

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

# Groundwater Quality in the North San Francisco Bay Groundwater Basins, 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 basins north of San Francisco constitute one of the study units being evaluated.



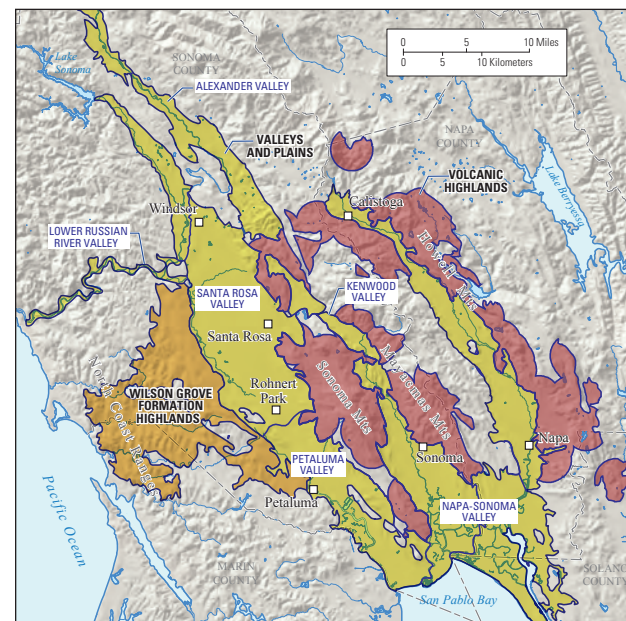
## The North San Francisco Bay Study Unit

The North San Francisco Bay study unit is approximately 1,000 square miles and consists of the Wilson Grove Formation Highlands, Alexander Valley, Santa Rosa Valley, Petaluma Valley, Lower Russian River Valley, Kenwood Valley, Volcanic Highlands, and Napa-Sonoma Valley groundwater basins (California Department of Water Resources, 2003). These basins were grouped into three study areas primarily on the basis of geology. The alluvium-filled valleys were combined to form the Valleys and Plains study area; the Wilson Grove Formation Highlands and the Volcanic Highlands were designated as the other two study areas (Kulongoski and others, 2006).

The study unit has warm, dry summers and cool, moist winters. Average annual rainfall is 30 inches. The study areas are drained by several rivers and their principal tributaries. The primary aquifers consist of alluvial sediments (mixtures of sand, silt, clay, cobbles, and boulders), marine deposits (fossiliferous sandstones containing lenses of conglomerate and sandy shale), and volcanic deposits (pumice tuff, tuff breccias). The primary

aquifers are defined as those parts of the aquifers corresponding to the perforated intervals of wells listed in the California Department of Public Health database. Public-supply wells are typically drilled to depths between 200 and 500 feet, consist of solid casing from the land surface to a depth of about 60 to 200 feet, and are perforated below the solid casing. Water quality in the shallower and deeper parts of the aquifer system may differ from that in the primary aquifers.

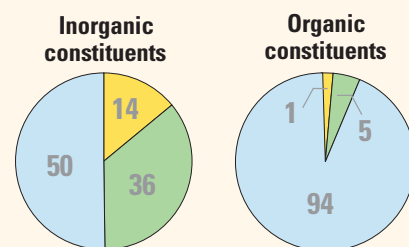
Land use in the study unit is approximately 55 percent (%) natural (mostly grasslands and forests), 31%



agricultural, and 14% urban. The primary agricultural uses are for pasture, hay, vineyards, flowers, nurseries, and orchards. The largest urban areas are the cities of Santa Rosa, Petaluma, Rohnert Park, Windsor, and Napa.

Municipal water use accounts for nearly half of the total water use in the study unit; the remainder is used for irrigated agriculture. Groundwater accounts for about a quarter of the municipal supply, depending on the area, and surface water accounts for the remainder. Recharge to groundwater is primarily stream-channel infiltration from the major rivers and their tributaries, and infiltration of water from precipitation and irrigation. The primary sources of discharge are water pumped for irrigation and municipal supply, evaporation, and discharge to streams.

## Overview of Water Quality



### CONSTITUENT CONCENTRATIONS

● High ● Moderate ● Low or not detected  
 Values are a percentage of the area of the primary aquifers with concentrations in the three specified categories.

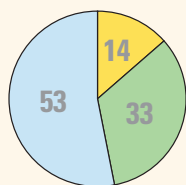
GAMA's Priority Basin Project evaluates the quality of untreated groundwater. However, for context, benchmarks established for drinking-water quality are used for comparison. Benchmarks and definitions of high, moderate, and low concentrations are discussed in the inset box on page 3.

Many inorganic constituents occur 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 study unit, one or more inorganic constituents were present at high concentrations in about 14% of the primary aquifers and at moderate concentrations in about 36%.

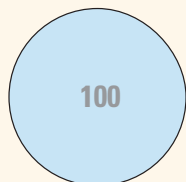
Organic constituents are found in products used in the home, business, industry, and agriculture. Organic constituents can enter the environment through normal usage, spills, or improper disposal. In this study unit, one or more organic constituents were present at high concentrations in about 1% of the primary aquifers and at moderate concentrations in about 5%.

# RESULTS: Groundwater Quality in the North San Francisco Bay Study Unit

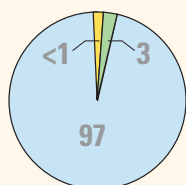
## INORGANIC CONSTITUENTS



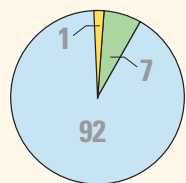
**Trace and minor elements**



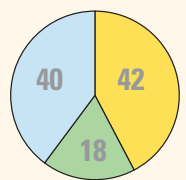
**Radioactive constituents**



**Nutrients**

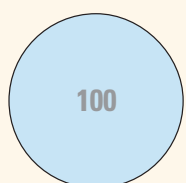


**Total dissolved solids**



**Iron or manganese**

## SPECIAL INTEREST CONSTITUENTS



**Perchlorate and NDMA**

## 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 study unit, trace elements were present at high concentrations in about 14% of the primary aquifers. Arsenic, boron, and lead were the trace elements that most frequently occurred at high concentrations. Aluminum, antimony, and nickel also were detected at high concentrations, but in less than (<) 1% of the primary aquifers. Fluoride is a minor element that was present at high concentrations in about 1% of the primary aquifers and at moderate concentrations in <1%.

Radioactivity is the release of energy or energetic particles during structural changes in the nucleus of an atom. Most of the radioactivity in groundwater comes from decay of naturally occurring isotopes of uranium and thorium in minerals in the sediments of the aquifer. Radioactivity from the radioactive constituents occurred at low levels in 100% of the primary aquifers.

Nutrients, such as nitrate and nitrite, are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities, such as applying fertilizer to crops. Livestock, when in concentrated numbers, and septic systems also produce nitrogenous waste that can leach into groundwater. Nitrate was present at high concentrations in <1% of the primary aquifers, and nitrate was present at moderate concentrations in about 3% of the primary aquifers.

## Inorganic Constituents with Non-Health Benchmarks

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

Some constituents, such as total dissolved solids (TDS) and chloride, affect the aesthetic properties of water, such as taste, color, and odor. Other constituents, such as iron and manganese, can create nuisance problems, such as scaling and staining.

The State of California has a recommended and an upper limit for TDS in drinking water. In the North San Francisco Bay study unit, TDS was present at high concentrations (greater than the upper limit) in about 1% of the primary aquifers. About 7% of the primary aquifers had moderate TDS concentrations (between the recommended and upper limit), and about 92% had low concentrations (less than the recommended limit).

Iron and manganese are naturally occurring elements, and either were present at high concentrations in about 42% of the primary aquifers. Iron or manganese were present at moderate concentrations in about 18% of the primary aquifers and at low concentrations in about 40%.

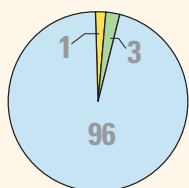
## Perchlorate and N-Nitrosodimethylamine (NDMA)

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

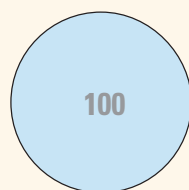
Perchlorate, an inorganic constituent, and NDMA, a semi-volatile organic chemical, are of special interest in California because these constituents have recently been found in or are considered to have the potential to affect drinking-water supplies. Their presence in groundwater is monitored by the California Department of Public Health (<http://www.cdph.ca.gov>). In the North San Francisco Bay study unit, perchlorate and NDMA were not detected in the primary aquifers.

# RESULTS: Groundwater Quality in the North San Francisco Bay Study Unit

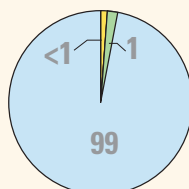
## ORGANIC CONSTITUENTS



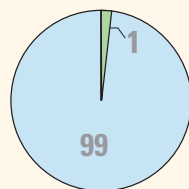
**Solvents**



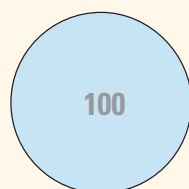
**Trihalomethanes**



**Other volatile organic compounds**



**Insecticides**



**Herbicides and fumigants**

## Organic Constituents

The Priority Basin Project uses laboratory methods that can detect low concentrations of volatile organic compounds (VOC) 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 their tendency to volatilize into the air.

Solvents are used for a number of purposes, including manufacturing and cleaning. In the North San Francisco Bay study unit, solvents were present at high concentrations in about 1% of the primary aquifers. The solvents found at high concentrations were tetrachloroethene and trichloroethene. Solvents were present at moderate concentrations in about 3% of the primary aquifers and were low in about 96%. Trihalomethanes may form during municipal water purification and enter groundwater by the infiltration of landscape irrigation water. Trihalomethanes were detected at low concentrations in the primary aquifers.

Other VOCs include organic synthesis reagents and gasoline additives. Other VOCs were present at high concentrations in <1% of the primary aquifers, at moderate concentrations in about 1% of the primary aquifers, and at low concentrations in about 99%. The reagent found at high concentrations was 1,1-dichloroethene.

## Pesticides with Human-Health Benchmarks

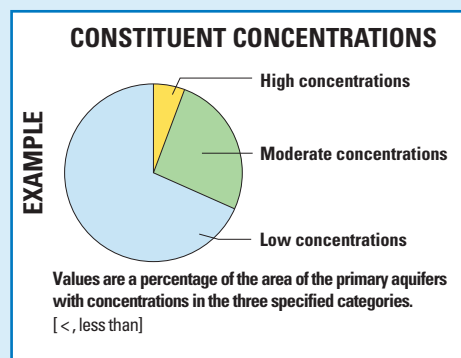
Pesticides are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation (weeds), insects, fungi, and other pests. In the North San Francisco Bay study unit, insecticides were not detected at high concentrations in the primary aquifers, but the insecticide diazinon was detected at moderate concentrations in about 1% of the primary aquifers. Herbicides and fumigants were detected at low concentrations.

## BENCHMARKS FOR EVALUATING GROUNDWATER QUALITY

GAMA's Priority Basin Project uses benchmarks established for drinking water to provide context for evaluating the quality of untreated groundwater. After withdrawal, groundwater may be disinfected, filtered, mixed, and exposed to the atmosphere before being delivered to consumers. Federal and California regulatory benchmarks for protecting human health (Maximum Contaminant Level, MCL) are used when available. Otherwise, nonregulatory benchmarks for protecting aesthetic properties, such as taste and odor (Secondary Maximum Contaminant Level, SMCL), and nonregulatory benchmarks for protecting human health (Notification Level, NL, and Lifetime Health Advisory, HAL) are used.

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

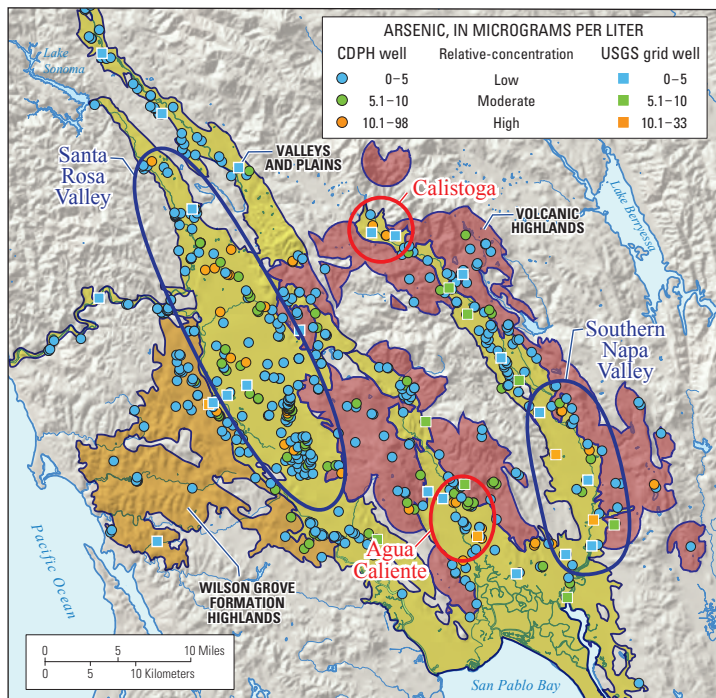
Concentrations are considered *high* if they are greater than a benchmark. For inorganic constituents, concentrations are *moderate* if they are greater than one-half of a benchmark. For organic and special-interest constituents, concentrations are *moderate* if they are greater than one-tenth of a benchmark; this lower threshold was used because organic constituents are generally less prevalent and have smaller concentrations relative to benchmarks than inorganic constituents. *Low* concentrations include non-detections and values less than moderate concentrations. Methods for evaluating water quality are discussed by Kulongoski and others (2010).





## Factors that Affect Groundwater Quality

In the North San Francisco Bay study unit, arsenic is the constituent that most frequently exists at high concentrations in the primary aquifers (about 10%). Natural sources of arsenic include the dissolution of arsenic-rich minerals such as apatite and arsenian pyrite, a common constituent of shale. Arsenic has been used as a wood preservative, in glass production, and in the mining of copper and gold, and consequently might enter groundwater as a result of these uses. The human-health regulatory benchmark for arsenic is 10 micrograms per liter.



waters from the Santa Rosa Valley and southern Napa Valley are primarily caused by the release of arsenic during dissolution of iron or manganese oxides under iron- or manganese-reducing (anoxic) conditions (Kulongoski and others, 2010).

The elevated arsenic concentrations in the Calistoga and Agua Caliente hydrothermal areas most likely result from shallow groundwater mixing with deep thermal waters, which have elevated temperatures and high pH values. The increase in arsenic solubility with increase in water temperature, and the desorption or inhibition of sorption of arsenic to aquifer sediments under alkaline conditions (pH greater than 8.0) (Ballantyne and Moore, 1988; Welch and others, 2000) likely contribute to the higher arsenic concentrations in groundwater from the Calistoga and Agua Caliente hydrothermal areas.

By Justin T. Kulongoski and Kenneth Belitz

### SELECTED REFERENCES

- Ballantyne, J.M., and Moore, J.N., 1988, Arsenic geochemistry in geothermal systems: *Geochimica et Cosmochimica Acta*, v. 52, p. 475–483.
- California Department of Water Resources, 2003, California's groundwater: California Department of Water Resources Bulletin 118, 246 p. Available at <http://www.groundwater.water.ca.gov/bulletin118>.
- Kulongoski, J.T., Belitz, Kenneth, and Dawson, B.J., 2006, Ground-water quality data in the North San Francisco Bay Hydrogeologic Provinces, California, 2004: Results from the California Ground-Water Ambient Monitoring and Assessment Program: U.S. Geological Survey Data Series Report 167, 100 p. Available at <http://pubs.usgs.gov/ds/ds167>.
- Kulongoski, J.T., Belitz, Kenneth, Landon, M.K., and Farrar, Christopher, 2010, Status and understanding of groundwater quality in the North San Francisco Bay Groundwater Basins, 2004: California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2010-5089, 87 p. Available at <http://pubs.usgs.gov/sir/2010/5089/>.
- Welch, A.H., Westjohn, D.B., Helsel, D.R., and Wanty, R.B., 2000, Arsenic in ground water of the United States—Occurrence and geochemistry: *Ground Water*, v. 38, no. 4, p. 589–604.

## Priority Basin Assessments

GAMA's Priority Basin Project (PBP) assesses water quality in that part of the aquifer system used for drinking water, primarily public supply. Water quality in shallower and deeper parts may differ from that in the primary aquifers. GAMA's Domestic Well Project assesses water quality in the shallower parts of the aquifer system. Ongoing assessments are being conducted in more than 120 basins throughout California.

The 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 PBP does not evaluate the quality of drinking water delivered to consumers.

The 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 study unit, data were collected by the PBP in 2004 and from the CDPH database for 2001–2004. The 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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