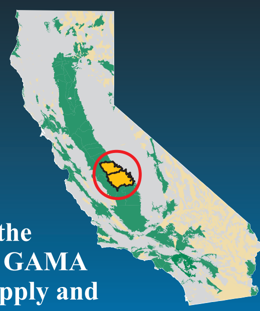
U.S. Geological Survey and the California State Water Resources Control Board

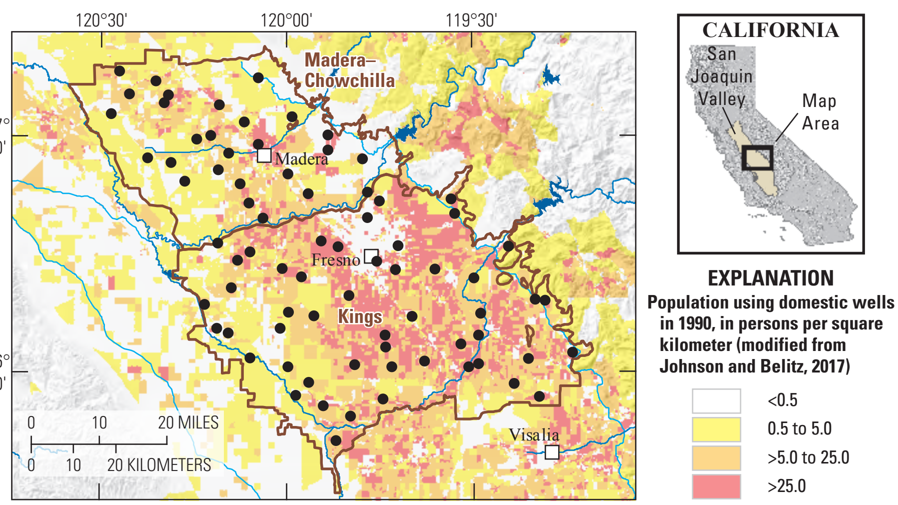
Groundwater Quality in the Shallow Aquifers of the Madera–Chowchilla and Kings Subbasins, San Joaquin Valley, California



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 GAMA Program's Priority Basin Project assesses the quality of groundwater resources used for drinking-water supply and increases public access to groundwater-quality information. Many households and small communities in the Madera–Chowchilla and Kings subbasins of the San Joaquin Valley rely on private domestic wells for their drinking-water supplies.

The Madera-Chowchilla and Kings Subbasins

The Madera–Chowchilla and Kings shallow aquifer study unit consists of groundwater resources in the Madera, Chowchilla, and Kings groundwater subbasins of the San Joaquin Valley that are used for private domestic drinking water supply. Over 150,000 people in the study unit rely on private domestic wells for their water supply (Johnson and Belitz, 2017). These domestic wells generally are shallower than public drinking-water supply wells in the same areas (Shelton and Fram, 2017; Shelton and others, 2013; Burton and others, 2012). Groundwater quality can vary with depth in aquifer systems; in particular, shallower groundwater can be more susceptible to contamination from human activities at the land surface.



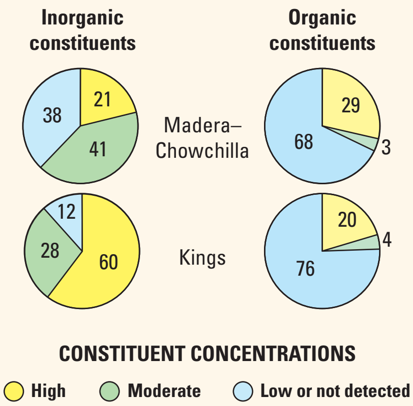
Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Albers Equal-Area Conic projection, standard parallels are 29°30' N. and 45°30' N.; North American Datum of 1983

Land use in the study unit is approximately 72 percent agricultural, 14 percent urban, and 14 percent natural, and the largest urban area is the city of Fresno. The dominant crop types are orchards and vineyards. Irrigation return flows are the major source of groundwater recharge, and pumping for irrigation and municipal supplies is the major source of discharge.

Previous groundwater studies in this region have identified several water-quality constituents of concern in the shallow groundwater resources used by domestic wells, including nitrate, uranium, and fumigants (for example, Burow and others, 1999; Jurgens and others, 2010; Harter and Lund, 2012).

This study was designed to provide a statistically representative assessment of the quality of groundwater resources used for domestic drinking water in the Madera–Chowchilla and Kings subbasins. A total of 77 wells were sampled by the GAMA Priority Basin Project between August 2013 and April 2014 (Shelton and Fram, 2017). The wells in Madera–Chowchilla typically were 52 to 122 meters deep, and wells in Kings typically were 35 to 87 meters deep. Data from 27 domestic wells sampled by the USGS National Water Quality Assessment Project between April 2009 and April 2015 also were included in this study.

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.

The GAMA Priority Basin Project evaluates the quality of untreated groundwater. Concentrations measured in groundwater are compared to benchmarks established for drinking-water quality for context. A concentration above a benchmark is defined as high (see page 3).

Many inorganic constituents are present naturally in groundwater, and their concentrations can be affected by natural processes and by human activities. About 21 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 60 percent of those in Kings, had high concentrations of one or more inorganic constituent.

Organic constituents are found in products used in the home, business, industry, and agriculture and can enter the environment through normal usage, spills, or improper disposal. About 29 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 20 percent of those in Kings, had high concentrations of one or more organic constituent.

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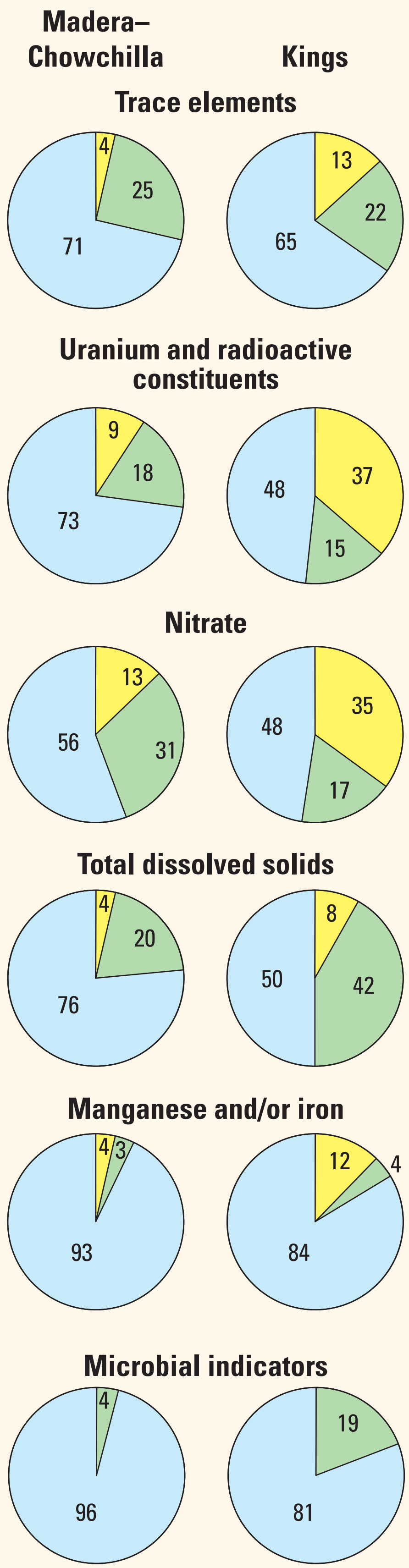
INORGANIC CONSTITUENTS



Inorganic Constituents with Human-Health Benchmarks

Trace elements are naturally present in the minerals of rocks and sediments and in the groundwater that comes into contact with those materials. About 4 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 13 percent in Kings, had high concentrations of one or more trace elements. Arsenic and vanadium were present at high concentrations.

Most of the radioactivity in groundwater comes from the decay of natural radioactive isotopes of uranium, thorium, and potassium in minerals in aquifer materials. About 9 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 37 percent in Kings, had high levels of one or more radioactive constituent. Uranium, gross alpha-particle activity, and gross beta-particle activity were present at high levels.

Nutrients, including nitrate, are naturally present at low concentrations in groundwater, but moderate and high concentrations generally indicate contamination from human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. About 13 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 35 percent in Kings, had high concentrations of nitrate.

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 were non-regulatory secondary maximum contaminant level benchmarks.

Total dissolved solids (TDS) concentration is a measure of the salinity of the groundwater, and all water naturally contains 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 limit for TDS in drinking water (see box on page 3). About 4 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla, and about 8 percent in Kings, had high concentrations (greater than the upper limit) of TDS.

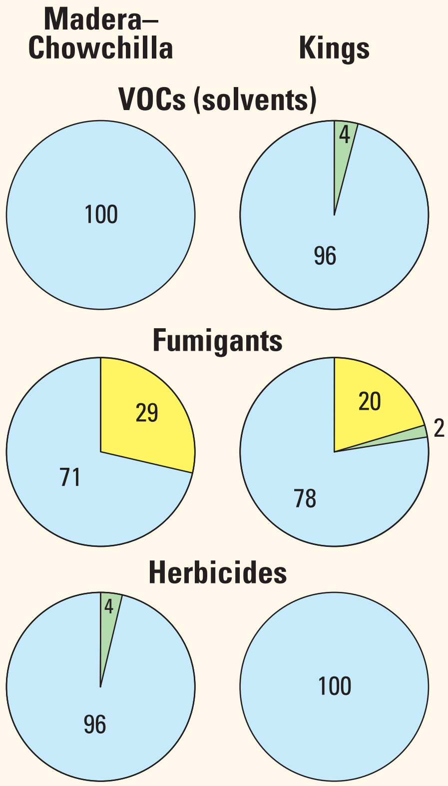
Anoxic conditions (low amounts of dissolved oxygen) can result in the release of naturally occurring manganese, iron, and other associated trace elements from minerals into groundwater. Manganese or iron was present at high concentrations in about 4 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla and about 12 percent in Kings.

Microbial Indicators

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

Microbial indicators are used to evaluate the potential for fecal contamination of water sources. *Escherichia coli* (*E. coli*) were not detected in any of the wells sampled, and total coliforms were detected in 4 percent of the Madera–Chowchilla and 19 percent of the Kings wells sampled. Total coliforms are present naturally in soils and in digestive tracts of animals, whereas *E. coli* specifically indicate contamination with animal (or human) fecal waste (California State Water Resources Control Board, 2016).

ORGANIC CONSTITUENTS



Organic Constituents with Human-Health Benchmarks

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

VOCs, including solvents, gasoline components, and refrigerants, are present in many household, commercial, and industrial products. VOCs were not detected at high concentrations in the groundwater resources used for domestic drinking water in Madera–Chowchilla or Kings. The VOC tetrachloroethene (PCE), a commonly used solvent, was detected at moderate concentrations in Kings.

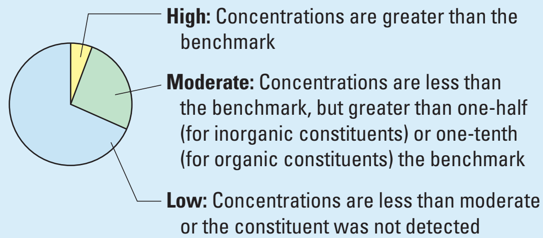
Pesticides, including herbicides, insecticides, and fumigants, are applied to crops, gardens, lawns, around buildings, and along roads to help control unwanted vegetation, insects, and other pests. Fumigants are VOCs, but are grouped with the pesticides because of how they are used. Fumigants are of special interest in California because of their historical use to control nematodes in vineyards and orchards.

Fumigant chemicals were present at high concentrations in about 29 percent of the groundwater resources used for domestic drinking water in Madera–Chowchilla and in about 20 percent in Kings. The fumigant chemicals detected at high concentrations were 1,2-dibromo-3-chloropropane (DBCP), 1,2- dibromoethane (EDB), and 1,2,3-trichloropropane (1,2,3-TCP). Herbicides and insecticides were not detected at high concentrations in the groundwater resources used for domestic drinking water in Madera–Chowchilla or Kings. The herbicide simazine was detected at moderate concentrations in Madera-Chowchilla.

METHODS FOR EVALUATING GROUNDWATER QUALITY

This study uses comparison to benchmarks established for drinking water to provide context for evaluating the quality of groundwater. The quality of drinking water may differ from the quality of groundwater because of contact with household plumbing, exposure to the atmosphere, or water treatment. U.S. Environmental Protection Agency and California State Water Resources Control Board Division of Drinking Water regulatory benchmarks set for the protection of human health (maximum contaminant level, MCL) are used for comparison when available. Otherwise, nonregulatory benchmarks set for protection of aesthetic and technical properties, such as taste and odor (secondary maximum contaminant level, SMCL) and nonregulatory benchmarks set for the protection of human health (for example, notification levels, NL) are used. Water quality in domestic wells is not regulated in California.

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 Shelton and others (2013) and Burton and others (2012).



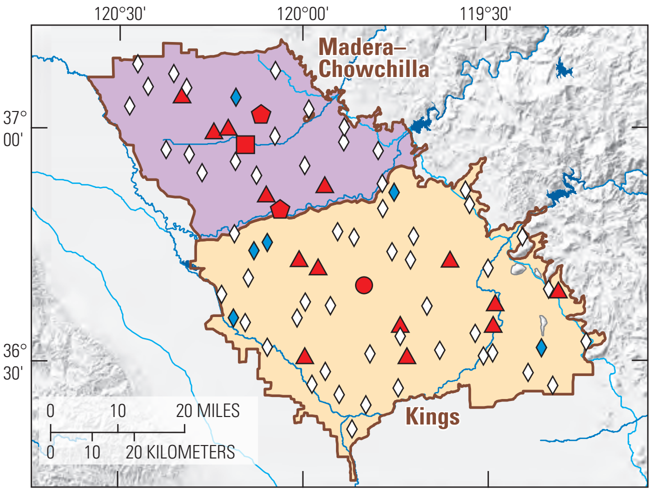
Benchmark type and value for selected constituents.

[Benchmarks are listed as EPA (U.S. Environmental Protection Agency) if the EPA and CA (California State Water Resources Control Board Division of Drinking Water) values are the same, and as CA if the EPA and CA values are different or if no EPA value exists. MCL, maximum contaminant level; NL, notification level; ppm, parts per million (equivalent to milligrams per liter); ppb, parts per billion (equivalent to micrograms per liter); ppt, parts per trillion (equivalent to nanograms per liter); pCi/L, picocuries per liter; SMCL, secondary maximum contaminant level]

Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	EPA MCL	10 ppb	Manganese	EPA SMCL	50 ppb
Vanadium	CA NL	50 ppb	Iron	EPA SMCL	300 ppb
Uranium	EPA MCL	30 ppb	1,2-Dibromo-3-chloropropane (DBCP)	EPA MCL	0.2 ppb
Gross alpha particle activity	EPA MCL	15 pCi/L	1,2-Dibromomethane (EDB)	EPA MCL	0.05 ppb
Gross beta particle activity	CA MCL	50 pCi/L	1,2,3-Trichloropropane (1,2,3-TCP)	CA MCL	5 ppt
Nitrate, as nitrogen	EPA MCL	10 ppm	1,2-Dichloropropane	EPA MCL	5 ppb
Total dissolved solids (TDS) (upper and recommended)	CA SMCL	1,000 ppm 500 ppm	Trichloroethene Simazine	EPA MCL CA MCL	5 ppb 4 ppb

Factors that Affect Groundwater Quality

The State of California adopted an MCL for 1,2,3-TCP in 2017 (California State Water Resources Control Board, 2017). 1,2,3-TCP is used as an industrial solvent and was also present as an impurity in some fumigant products. 1,2,3-TCP was detected in about 20 percent of the groundwater resources used for domestic drinking water in the Madera–Chowchilla and Kings subbasins of the San Joaquin Valley, and all detections were at concentrations greater than the MCL of 5 parts per trillion (Shelton and Fram, 2017).



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

EXPLANATION

Fumigants detected above MCL
- DBCP
- 1,2,3-TCP
- 1,2,3-TCP and DBCP
- 1,2,3-TCP and EDB

Fumigants detected below MCL

No fumigants detected

Study-unit boundary

All samples that had detections of 1,2,3-TCP also had detections of at least one other fumigant chemical (DBCP, EDB, or 1,2-dichloropropane; Shelton and Fram, 2017). This pattern indicates the source of 1,2,3-TCP in Madera–Chowchilla and Kings groundwater resources used for domestic supply was likely application of fumigants rather than contamination with solvents. The use of DBCP, EDB, and 1,2-dichloropropane as soil fumigants was discontinued in California by the early 1980s. The presence of these fumigants and associated 1,2,3-TCP in groundwater indicates that at least some of the groundwater tapped by domestic wells originated as water at the land surface in areas where fumigants were applied approximately 35 to 40 years ago. Concentrations of fumigant chemicals in groundwater decrease with time because of chemical degradation of the fumigants and mixing with other groundwater that does not contain fumigants (Burow and others, 1999).

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Priority Basin Assessments

The GAMA Priority Basin Project (PBP) assesses water quality in groundwater resources used for public and domestic drinking-water supplies. This study in the Madera–Chowchilla and Kings subbasins of the San Joaquin Valley focused on groundwater resources used for domestic drinking water. Ongoing assessments are being carried out in more than 120 basins and in hard-rock aquifers outside of basins throughout California. The PBP assessments compare 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.

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. The PBP includes chemical analyses not generally available as part of regulatory compliance monitoring, including measurements at concentrations much less 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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Sacramento, CA 95819
Telephone number: (916) 278-3000
WEB: *http://ca.water.usgs.gov/gama*

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