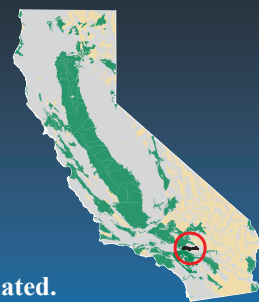


U.S. Geological Survey and the California State Water Resources Control Board

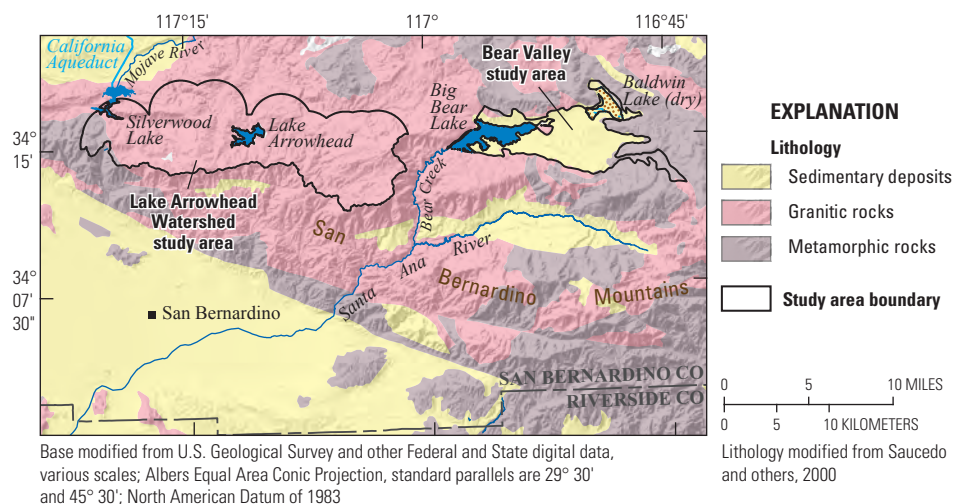
Groundwater Quality in the Bear Valley and Lake Arrowhead Watershed, California

Groundwater provides more than 40 percent of California's drinking water. To protect this vital resource, the State of California created the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The Priority Basin Project of the GAMA Program provides a comprehensive assessment of the State's groundwater quality and increases public access to groundwater-quality information. The Bear Valley and Lake Arrowhead Watershed study areas in southern California compose one of the study units being evaluated.



The Bear Valley and Lake Arrowhead Watershed Study Unit

The Bear Valley and Lake Arrowhead Watershed study unit covers about 112 square miles (290 square kilometers) in the San Bernardino Mountains of southern California. The Bear Valley study area is an alluvium-filled valley surrounding Big Bear and Baldwin Lakes and corresponds to the Bear Valley groundwater basin (California Department of Water Resources, 2003). The Lake Arrowhead Watershed study area consists primarily of granitic bedrock and includes parts of six watersheds around Lake Arrowhead (Mathany and Burton, 2017).

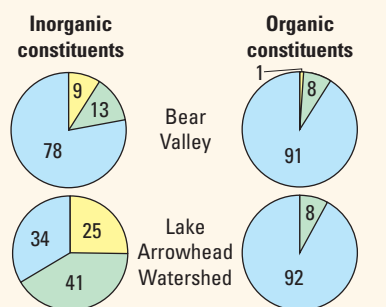


This study examined the quality of groundwater resources used for public drinking water supply in the two study areas. In 2010, the U.S. Geological Survey (USGS) collected samples from 38 wells and springs distributed across the two study areas. Data from 2007 to 2010 were compiled from the California State Water Resources Control Board (SWRCB) Division of Drinking Water database for 78 other public-supply sources in the study unit.

In the Bear Valley study area, public-supply wells are typically drilled to depths between 250 and 550 feet and screened in sedimentary deposits, but sometimes extend into the underlying metamorphic and granitic basement rocks. Groundwater is primarily recharged by winter precipitation in the mountains surrounding the valley, and groundwater pumping for municipal use has resulted in decreased groundwater levels in the Bear Valley study area (Flint and Martin, 2012). In the Lake Arrowhead Watershed study area, more than half of the public-supply sources are springs or horizontal wells, and vertical wells typically are drilled to depths of 230 to 500 feet. Wells and springs tap groundwater in the fracture systems of granitic bedrock.

Land use in both study areas is a mixture of natural and urban. Natural land cover is predominately forests. The Bear Valley study area has much more urban land use than the Lake Arrowhead Watershed study area, at 58 percent and 21 percent, respectively.

Overview of Water Quality



CONSTITUENT CONCENTRATIONS

● High ● Moderate ● Low or not detected

Values indicate percentages of the area of the groundwater resources used for public drinking water with concentrations in the specified categories.

GAMA's Priority Basin Project evaluates the quality of untreated groundwater. However, for context, concentrations measured in groundwater are compared to benchmarks established for drinking-water quality. A concentration greater than a benchmark is defined as high. Benchmarks and definitions of moderate and low concentrations are discussed in the inset box on page 3.

Many inorganic constituents are natural in groundwater, although the concentrations can also be affected by human activities. One or more inorganic constituent was detected at high concentrations in the groundwater resources used for public drinking water in about 9 percent of samples from the Bear Valley study area and in about 25 percent from the Lake Arrowhead Watershed study area.

Organic constituents are in products used in the home, business, industry, and agriculture, and they can enter the environment through normal usage, spills, or improper disposal. One or more organic constituent was present in the groundwater resources used for public drinking water at high concentrations in about 1 percent of samples from the Bear Valley study area, and none were detected at high concentrations in the Lake Arrowhead Watershed study area.

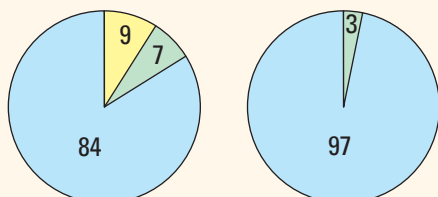
RESULTS: Groundwater Quality in the Bear Valley and Lake Arrowhead Watershed Study Unit

INORGANIC CONSTITUENTS

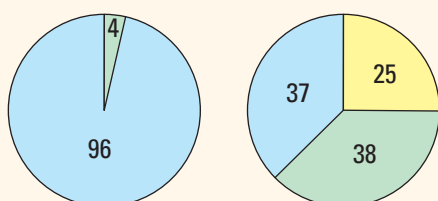
Bear Valley

Lake Arrowhead Watershed

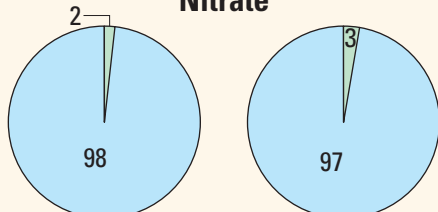
Trace elements



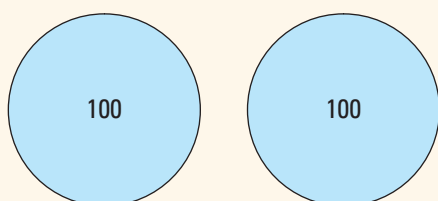
Uranium and radioactive constituents



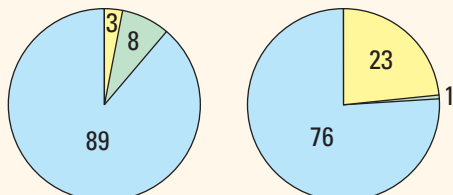
Nitrate



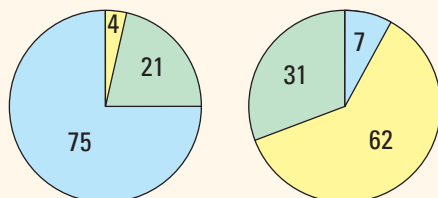
Total dissolved solids



Manganese and iron



Radon-222



Inorganic Constituents with Human-Health Benchmarks

Trace elements are part of the natural composition of the minerals in rocks and sediments and, as a result, are in the water that comes into contact with those materials. In the Bear Valley study area, one or more trace element was in the groundwater resources used for public drinking water at high concentrations in about 9 percent of the samples. Fluoride and arsenic were detected at concentrations greater than benchmarks. Trace elements were not detected at concentrations greater than benchmarks in the Lake Arrowhead Watershed study area.

Radioactivity is the release of energy or energetic particles during spontaneous decay of unstable atoms. Most of the radioactivity in groundwater comes from the decay of uranium and thorium isotopes that are part of the natural composition of minerals in aquifer materials. In the groundwater resources used for public drinking water, radioactive constituents were detected at high levels in samples from about 25 percent of the Lake Arrowhead Watershed study area. Uranium and adjusted gross alpha particle activity were both present at high levels. No radioactive constituents were detected at concentrations greater than benchmarks in the Bear Valley study area.

Nutrients, including nitrate, are naturally present at low concentrations in groundwater, and high concentrations generally occur as a result of human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. Nitrate was not present at high concentrations in the groundwater resources used for public drinking water in either the Bear Valley or Lake Arrowhead Watershed study areas.

Inorganic Constituents with Non-Health Benchmarks

(Not included in water-quality overview charts shown on the front page)

Some constituents affect the aesthetic properties of water, such as taste, color, and odor, or can create nuisance problems, such as staining and scaling. The benchmarks used for these constituents are non-regulatory secondary maximum contaminant level benchmarks.

Total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater, and all natural waters contain TDS as a result of the weathering and dissolution of minerals in rocks and sediments. The State of California has a recommended and an upper benchmark for TDS in drinking water. TDS was not found at concentrations greater than either benchmark in groundwater resources used for public supply in both the Bear Valley and the Lake Arrowhead Watershed study areas.

Anoxic conditions (low amounts of dissolved oxygen) can result in release of natural forms of manganese, iron, and other trace elements from minerals to groundwater. Manganese or iron was present in the groundwater resources used for public drinking water at concentrations greater than benchmarks set for aesthetic concerns in about 3 percent of samples from the Bear Valley study area and in about 23 percent from the Lake Arrowhead Watershed study area.

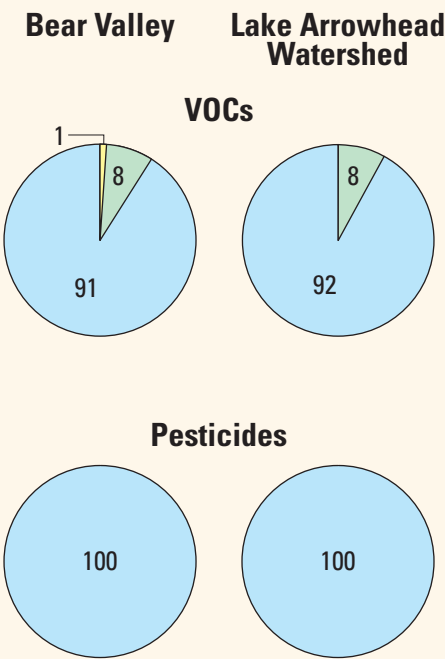
Inorganic Constituents with Proposed Benchmarks

(Not included in water-quality overview charts shown on the front page)

Radon-222, a radioactive gas formed from decay of uranium in aquifer materials, is primarily a health concern for air quality inside buildings. It has a proposed water-quality benchmark because levels in groundwater are predictive of potential levels in indoor air (National Academy of Sciences, 1999). Radon-222 was present in the groundwater resources used for public drinking water at levels greater than the proposed benchmark in samples from about 4 percent of the Bear Valley study area and in about 62 percent of the Lake Arrowhead Watershed study area.

RESULTS: Groundwater Quality in the Bear Valley and Lake Arrowhead Watershed Study Unit

ORGANIC CONSTITUENTS



Organic Constituents with Human-Health Benchmarks

The GAMA Priority Basin Project uses laboratory methods that can detect volatile organic compounds (VOCs) and pesticides at concentrations much less than human-health benchmarks. The VOCs and pesticides detected at very low concentrations can be used to help trace water movement from the landscape into the aquifer system.

VOCs are present in many household, commercial, and industrial products. In groundwater resources used for public drinking water, VOCs were detected at high or moderate concentrations in about 8 percent of both the Bear Valley and Lake Arrowhead Watershed study areas. The VOCs detected at high or moderate concentrations were the solvents, trichloroethene, carbon tetrachloride, and 1,1-dichloroethene. Solvents are used for a wide variety of applications, including dry cleaning, degreasing of metal parts, paint stripping, fire extinguishers, and lubricants. Solvents and trihalomethanes were found at low concentrations in both study areas, and gasoline oxygenates were also detected at low concentrations in the Bear Valley study area. Trihalomethanes form during disinfection of water supplies and can enter groundwater by the infiltration of landscape irrigation water or leakage from water distribution lines. Gasoline oxygenates are added to gasoline to increase the efficiency of combustion and can enter groundwater in precipitation or from point sources.

Pesticides—including herbicides, insecticides, and fumigants—are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation, insects, fungi, and other pests. Pesticides were not found at high or moderate concentrations, but herbicides were detected at low concentrations in both study areas.

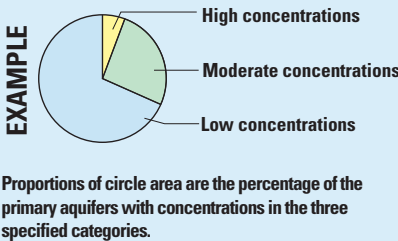
BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

The GAMA Priority Basin Project uses benchmarks established for drinking water to provide context for evaluating the quality of groundwater. The quality of drinking water can differ from the quality of groundwater because of contact with plumbing, exposure to the atmosphere, or water treatment. Federal and California regulatory benchmarks for protecting human health (maximum contaminant level, MCL) were used when available. Otherwise, non-regulatory benchmarks for protecting human health (lifetime health advisory level, HAL, and notification level, NL) and non-regulatory benchmarks for protecting aesthetic properties, such as taste and odor (secondary maximum contaminant level, SMCL) were used.

High, moderate, and low concentrations are defined relative to benchmarks

Concentrations are considered high if they are greater than a benchmark. For inorganic constituents, concentrations are moderate if they are greater than one-half of a benchmark. For organic constituents, concentrations are moderate if they are greater than one-tenth of a benchmark. Low concentrations include non-detections and values less than moderate concentrations. Methods for evaluating water quality are discussed in Mathany and Burton (2017).

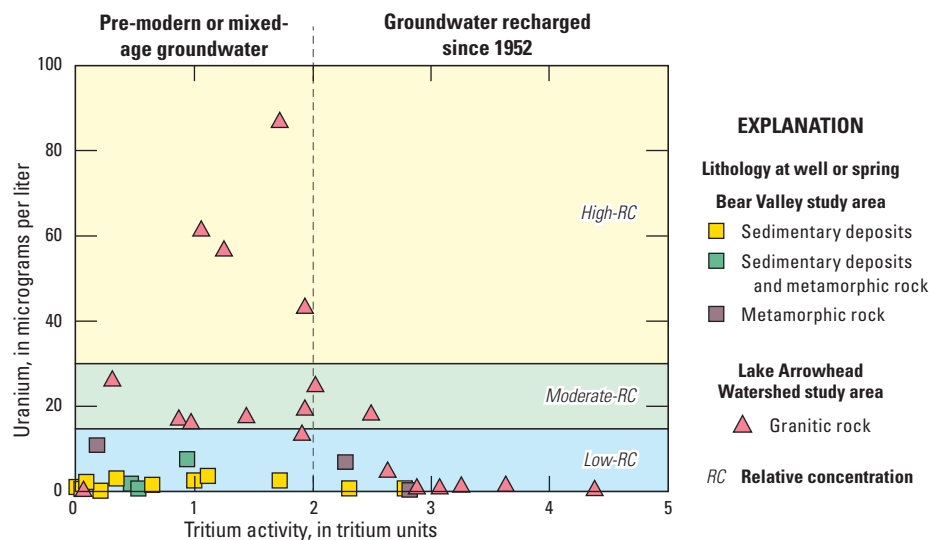
CONSTITUENT CONCENTRATIONS



| Benchmark type and value for constituents named in this factsheet. | | | | | |
|--|-----------------|------------|----------------------|----------------------|-------------|
| [Benchmark type: California, State Water Resources Control Board Division of Drinking Water; Federal, U.S. Environmental Protection Agency. Abbreviations: MCL, maximum contaminant level; mg/L, milligrams per liter; pCi/L, picocuries per liter; SMCL, secondary maximum contaminant level; µg/L, micrograms per liter] | | | | | |
| Constituent | Benchmark | | Constituent | Benchmark | |
| | Type | Value | | Type | Value |
| Arsenic | Federal MCL | 10 µg/L | Iron | California SMCL | 300 µg/L |
| Fluoride | California MCL | 2 mg/L | Manganese | California SMCL | 50 µg/L |
| Uranium | Federal MCL | 30 µg/L | Trichloroethene | Federal MCL | 5 µg/L |
| Gross alpha particle activity | Federal MCL | 15 pCi/L | Carbon tetrachloride | California MCL | 0.5 µg/L |
| Nitrate, as nitrate | Federal MCL | 45 mg/L | 1,1-Dichloroethene | California MCL | 6 µg/L |
| Total dissolved solids (TDS) | California SMCL | 1,000 mg/L | Radon-222 | Proposed Federal MCL | 4,000 pCi/L |

Factors that Affect Groundwater Quality

Uranium was present in groundwater resources used for public drinking water at high concentrations (greater than the Federal MCL) in 25 percent of samples from the Lake Arrowhead Watershed study area, but was not detected at high concentrations in the Bear Valley study area. Fractured granitic rocks, like those that form the aquifer system in the Lake Arrowhead Watershed study area, commonly contain uranium-bearing minerals that can dissolve in the groundwater. In contrast, the metamorphic rocks in the mountains around the Bear Valley study area usually do not contain uranium-bearing minerals nor do the sedimentary deposits derived from those rocks that make up the groundwater basin.



Activity of radioactive constituents in groundwater samples from the Bear Valley and Lake Arrowhead Watershed study areas by aquifer lithology.

In water from the granitic fractured-rock aquifer in the Lake Arrowhead Watershed study area, the concentration of uranium was inversely correlated to the activity of tritium (Mathany and Burton, 2017). Tritium is a radioactive isotope of hydrogen that is formed in the upper atmosphere and becomes part of some water molecules, thereby entering the hydrologic cycle. The tritium decays over time, therefore its concentration can be used to estimate the time since water fell as precipitation. In the Lake Arrowhead Watershed study area, groundwater with tritium concentrations greater than 2.0 tritium units (TU) is largely composed of water recharged within the last 60 years (modern age), and groundwater with tritium concentrations less than 2.0 TU is a mixture of modern recharge and water recharged hundreds to thousands of years ago (pre-modern or mixed-age). High concentrations of uranium most frequently occurred in older groundwater, indicating that dissolution of large amounts of the uranium-bearing minerals could require a long period of contact between the groundwater and the minerals.

By Timothy M. Mathany, Carmen A. Burton, and Miranda S. Fram

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Priority Basin Assessments

The GAMA Priority Basin Project (PBP) assesses water quality in groundwater resources used for drinking-water supply. This study in the Bear Valley groundwater basin and Lake Arrowhead Watershed focused on groundwater resources used for public drinking water. Public-supply wells typically tap deeper parts of aquifer systems than domestic wells, and water quality can vary by its depth in aquifer systems. Springs tap groundwater in the fracture systems of granitic bedrock and water quality can vary by location and source. Ongoing assessments are underway in more than 120 groundwater basins and areas outside of basins throughout California.

The GAMA PBP assessments compare constituent concentrations in untreated groundwater to benchmarks established for the protection of human health and for aesthetic concerns. The GAMA PBP does not evaluate the quality of drinking water.

The GAMA PBP uses two scientific approaches for assessing groundwater quality. The first approach uses a network of wells to statistically assess the status of groundwater quality. The second approach combines water-quality, hydrologic, geographic, and other data to help understand the factors that affect water quality. In the Bear Valley and Lake Arrowhead Watershed study unit, data were collected by the GAMA PBP in 2010 and from the SWRCB Division of Drinking Water database for 2007–10. The GAMA PBP includes chemical analyses not generally available as part of regulatory compliance monitoring, including measurements at concentrations much lower than human-health benchmarks and measurement of constituents that can be used to trace the sources and movement of groundwater.

For more information

Technical reports and hydrologic data collected for the GAMA Program may be obtained from:

GAMA Project Chief

U.S. Geological Survey
California Water Science Center
6000 J Street, Placer Hall
Sacramento, CA 95819
Telephone number: (916) 278-3000
WEB: <http://ca.water.usgs.gov/gama>

GAMA Program Unit Chief

State Water Resources Control Board
Division of Water Quality
PO Box 2231, Sacramento, CA 95812
Telephone number: (916) 341-5585
WEB: <http://www.waterboards.ca.gov/gama>