detections or two values reported as detections. The analyses for all replicate pairs reported as detections resulted in SDs and RSDs within acceptable variability.

Five replicate pairs of samples were analyzed for uranium and other radioactive constituents. All replicate pairs yielded statistically similar results ($p \leq 0.05$), with the exception of one replicate pair for gross alpha radioactivity (72-hour count).

Five replicate pairs of samples were analyzed for microbial indicators, and all pairs were composed of two values reported as non-detections with the exception of three replicate pairs of total coliform. These replicate pairs each yielded one value reported as M (presence verified but not quantified) and one value reported as a non-detection.

Groundwater data were not flagged in any way on the basis of the results of replicate sample pair analyses.

Matrix-Spike Samples

Addition of a known concentration of a constituent (spike) to a replicate groundwater sample enables the laboratory to determine the effect of the matrix, in this case groundwater, on the analytical technique used to measure the constituent in the sample. The known compounds added in matrix-spike samples are the same as those analyzed in the groundwater samples. This enables an analysis of matrix interferences on a compound-by-compound basis. As part of the GAMA Program, matrix spikes were added by the laboratories performing the analysis rather than in the field. Low matrix-spike recoveries may indicate that measured concentrations in some groundwater samples could be lower than actual concentrations—including the possibility that some samples containing low concentrations of a constituent may be reported as having non-detections for a constituent. High matrix-spike recoveries may indicate that measured concentrations in some groundwater samples could be greater than actual concentrations.

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. Matrix spikes were performed for VOCs and pesticides and pesticide degradates because the analytical methods for these constituents may be susceptible to matrix interferences.

Matrix-Spike Sample Recoveries

Tables A5A, B present a summary of matrix-spike sample recoveries for the KLAM study unit. Spiked samples were collected at 13 percent of the sites sampled.

Five groundwater samples were spiked with VOCs to calculate matrix-spike recoveries. Median matrix-spike recoveries for all 85 spike compounds were between 70 and 130 percent (table A5A).

Five groundwater samples were spiked with pesticide and pesticide degradate compounds to calculate matrix-spike recoveries. Median matrix-spike recoveries for 50 of the 63 spike compounds were between 70 and 130 percent. Seventeen of the spike compounds had median matrix-spike recoveries < 70 percent. All four pesticide and pesticide degradate compounds detected in groundwater samples had median matrix-spike recoveries within the acceptable range (table A5B).

Data for groundwater samples were not flagged on the basis of the results from the matrix-spike recovery analyses.

Surrogate Compounds

Surrogate compounds are added to groundwater samples in the laboratory prior to analysis to evaluate the recovery of chemically similar constituents. Surrogate compounds were added in the laboratory to all groundwater and QC samples 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 analysis results for many compounds in that sample. Potential problems include changes in instrument response and matrix interferences (such as high dissolved organic carbon concentrations) that can produce a positive or 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 compound recoveries for the KLAM study unit. The table lists the surrogate compound, the analytical schedule for which it was applied, the number of analyses for blank and groundwater samples, the number of median surrogate recoveries < 70 percent, and the number of median surrogate recoveries > 130 percent for each matrix (blank and groundwater samples). Blank and groundwater samples were considered separately to assess whether or not the matrices present in groundwater samples affected surrogate recoveries.

Most surrogate compound recoveries for the blank and groundwater samples were within the acceptable range of 70 to 130 percent. In total, 92 percent of the blank and 93 percent of the groundwater sample surrogate recoveries for VOC analyses were within the acceptable range. In addition, 92 percent of the blank and 94 percent of the groundwater sample surrogate recoveries for pesticide and pesticide degradate analyses were within the acceptable range. There were no significant differences between VOC and pesticide and pesticide degradate surrogate recoveries in blank and groundwater samples (Wilcoxon rank sum test, $p < 0.05$).

Data for groundwater samples were not flagged on the basis of the results of surrogate compound recovery analyses.

Other Quality-Control Results

Three laboratory QC matters arose during the analysis of samples collected for KLAM study unit: (1) perchlorate data that did not meet QC standards as required by the GAMA Program, (2) holding-time violations for the results of radioactive constituent data, and (3) internal laboratory QC tests indicating bias on the results of trace element data.

Perchlorate

Groundwater samples were analyzed for perchlorate at Weck using a laboratory method with an MRL of 0.10 µg/L. Samples from three of the KLAM grid sites had reported detections of perchlorate at concentrations greater than the MCL-CA of 6 µg/L. These three grid sites were located in the southern part of the KLAM study unit. The occurrence of groundwater having perchlorate concentrations greater than the MCL-CA in that area was unusual because the area had no reported sites of perchlorate contamination in groundwater or sites where perchlorate was manufactured or used extensively (U.S. Environmental Protection Agency, 2005b; California Department of Toxic Substances Control, 2007; California State Water Resources Control Board, 2009), and the area around the sites is largely undeveloped, forested land with no agricultural crops. Concentrations of perchlorate > 1 µg/L in groundwater are unlikely to represent natural conditions and thus generally indicate presence of anthropogenic sources of perchlorate (Fram and Belitz, 2011). These three grid sites were re-sampled in November 2011, approximately 11 months after the initial KLAM study unit sampling took place. Perchlorate was not detected in the second set of groundwater samples. The groundwater at all three sites was oxic during both sampling events, thus, it is unlikely that the absence of perchlorate in the second sampling event was due to microbial reduction of perchlorate. The fact that perchlorate was not detected in the second set of groundwater samples from the three grid sites casts doubt on the validity of the detections of perchlorate at concentrations > 6 µg/L in the first set of groundwater samples from those three grid sites.

In addition, the detection frequency of perchlorate in the KLAM study unit as a whole was unexpectedly high, given the absence of indicators of potential anthropogenic sources of perchlorate. The observed detection frequency of perchlorate at concentrations > MRL (0.10 µg/L) was 65 percent. The study unit has a relatively wet climate; thus, the predicted probability of detecting perchlorate under natural conditions is relatively low. The predicted probability of detecting perchlorate at concentrations > 0.10 µg/L under natural conditions for the average aridity index of all of the KLAM sampling sites (aridity index = 1.20) is 22 percent (Fram and Belitz, 2011).

Analysis of the QC samples (blank samples, replicate sample pairs, and matrix spikes) collected in the KLAM study unit did not reveal any obvious QC problems. Perchlorate was not detected in any of the five field blank samples collected during the KLAM study. Five replicate sample pairs were within acceptable precision; four of the five replicate sample pairs had two values reported as non-detections, and the fifth replicate sample pair consisted of one non-detection and one detection (with a concentration of 0.11 µg/L). One matrix-spike recovery was performed (at a spike level of 5 µg/L), and the recovery was within the acceptable range of 70 to 130 percent (97 percent).

Even though the results from QC samples collected for perchlorate by the GAMA Program for the KLAM study unit were acceptable, the puzzling results for the groundwater samples raised questions about the quality of the data for the groundwater samples. It is a very serious matter to report detections of anthropogenic constituents like perchlorate with concentrations greater than the MCL-CA (or MCL-US) in CDPH and non-CDPH sites; thus, the GAMA Program maintains high standards for confidence in the quality of datasets. The perchlorate data for the KLAM study unit did not meet those high standards, and therefore, the GAMA Program is not reporting those data.

Holding-Time Violations for Radioactive Constituents

Holding time refers to the time (in calendar days) from sample collection to analysis. A holding-time violation occurs when a sample is analyzed past the given holding time for a particular analysis. The remote sampling areas within the KLAM study unit did not allow for immediate shipment of a few groundwater samples for the analysis of gross alpha and beta radioactivity. This resulted in later arrival times at the laboratory; thus, the analyses were completed after the acceptable holding time. This is important to consider because a delay in the analysis may result in lower measured activities than what may have been present in the groundwater.

The gross alpha and beta radioactivities reported are the amounts measured in the samples. Radioactive decay occurs between the time of sample collection and measurement; therefore, gross alpha and gross beta radioactivity change with time. Generally, gross alpha decreases during the first 10 days due to decay of unsupported members of the thorium-232 decay series (in particular, Ra-224 and its progeny). Four groundwater samples were analyzed past the holding time for gross alpha and beta radioactivity (72-hour count). The results for these four groundwater samples are footnoted in table 13. If samples with gross alpha or beta radioactivity counts ranging from about one-half of the benchmark to the benchmark values were present in the sample, a late analysis could result in reported activities below the benchmark. None of the late groundwater samples in the KLAM study unit were in this category.

Laboratory Bias in Trace Element Analyses

Laboratory bias, as indicated from internal laboratory QC tests, was investigated to determine whether or not the KLAM study unit data were affected by laboratory procedures. The BQS operates the Inorganic Blind Sample Project (IBSP) 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 water samples spiked with known concentrations of the inorganic constituents (Farrar and Long, 1997). The IBSP data are readily available on the BQS website, and the BQS issues monthly summaries of the results, reporting the amount of bias observed in the results (http://bqs.usgs.gov/IBSP/).

The BQS monthly summaries were examined for October through December 2010, the period of sample collection and analyses for the KLAM study unit. During this time, the BQS reported that two inorganic constituents showed evidence of bias: a negative bias for boron and a positive bias for cadmium. Examination of the results for the IBSP samples for these two constituents indicated that the analytical biases reported by the BQS were not significant.

The IBSP samples for boron had concentrations ranging from 16 µg/L to 45 µg/L. The average difference between the measured and expected concentrations was –3 µg/L (standard deviation = 3 µg/L), and the average RPD between the measured and expected concentrations was –10 percent (standard deviation = 8 percent). Boron concentrations in samples collected from the KLAM study unit ranged from “non-detection” to 2,230 µg/L (table 7). Given that the NL-CA for boron is 1,000 µg/L, a concentration much higher than the maximum concentration in the IBSP sample, a negative bias of 10 percent (or 3 µg/L) does not affect the assessment of whether groundwater samples in the KLAM study unit have boron concentrations greater than or less than the NL-CA concentration. A determination of bias at low concentrations does not imply that there is equivalent bias at higher concentrations.

The IBSP samples for cadmium had concentrations ranging from 0.2 µg/L to 2.5 µg/L. The average difference between the measured and expected concentrations was 0.06 µg/L (standard deviation = 0.07 µg/L), and the average RPD between the measured and expected concentrations was 9 percent (standard deviation = 25 percent). The MCL-US for cadmium is 5 µg/L, thus the estimate of bias from the IBSP samples would be relevant for an assessment of whether or not groundwater samples have cadmium concentrations greater than or less than the MCL-US. However, the maximum concentration of cadmium in samples from the KLAM study unit was 0.076 µg/L (table 7); thus, a potential positive bias of 0.06 µg/L, or 8 percent, would not result in an inflated measured concentration value greater than the benchmark when the true concentration is less than the benchmark.

Table A1. Analytical methods used 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**: UV, ultraviolet; 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
Constituent 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, 2005a
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; Garbarino, 1999; American Public Health Association, 1998; Garbarino and others, 2006
Nutrients	Alkaline persulfate digestion, Kjedahl digestion	NWQL, Schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Arsenic and iron species	Various techniques of ultraviolet visible (UV-VIS) spectrophotometry and atomic absorbance spectroscopy	USGS NRP Trace Metal Laboratory [TML], Boulder, Colorado (USGSTMCO)	Stookey, 1970; To and others, 1998; McCleskey and others, 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
Isotopic ratios 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
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

Table A1. Analytical methods used 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**: UV, ultraviolet; USEPA, U.S. Environmental Protection Agency; VOC, volatile organic compound; NRP, USGS National Research Program]

Analyte	Analytical method	Laboratory and analytical schedule	Citation(s)
Radioactivity and dissolved gases			
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	Kreiger and Whittaker, 1980
Dissolved noble gases, tritium, and helium isotope ratios	Helium-3 in-growth and mass spectrometry	Lawrence Livermore National Laboratory [LLNL], Livermore, California (CA-LLNL)	Moran and others, 2002; Eaton and others, 2004
Microbial constituents			
Escherichia coli (*E. coli*) and total coliform	IDEXX Colilert® test kit (Standard Method 9223)	USGS field measurement	American Public Health Association, 1998

Table A2. Preferred analytical methods or laboratories for selected constituents in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[Preferred analytical schedules/methods are selected on the basis of the procedure recommended by the NWQL (http://wwwnwql.cr.usgs.gov/dyn.shtml?Preferred_method_selection_procedure). **Abbreviations**: USGS, U.S. Geological Survey; NWQL, USGS National Water Quality Laboratory, Denver, Colorado; NRP, USGS National Research Project; TML, USGS-NRP Trace Metal Laboratory, Boulder, Colorado; LLNL, Lawrence Livermore National Laboratory, Livermore, California; SITL, USGS Stable Isotope and Tritium Laboratory, Menlo Park, California; np, no preference]

Constituent (synonym or abbreviation)	Primary constituent classification	Analytical methods or laboratory	Preferred analytical method or laboratory
Results from both methods reported			
pH	Water-quality indicator	field, Schedule 1948 (NWQL)	field
Specific conductance	Water-quality indicator	field, Schedule 1948 (NWQL)	field
Alkalinity	Water-quality indicator	field, Schedule 1948 (NWQL)	field
Arsenic (total)	Trace element	Schedule 1948 (NWQL), TML	Schedule 1948
Iron (total)	Trace element	Schedule 1948 (NWQL), TML	Schedule 1948
Tritium	Inorganic tracer	SITL, LLNL	np

Table A3. Constituents detected in the field blank samples and the study reporting level (SRL) analysis for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[**Abbreviations**: RL, reporting level; VOC, volatile organic compound; ≤, less than or equal to; µg/L, micrograms per liter; mg/L, milligrams per liter; 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 [1]	Number of groundwater samples ≤-coded / total number of groundwater detections
VOCs (µg/L)					
1,2,4-Trimethylbenzene	2/4	0.032	0.096, 0.024	0.56 [B]	31/31
Tetrahydrofuran	0/4	1.4	—	all data [B]	2/2
Toluene	0/4	0.018	—	0.69 [B]	1/2
Trace elements (µg/L)					
Chromium	0/5	0.06	—	0.42 [C]	17/32
Cobalt	4/5	0.02	0.04, 0.06, 0.09, 0.23	0.23 [A]	28/29
Copper	1/5	0.5	1.0	1.7 [C]	16/28
Iron	1/5	3.2	4.9	6.0 [C]	3/28
Lead	2/5	0.015	0.12, 0.28	0.65 [C]	28/35
Manganese	2/5	0.13	0.16, 0.36	0.36 [A]	7/31
Molybdenum	1/5	0.014	0.02	nv	0/38
Nickel	0/5	0.09	—	0.36 [C]	11/34
Tungsten	1/5	0.01	0.02	0.11 [C]	11/17
Zinc	0/5	1.4	—	4.8 [C]	15/35
Major and minor ions, silica, and total dissolved solids (TDS) (mg/L)					
Silica (as SiO_2)	1/4	0.029	0.030	nv	0/38

[1] SRLs were defined (A) by the highest concentration in field blank samples collected for the KLAM study unit, (B) by Fram and others (2012), and (C) by Olsen and others (2010).

Table A4A. Quality-control summary for replicate sample pair analyses of organic constituents in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[Constituents for which all replicate pair samples 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 pair samples	Number of SDs > ½ RL / number of replicate pair samples with concentration < 5 times the RL
Volatile organic compounds (VOCs)		
Chloroform (Trichloromethane)	4/5	0/1
Pesticides and pesticide degradates		
Simazine	5/6	0/1

Table A4B. Quality-control summary for replicate sample pair analyses of inorganic constituents in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[Constituents for which all replicate pair 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 pairs / number of replicate pair samples	Number of SDs > ½ RL / number of replicate pair samples with concentrations < 5 times the RL	Number of RSDs > 10 percent / number of replicate pair samples with concentrations > 5 times the RL
Trace Elements			
Aluminum	2/5	0/3	nv
Antimony	2/5	0/2	0/1
Arsenic	0/5	0/3	0/2
Barium	0/5	nv	0/5
Boron	2/5	0/1	0/2
Chromium	1/5	0/4	nv
Cobalt	2/5	0/3	nv
Copper	1/5	0/4	nv
Iron	1/5	0/3	0/1
Lead	0/5	0/5	nv
Lithium	3/5	0/1	0/1
Manganese	1/5	0/3	0/1
Molybdenum	1/5	nv	0/4
Nickel	0/5	0/2	0/3
Selenium	2/5	0/1	0/2
Strontium	0/5	nv	0/5
Tungsten	4/5	0/1	nv
Uranium	0/5	0/3	0/2
Vanadium	1/5	nv	0/4
Zinc	0/5	0/2	0/3
Nutrients			
Ammonia (as nitrogen)	4/5	0/1	nv
Nitrate plus nitrite (as nitrogen) [1]	2/5	0/3	nv
Total nitrogen (ammonia + nitrite + nitrate + organic nitrogen)	0/4	0/1	nv
Phosphate, orthophosphate (as phosphorus)	0/5	0/2	0/3

Table A4B. Quality-control summary for replicate sample pair analyses of inorganic constituents in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—Continued

[Constituents for which all replicate pair 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 pairs / number of replicate pair samples	Number of SDs > ½ RL / number of replicate pair samples with concentrations < 5 times the RL	Number of RSDs > 10 percent / number of replicate pair samples with concentrations > 5 times the RL
Major and minor ions, silica, and total dissolved solids (TDS)			
Calcium	0/5	nv	0/5
Chloride	0/5	nv	0/5
Fluoride	1/5	0/2	0/2
Magnesium	0/5	nv	0/5
Potassium	0/5	nv	0/5
Sodium	0/5	nv	0/5
Sulfate	0/5	0/1	0/4
Silica (as SiO_2)	0/5	nv	0/5
TDS	0/5	nv	0/5
Arsenic and iron species			
Arsenic (total)	0/4	nv	0/1
Iron (total)	2/5	nv	0/3
Iron-II	2/5	nv	0/3

[1] Nitrite plus nitrate (as nitrogen) is referred to as nitrate in the text for clarity.

Table A4C. Quality-control summary for replicate sample pair analyses of radioactive constituents in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[For activities of radioactive constituents, a replicate pair sample analysis 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]

Constituent	Number of replicate pair samples with $p < 0.05$ /number of replicate pair samples	Activities for replicate pair samples with $p > 0.05$ (groundwater sample, replicate sample)
Gross alpha radioactivity, 72-hour count	4/5	(—, 1.43)

Table A4D. Quality-control summary for replicate sample pair analyses of microbial indicators in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[**Abbreviations**: —, not detected; M, presence verified but not quantified]

Constituent	Number of non-detections / number of replicate pair samples	Results for replicate pair samples (groundwater sample, replicate sample)
Total coliform (including fecal coliform and *Escherichia coli* [*E. coli*])	1/4	(—, M) (M, —) (M, —)

Table A5A. Quality-control summary for matrix-spike sample recoveries of volatile organic compounds (VOCs) in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[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	5	96	141	113
Acrylonitrile	5	94	124	102
tert-Amyl methyl ether (TAME)	5	80	90	83
Benzene	5	94	106	98
Bromobenzene	5	91	98	96
Bromochloromethane	5	96	106	101
Bromodichloromethane [1]	5	83	96	90
Bromoform (Tribromomethane)	5	71	96	93
Bromomethane (Methyl bromide)	5	98	105	100
n-Butylbenzene	5	65	95	81
sec-Butylbenzene	5	86	102	92
tert-Butylbenzene	5	88	106	96
Carbon disulfide [1]	5	69	104	72
Carbon tetrachloride (Tetrachloromethane)	5	77	97	89
Chlorobenzene	5	88	101	98
Chloroethane	5	96	112	100
Chloroform (Trichloromethane) [1]	5	100	110	101
Chloromethane	5	97	121	103
3-Chloropropene	5	92	97	95
2-Chlorotoluene	5	84	99	92
4-Chlorotoluene	5	82	100	95
Dibromochloromethane [1]	5	81	92	89
1,2-Dibromo-3-chloropropane (DBCP)	5	80	93	87
1,2-Dibromoethane (EDB)	5	94	108	98
Dibromomethane	5	93	104	97
1,2-Dichlorobenzene	5	86	101	97
1,3-Dichlorobenzene	5	83	100	93
1,4-Dichlorobenzene	5	85	102	95
trans-1,4-Dichloro-2-butene	5	48	104	91
Dichlorodifluoromethane (CFC-12)	5	74	99	81
1,1-Dichloroethane (1,1-DCA)	5	98	106	98
1,2-Dichloroethane (1,2-DCA)	5	96	114	100
1,1-Dichloroethene (1,1-DCE)	5	87	96	94
cis-1,2-Dichloroethene (*cis*-1,2-DCE)	5	93	102	95
trans-1,2-Dichloroethene (*trans*-1,2-DCE)	5	89	99	96
1,2-Dichloropropane	5	88	103	96
1,3-Dichloropropane	5	92	108	98
2,2-Dichloropropane	5	74	80	75
1,1-Dichloropropene	5	82	94	87
cis-1,3-Dichloropropene	5	82	94	84
trans-1,3-Dichloropropene	5	71	97	82
Diethyl ether	5	96	106	102
Diisopropyl ether (DIPE)	5	84	93	90

Table A5A. Quality-control summary for matrix-spike sample recoveries of volatile organic compounds (VOCs) in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—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)
Ethylbenzene	5	86	98	92
Ethyl *tert*-butyl ether (ETBE)	5	82	93	91
Ethyl methacrylate	5	85	94	87
o-Ethyl toluene	5	90	101	95
Hexachlorobutadiene	5	58	88	79
Hexachloroethane	5	73	95	87
2-Hexanone (*n*-Butyl methyl ketone)	5	88	101	95
Iodomethane (Methyl iodide)	5	100	131	107
Isopropylbenzene	5	85	99	94
4-Isopropyl-1-methyl benzene	5	78	101	87
Methyl acrylate	5	92	103	97
Methyl acrylonitrile	5	92	110	103
Methyl *tert*-butyl ether (MTBE) [1]	5	91	98	96
Methyl *iso*-butyl ketone (MIBK)	5	87	99	94
Methylene chloride (Dichloromethane)	5	100	111	101
Methyl ethyl ketone (2-butanone, MEK) [1]	5	91	122	100
Methyl methacrylate	5	85	94	88
Naphthalene	5	89	104	94
Perchloroethene (PCE, Tetrachloroethene) [1]	5	92	111	100
n-Propylbenzene	5	79	99	84
Styrene [1]	5	93	98	96
1,1,1,2-Tetrachloroethane	5	85	97	94
1,1,2,2-Tetrachloroethane	5	92	104	96
Tetrahydrofuran	5	95	114	102
1,2,3,4-Tetramethylbenzene	5	88	98	94
1,2,3,5-Tetramethylbenzene	5	87	99	96
Toluene [1]	5	95	107	105
1,2,3-Trichlorobenzene	5	83	103	95
1,2,4-Trichlorobenzene	5	72	94	86
1,1,1-Trichloroethane (1,1,1-TCA)	5	93	103	99
1,1,2-Trichloroethane (1,1,2-TCA)	5	87	106	100
Trichloroethene (TCE) [1]	5	85	98	96
Trichlorofluoromethane (CFC-11)	5	100	117	105
1,2,3-Trichloropropane (1,2,3-TCP)	5	93	107	100
Trichlorotrifluoroethane (CFC-113)	5	85	101	95
1,2,3-Trimethylbenzene	5	93	102	100
1,2,4-Trimethylbenzene	5	81	133	100
1,3,5-Trimethylbenzene	5	85	98	93
Vinyl bromide (Bromoethene)	5	96	101	100
Vinyl chloride (Chloroethene)	5	96	124	101
m- plus *p*-Xylene	5	91	100	94
o-Xylene	5	90	98	94

[1] Constituent detected in groundwater sample(s).

Table A5B. Quality-control summary for matrix-spike sample recoveries of pesticides and pesticide degradates in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

[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	5	82	100	95
Alachlor	5	87	101	95
Atrazine [1]	5	77	103	94
Azinphos-methyl	5	82	115	97
Azinphos-methyl oxon	5	48	103	82
Benfluralin	5	63	72	68
Carbaryl	5	75	102	98
2-Chloro-2,6-diethylacetanilide	5	88	105	103
4-Chloro-2-methylphenol	5	58	85	75
Chlorpyrifos	5	75	93	82
Chlorpyrifos oxon	5	28	53	50
Cyfluthrin	5	56	80	64
Cypermethrin	5	54	77	66
DCPA (Dacthal)	5	98	106	104
Deethylatrazine (2-Chloro-4-isopropylamino-6-amino-*s*-triazine) [1]	5	69	101	78
Desulfinylfipronil	5	81	103	97
Desulfinylfipronil amide	5	81	89	87
Diazinon	5	87	97	95
3,4-Dichloroaniline	5	77	89	85
Dichlorvos	5	15	45	33
Dicrotophos	5	31	46	36
Dieldrin	5	87	98	92
2,6-Diethylaniline	5	95	100	97
Dimethoate	5	51	72	58
Ethion	5	62	72	69
Ethion monoxon	5	78	100	84
2-Ethyl-6-methylaniline	5	86	95	95
Fenamiphos	5	84	97	90
Fenamiphos sulfone	5	90	115	103
Fenamiphos sulfoxide	5	17	53	39
Fipronil	5	79	104	92
Fipronil sulfide	5	70	95	82
Fipronil sulfone	5	73	84	77
Fonofos	5	87	92	89
Hexazinone [1]	5	58	74	65
Iprodione	5	54	91	66
Isofenphos	5	74	95	89
Malaoxon	5	70	91	84
Malathion	5	68	95	89
Metalaxyl	5	87	107	103

Table A5B. Quality-control summary for matrix-spike sample recoveries of pesticides and pesticide degradates in groundwater samples collected for the Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.—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)
Methidathion	5	82	92	86
Metolachlor	5	78	102	92
Metribuzin	5	69	93	84
Myclobutanil	5	75	85	76
1-Naphthol	5	33	73	51
Paraoxon-methyl	5	49	84	68
Parathion-methyl	5	73	90	83
Pendimethalin	5	68	91	80
cis-Permethrin	5	55	73	62
Phorate	5	70	87	80
Phorate oxon	5	83	102	96
Phosmet	5	15	51	42
Phosmet oxon	5	13	64	45
Prometon	5	72	97	92
Prometryn	5	77	101	94
Pronamide	5	78	100	97
Simazine [1]	5	82	98	95
Tebuthiuron	5	106	139	116
Terbufos	5	77	87	81
Terbufos oxon sulfone	5	58	86	71
Terbuthylazine	5	88	106	101
Tribufos	5	43	57	55
Trifluralin	5	68	78	75

[1] 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 Klamath Mountains (KLAM) Groundwater Ambient Monitoring and Assessment (GAMA) study unit, California, October to December 2010.

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

Surrogate compound	NWQL analytical schedule	Constituent class analyzed	Number of blank samples analyzed	Median recovery in field blank samples (percent)	Number of surrogate recoveries < 70 percent in field blank samples	Number of surrogate recoveries > 130 percent in field blank samples	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	4	90	0	0	39	92	0	0
1,2-Dichloroethane-*d*4	2020	VOC	4	119	0	0	39	120	0	3
Toluene-*d*8	2020	VOC	4	95	0	0	39	96	0	0
Diazinon-*d*10	2003	Pesticide	5	77	1	0	39	77	7	0
α-HCH-*d*6	2003	Pesticide	5	90	0	0	39	96	0	0

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