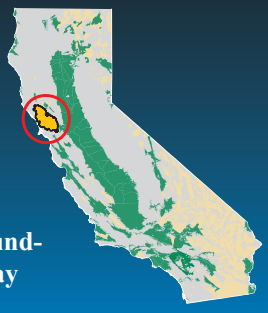
U.S. Geological Survey and the California State Water Resources Control Board

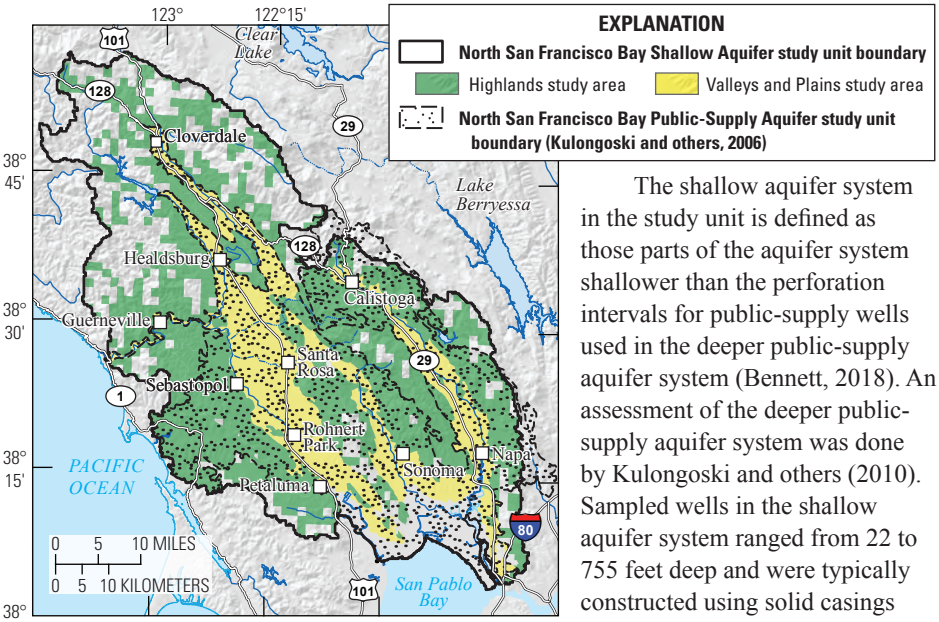
Groundwater Quality in the North San Francisco Bay Shallow Aquifer, California



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 North San Francisco Bay Shallow Aquifer constitutes one of the study units being evaluated.

The North San Francisco Bay Shallow Aquifer Study Unit

The North San Francisco Bay Shallow Aquifer study unit covers over 1,800 square miles near the coast in Central California. The study unit consists of 6 groundwater basins, some of which have multiple subbasins (California Department of Water Resources, 2003), as well as the surrounding highland terranes and is split into two study areas (Bennett and Fram, 2014). Alluvial-filled valleys in the study unit were combined to form the Valleys and Plains study area. Volcanic, metamorphic, and ultramafic hardrock highlands surrounding the Valleys and Plains form the Highlands study area.



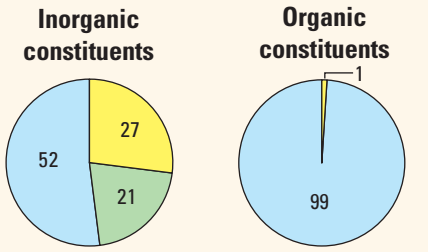
Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Albers Equal-Area Conic projection, standard parallels are 29°30' N. and 45°30' N.; North American Datum of 1983

The shallow aquifer system in the study unit is defined as those parts of the aquifer system shallower than the perforation intervals for public-supply wells used in the deeper public-supply aquifer system (Bennett, 2018). An assessment of the deeper public-supply aquifer system was done by Kulongoski and others (2010). Sampled wells in the shallow aquifer system ranged from 22 to 755 feet deep and were typically constructed using solid casings that extended below land surface to open or perforated intervals that ranged between 8 and 550 feet deep. Water quality in the shallow aquifer system can differ from that in the deeper public-supply aquifer system.

The study unit has warm, dry summers and cool, moist winters. Average annual rainfall is about 30 inches. The study unit is drained by several rivers and streams along with their principal tributaries. Land use in the study unit is approximately 73 percent natural (forest, grasslands, and bare rock), 16 percent urban, and 11 percent agricultural. Primary agricultural uses include pasture, vineyards, flower nurseries, and orchards (Bennett, 2018). The largest urban areas are the cities of Santa Rosa, Petaluma, Rohnert Park, and Napa.

Recharge to the groundwater system is primarily by stream-channel infiltration from the major rivers and their tributaries and by infiltration of precipitation. The primary sources of discharge are water pumped for municipal supply, evaporation, and discharge to streams.

Overview of Water Quality



Values are a percentage of the area of the groundwater resources used for domestic drinking water with concentrations in the three specified categories.

GAMA's Priority Basin Project evaluates the quality of untreated groundwater. For context, however, benchmarks established for drinking-water quality are used for comparison. Benchmarks and definitions of high, moderate, and low concentrations are discussed in the inset box "Benchmarks for Evaluating Groundwater Quality" on page 3.

Many inorganic constituents are naturally in groundwater. The concentrations of the inorganic constituents can be affected by natural processes as well as by human activities. In the North San Francisco Bay Shallow Aquifer study unit, one or more inorganic constituents were present at high concentrations in about 27 percent of the shallow aquifers and at moderate concentrations in about 21 percent.

Man-made organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal usage, spills, or improper disposal. In this study unit, organic constituents were present at high concentrations in about 1 percent of the shallow aquifer system, but were not present at moderate concentrations.

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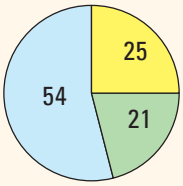
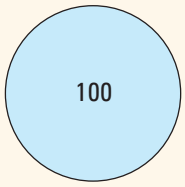
INORGANIC CONSTITUENTS

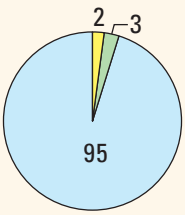
Trace elements



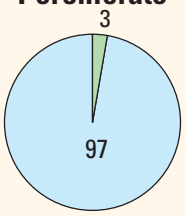
Radioactive constituents



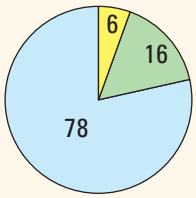
Nutrients



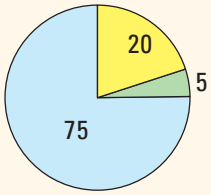
Perchlorate



Major ions and TDS



Iron



Inorganic Constituents with Human-Health Benchmarks

Trace and minor elements are naturally present in the minerals in rocks and soils and in the water that comes into contact with those materials. In the North San Francisco Bay Shallow Aquifer study unit, trace elements were present at high concentrations in about 25 percent of the shallow aquifer system and at moderate concentrations in about 21 percent. Arsenic, boron, fluoride, and manganese were the trace elements detected at high concentrations.

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 naturally present isotopes of uranium and thorium in minerals in the sediments of the aquifer. Radon-222, which primarily poses a threat to indoor air quality as a gas, was the only radioactive constituent present at high concentrations (2 samples). Because the danger posed by radon-222 is based on its concentrations in air, it is not represented in the pie chart for radioactive constituents.

Nutrients, such as nitrogen, are naturally present at low concentrations in groundwater. High and moderate concentrations generally are a result of human activities, such as applying fertilizer to crops and landscaping, seepage from septic systems, and human and animal waste. In the North San Francisco Bay Shallow Aquifer study unit, nutrients were detected at high concentrations in about 2 percent of the shallow aquifer system and were present at moderate concentrations in about 3 percent.

Perchlorate

Perchlorate is an inorganic constituent that has been regulated in California drinking water since 2007. It is used in solid rocket fuel, fireworks, safety flares, and is present in some fertilizers. Perchlorate exists naturally at low concentrations in groundwater and was detected at moderate concentrations in about 3 percent of the shallow aquifer system.

Inorganic Constituents with Non-Health Benchmarks

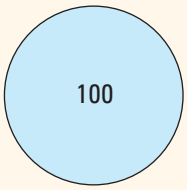
(Not included in water-quality overview charts shown on the front page)

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 State of California has a recommended and an upper limit for total dissolved solids (TDS) in drinking water. All water naturally contains TDS as a result of the weathering and dissolution of minerals in soils. Individual major ions that contribute to TDS concentrations include sulfate and chloride. The trace element iron exists naturally in minerals in rocks and soils. Anoxic conditions (very low amounts of dissolved oxygen) in groundwater can result in release of iron from minerals into groundwater (Hem, 1985).

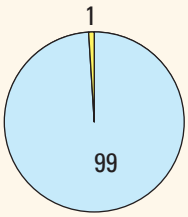
In the North San Francisco Bay Shallow Aquifer study unit, TDS or the major ions chloride and sulfate were present at high concentrations (greater than the upper limit) in about 6 percent of the shallow aquifer system and at moderate concentrations (between the recommended and upper limit) in about 16 percent. Iron was present at high concentrations in about 20 percent of the shallow aquifer system and at moderate concentrations in about 5 percent.

ORGANIC CONSTITUENTS

Volatile organic compounds



Pesticides



Organic Constituents

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

Volatile Organic Compounds with Human-Health Benchmarks

VOCs are in many household, commercial, industrial, and agricultural products and are characterized by a tendency to volatilize (evaporate) into the air. VOCs include solvents, trihalomethanes, refrigerants, and organic synthesis reagents. In the North San Francisco Bay Shallow Aquifer study unit, VOCs were at low concentrations when detected and were not present at high or moderate concentrations in the shallow aquifer system.

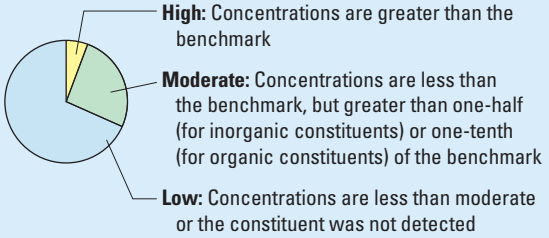
Pesticides with Human-Health Benchmarks

Pesticides, including herbicides, insecticides, fungicides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. In the North San Francisco Bay Shallow Aquifer study unit, pesticides were detected at high concentrations in about 1 percent of the shallow aquifer system, but none were detected at moderate concentrations. The insecticide dieldrin was the only pesticide detected at a high concentration.

BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

GAMA's 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 household 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 nonregulatory benchmarks for protecting aesthetic properties, such as taste and odor (secondary maximum contaminant level, SMCL) were used.

Pie diagrams are used to summarize groundwater-quality results. The pie slices represent the percentages of the groundwater resources with high, moderate, and low concentrations of a constituent. Methods for calculating these percentages are discussed by Bennett (2018).



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 and special-interest 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 by Bennett and Fram (2014).

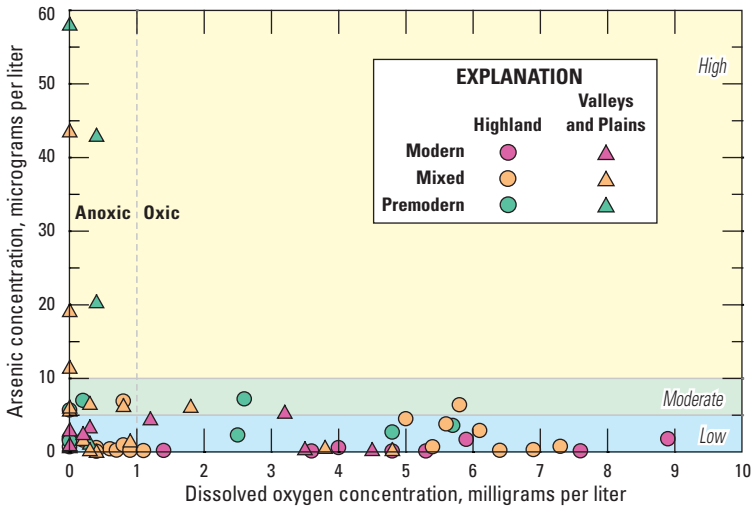
Benchmark type and value for selected constituents.

[Constituents are listed in the order in which they are discussed in this fact sheet. **Benchmark types:** California, State Water Resources Control Board Division of Drinking Water; Federal, U.S. Environmental Protection Agency; HAL, lifetime health advisory level; MCL, maximum contaminant level; RSD5, risk-specific dose at a risk factor of 10^{-5}; SMCL, secondary maximum contaminant level. **Abbreviations:** ppb, parts per billion or micrograms per liter; ppm, parts per million or milligrams per liter; pCi/L, picocuries per liter]

Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	Federal MCL	10 ppb	Perchlorate	California MCL	6 ppb
Boron	Federal HAL	6,000 ppb	Total dissolved solids (TDS)	California SMCL	1,000 ppm
Fluoride	California MCL	2 ppm	Chloride	California SMCL	500 ppm
Manganese	Federal HAL	300 ppb	Sulfate	California SMCL	500 ppm
Radon-222	Proposed Federal MCL	4,000 pCi/L	Iron	California SMCL	300 ppb
Nitrate	Federal MCL	10 ppm	Dieldrin	Federal RSD5	0.02 ppb

Factors that Affect Groundwater Quality

In the North San Francisco Bay Shallow Aquifer study unit, trace elements such as arsenic, boron, fluoride and manganese were detected at high concentrations in about one-quarter of the aquifer system. Groundwater age and geochemical conditions in the aquifer are often related to trace-element concentrations. Arsenic concentration in the study unit, for example, exhibited relationships both to groundwater age and dissolved oxygen concetrations.



The highest concentrations of arsenic were in samples with low dissolved oxygen and premodern or mixed age groundwater. Arsenic can be released from iron or manganese oxyhydroxides under anoxic conditions (low dissolved oxygen), and the longer groundwater is in contact with aquifer materials that contain arsenic, the more time there is for chemicals to react (Smedley and Kinniburgh, 2002). Hydrothermal water, water heated by the Earth's internal heat, is present in some areas of the study unit (Forrest and others, 2013). These waters can ascend along faults or the fracture zone and mix with groundwater, and because mineral solubilities tend to increase with temperature, trace elements like arsenic, boron, and floride can become elevated (Forrest and others, 2013). Sites with the highest concentrations of arsenic in the North San Francisco Bay shallow aquifer study unit had slightly elevated groundwater temperatures, potentially indicating mixing with hydrothermal water (Bennett, 2018).

By George L. Bennett V and Miranda Fram

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Priority Basin Assessments

GAMA's Priority Basin Project (GAMA-PBP) assesses water quality in two distinct parts of the aquifer system used for drinking water: the public-supply aquifer system and the shallow aquifer system. The public-supply aquifer system is defined by the depths of public-supply wells. The shallow aquifer system is defined as that portion of the aquifer system shallower than the public-supply wells. Domestic wells are often in the shallow aquifer system. Assessments are ongoing in more than 120 basins throughout California.

The GAMA-PBP assessments are based on a comparison of constituent concentrations in untreated groundwater with benchmarks established for the protection of human health and for aesthetic concerns. The GAMA-PBP does not evaluate the quality of drinking water delivered to consumers.

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 assess the factors that affect water quality. In the North San Francisco Bay Shallow Aquifer study unit, data were collected by the GAMA-PBP in 2012. 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:

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Telephone number: (916) 278-3000
WEB: *http://ca.water.usgs.gov/gama*

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