

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

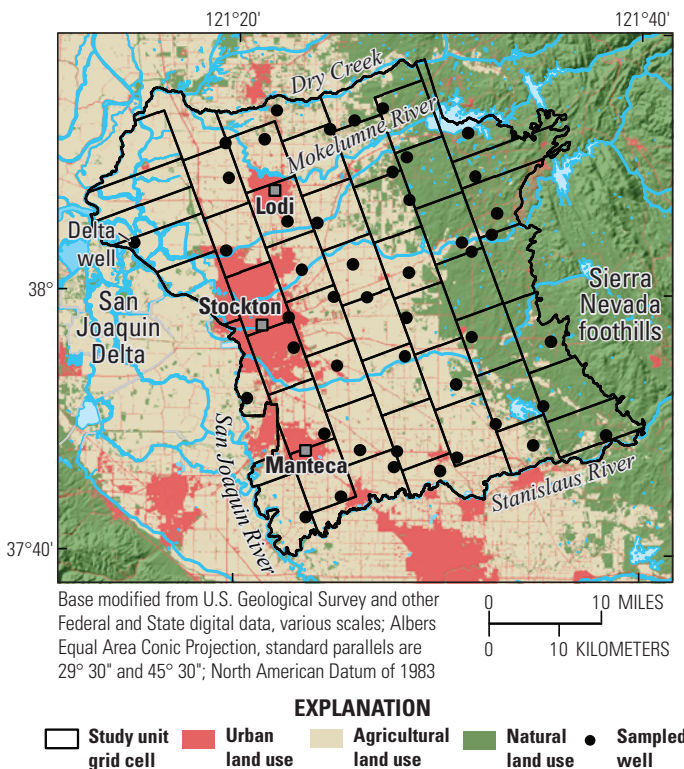
Quality of Groundwater Used for Domestic Supply in the Northern San Joaquin Valley, California

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 Priority Basin Project (PBP) of the GAMA Program provides a comprehensive assessment of the State's groundwater quality and provides increased public access to groundwater-quality information. Private domestic and small-system drinking-water wells in the Northern San Joaquin Valley (NSJV) were the target for this assessment. These wells tend to pump water from shallower parts of alluvial aquifers compared to deeper, long-screened public-supply wells in the region.

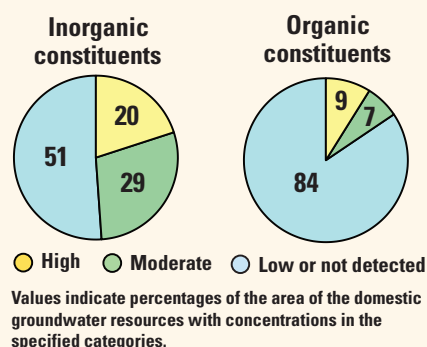
The Northern San Joaquin Valley Domestic-Supply Aquifer Study Unit

The NSJV domestic-supply aquifer study unit covers approximately 3,095 square kilometers (km²) of the northeastern portion of the San Joaquin Valley near Stockton, California. The study unit encompasses the eastern San Joaquin Valley subbasin of the greater San Joaquin Valley basin and is bounded by Dry Creek to the north and the Stanislaus River to the south (California Department of Water Resources, 2016). Land use is predominantly natural in the easternmost part of the study unit, which is bordered by the Sierra Nevada foothills, and transitions to agricultural and urban land uses toward its western boundary at the San Joaquin River. The study unit is underlain by several hundred meters (m) of partly consolidated and unconsolidated sedimentary deposits, the deepest of which are marine sediments that tend to contain saline water. Shallower alluvial aquifers are separated from deeper marine sediments by low-permeability volcanic deposits of the Mehrten Formation, which lies approximately 300 m below the land surface in the Stockton area (Izbicki and others, 2008).

This study was designed to provide a statistically representative assessment of the quality of groundwater resources used for domestic drinking-water supply (herein "domestic groundwater resources") in the NSJV. The study unit was divided into 50 equal-area (62 km²) grid cells, and 1 domestic or small-system well was sampled from 46 of the cells from July through September 2019 (Balkan and others, 2021). Four of the cells were not sampled because domestic or small-system supply wells were not identified within these cells. One non-domestic well on an island in the San Joaquin Delta ("delta well") was sampled to characterize groundwater originating from delta sediments and was not included in the drinking-water quality assessment results. Domestic well depths in the study unit ranged from 18 to 145 m below the land surface, with a median depth of approximately 80 m. Previous studies of public-supply wells in the study unit (typical depths from 75 to more than 150 m) reported groundwater with elevated levels of arsenic on a northwest trending band along the San Joaquin River running through the Stockton area (Izbicki and others, 2008; Bennett and others, 2010).



Overview of Water Quality



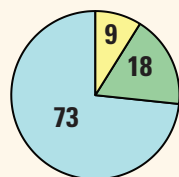
GAMA's PBP evaluates the quality of untreated groundwater by comparing concentrations measured in groundwater to benchmarks established for drinking-water quality, such as maximum contaminant levels (MCL); a concentration above a benchmark is defined as high. Benchmarks and definitions of moderate and low concentrations are discussed in the inset box on page 3.

Many inorganic constituents occur naturally in groundwater, and the concentrations can be affected by natural processes and human activities. In the NSJV domestic aquifer study unit, one or more inorganic constituents were present at high concentrations in 20 percent of domestic groundwater resources.

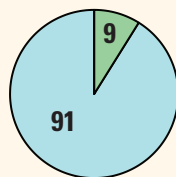
Organic constituents are found in products used in homes, businesses, industries, and agriculture and can enter the environment through normal usage, spills, or improper disposal. In this study unit, one or more organic constituents were present at high concentrations in 9 percent of domestic groundwater resources.

RESULTS: Quality of Groundwater in the Northern San Joaquin Valley

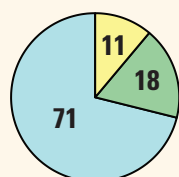
INORGANIC CONSTITUENTS



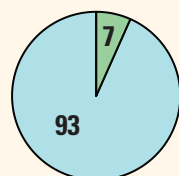
**Trace elements
(arsenic)**



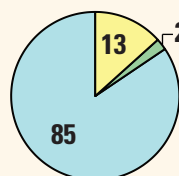
**Radioactive constituents
(uranium)**



**Nutrients
(nitrate)**



Total dissolved solids



Manganese or iron

Inorganic Constituents with Human-Health Benchmarks

Trace elements are naturally present in the minerals of rocks and sediment that compose groundwater aquifers, and they dissolve into groundwater that comes into contact with those materials. The only trace element present at high or moderate concentrations in the NSJV domestic-supply aquifer study unit was arsenic. Arsenic was present at high concentrations greater than the MCL of 10 micrograms per liter ($\mu\text{g/L}$) in 9 percent of domestic groundwater resources.

Radioactivity is the spontaneous release of energy or energetic particles from unstable atoms. Most of the radioactivity in groundwater comes from the decay of naturally occurring isotopes of uranium and thorium in aquifer materials. Uranium concentrations were the only results for radioactive constituents that were available during the publication of this report. Uranium was present at moderate concentrations greater than 15 $\mu\text{g/L}$ in 9 percent of domestic groundwater resources.

Nutrients (including nitrate, nitrite, ammonia, and phosphate) are naturally present at low concentrations in groundwater, and high concentrations of nutrients generally result from human activities. Common sources of nutrients include fertilizer applied to crops and landscaping, seepage from septic systems, and human and animal waste. The only nutrient present at high or moderate concentrations in the study unit was nitrate. Nitrate was present at high concentrations greater than 10 milligrams per liter (mg/L) as nitrogen in 11 percent of domestic groundwater resources.

Inorganic Constituents with Non-Health Benchmarks

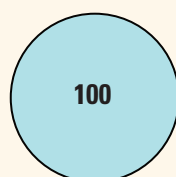
(not included in water-quality overview charts shown on the front page)

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

The concentration of total dissolved solids (TDS) is a measure of groundwater salinity, and all water naturally contains some TDS as a result of the weathering and dissolution of minerals in rocks and sediments. The State of California has a recommended concentration and an upper limit for TDS in drinking water, which is 500 and 1,000 mg/L , respectively, and the upper limit was used as the benchmark for this study. In the NSJV domestic-supply aquifer study unit, TDS was present at moderate concentrations greater than 500 mg/L in 7 percent of domestic groundwater resources.

Reducing conditions occur in groundwater with low concentrations of dissolved oxygen and can result in the release of manganese, iron, and other associated trace elements from aquifer minerals into groundwater. Manganese or iron were present at high concentrations greater than their respective SMCLs of 50 and 300 $\mu\text{g/L}$ in 13 percent of domestic groundwater resources.

CONSTITUENTS OF SPECIAL INTEREST



PFAS

Per- and Polyfluoroalkyl Substances (PFAS)

Per- and polyfluoroalkyl substances (PFAS) are a group of human-made chemicals that are commonly used as surfactants in a variety of industrial processes. Many PFAS compounds are resistant to degradation and are persistent in the environment and human body, which can lead to health concerns. The State of California has response levels (RLs) and notification levels (NLs) for perfluorooctanoate (PFOA) and perfluorooctanesulfonate (PFOS), which were detected in the study unit at low concentrations below their respective NLs. Groundwater samples were analyzed for 24 PFAS compounds. At least 1 of the 9 different PFAS compounds detected in the study unit were present in 11 percent of domestic groundwater resources.

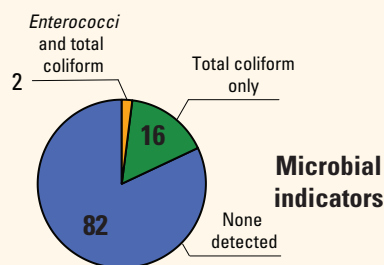
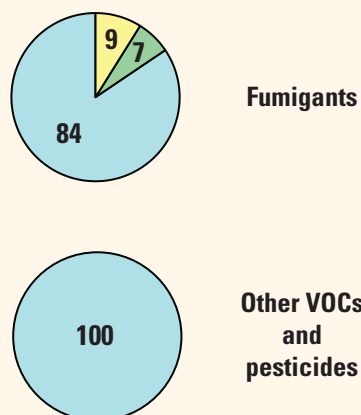
RESULTS: Quality of Groundwater in the Northern San Joaquin Valley

ORGANIC CONSTITUENTS

Organic Constituents with Human-Health Benchmarks

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

Fumigants are VOCs that are applied to soils for pest control. In the NSJV domestic-supply aquifer study unit, fumigants were present at high concentrations in 9 percent of domestic groundwater resources. The fumigants 1,2,3-trichloropropane (1,2,3-TCP) and 1,2-dibromo-3-chloropropane (DBCP) were detected at high concentrations in 9 and 2 percent of domestic groundwater resources, respectively; DBCP was detected at moderate concentrations in 7 percent of domestic groundwater resources. Another fumigant, 1,2-dichloropropane (1,2-DCP), also was detected at low concentrations in 11 percent of domestic groundwater resources. These three fumigants were historically applied to agricultural crops simultaneously or at alternate intervals and often co-occurred in groundwater samples. The State of California banned DBCP and 1,2-DCP in 1979 and 1984, respectively (Burow and others, 2019). Pesticides or VOCs other than fumigants were not detected at high or moderate concentrations.



Microbial Indicator Constituents

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

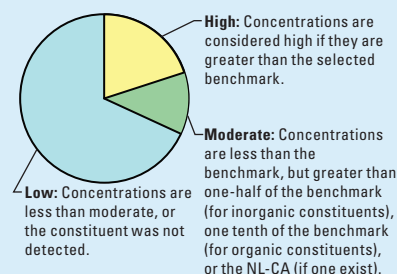
Microbial indicator constituents are used to evaluate the potential for fecal contamination of water sources and were evaluated in this study by percent presence or absence in the groundwater resource. In the study unit, total coliform bacteria were present in 18 percent of domestic groundwater resources and *Enterococci* co-occurred with total coliform in 2 percent of those resources. *Escherichia coli* (*E. coli*) were not detected. Total coliform and *Enterococci* are present naturally in soils and digestive tracts of animals and in wastewater.

METHODS FOR EVALUATING GROUNDWATER QUALITY

GAMA's PBP 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. The U.S. Environmental Protection Agency (EPA) and California State Water Resources Control Board Division of Drinking Water regulatory benchmarks set for the protection of human health (MCL) were used when available. Otherwise, non-regulatory benchmarks set for the protection of aesthetic properties, such as taste and odor (SMCL) and nonregulatory benchmarks set for the protection of human health (RLs and NLs) were used (Balkan and others, 2021). Water quality in private domestic wells is not regulated in California.

Benchmark type and value for selected constituents.

[**Benchmark types:** MCL-US, U.S. Environmental Protection Agency (EPA) maximum contaminant level; SMCL-CA, California Water Resources Control Board Division of Drinking Water (SWRCB-DDW) secondary maximum contaminant level; MCL-CA, SWRCB-DDW maximum contaminant level; RL-CA, SWRCB-DDW response level; NL-CA, SWRCB-DDW notification level. **Abbreviations:** µg/L, micrograms per liter; mg/L, milligrams per liter; ng/L, nanograms per liter; 1,2-DCP, 1,2-dichloropropane; 1,2,3-TCP, 1,2,3-trichloropropane; DBCP, 1,2-dibromo-3-chloropropane; PFOA, perfluorooctanoate; PFOS, perfluorooctanesulfonate]



Constituent	Benchmark		Constituent	Benchmark	
	Type	Value		Type	Value
Arsenic	MCL-US	10 µg/L	1,2-DCP	MCL-CA	5 µg/L
Uranium	MCL-US	30 µg/L	1,2,3-TCP	MCL-CA	0.005 µg/L
Nitrate, as nitrogen	MCL-US	10 mg/L	DBCP	MCL-CA	0.02 µg/L
Total dissolved solids	SMCL-CA (upper)	1,000 mg/L	PFOA	RL-CA (NL-CA)	10 (5.1) ng/L
Managanese	SMCL-CA	50 µg/L	PFOS	RL-CA (NL-CA)	40 (6.5) ng/L
Iron	SMCL-CA	300 µg/L			

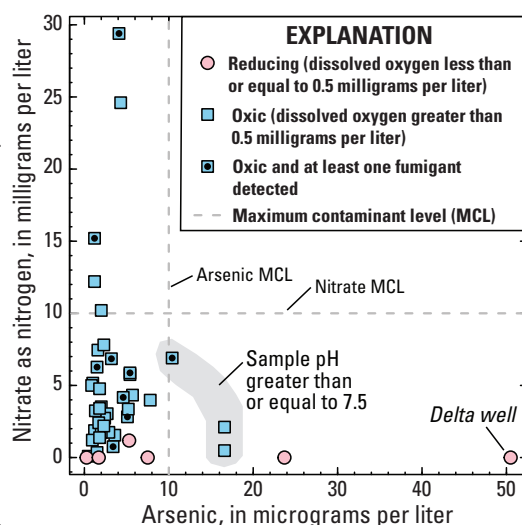
Factors that Affect Groundwater Quality

In the NSJV, either arsenic, nitrate, fumigants, or some combination of the three were present at high concentrations in 29 percent of domestic groundwater resources. Nitrate and fumigants are associated with legacy agricultural sources and are persistent in oxic groundwater (Burow and others, 2019). In this study, fumigants were only detected in oxic groundwater samples with mostly high or moderate concentrations of nitrate.

Arsenic in deeper public-supply wells in the NSJV has been a concern for water resource managers (Izbicki and others, 2008; Bennett and others, 2010). Arsenic becomes mobilized from aquifer sediments into groundwater under reducing conditions (dissolved oxygen less than or equal to 0.5 mg/L) and, to a lesser extent, at high pH (greater than or equal to 7.5; Izbicki and others, 2008). Arsenic is present in alluvial aquifers throughout the NSJV but tends to be highest in groundwater in contact with delta sediments, which is consistent with results from the “delta well” sampled in this study. High concentrations of arsenic only occurred in reducing groundwater or oxic groundwater at high pH.

Intensive groundwater pumping over decades has drawn oxic, agricultural recharge from shallower depth zones used for domestic supply into deeper, reducing parts of aquifers used for public supply throughout the San Joaquin Valley (Jurgens and others, 2010). A prior GAMA assessment in the NSJV reported that aquifers used for public supply had a greater proportion of high-arsenic groundwater (17 percent) and minimal high-nitrate groundwater (3 percent; Bennett and others, 2010). In this study, high-nitrate groundwater was more prevalent in the shallower domestic-supply aquifer, was uniformly oxic, and often contained fumigants indicative of legacy agricultural recharge; however, some oxic samples with high pH had elevated concentrations of nitrate and arsenic. Agricultural recharge in the San Joaquin Valley can raise the pH of groundwater (Jurgens and others, 2010), which could allow arsenic to remain mobile in aquifers under oxic conditions while mixing with nitrate and fumigants. Reactions between oxic agricultural recharge and reducing aquifer sediments in domestic-supply aquifers can have important implications for arsenic and nitrate trends in public-supply wells as shallow groundwater migrates deeper into the system.

By Zeno F. Levy, Mariia Balkan, and Jennifer L. Shelton



Priority Basin Assessments

GAMA's PBP assesses water quality in groundwater resources used for drinking-water supply. This study in the NSJV focused on groundwater resources used for domestic drinking-water supply. Water quality can vary with depth in aquifer systems; the domestic wells typically tap shallower parts of aquifer systems than the public-supply wells do. Ongoing assessments are being carried out in more than 120 basins and areas outside of basins throughout California.

The PBP assessments compare constituent concentrations in untreated “ambient” groundwater with benchmarks established for the protection of human health and for aesthetic concerns. The PBP does not evaluate the quality of treated 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 and spatial variability 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 NSJV domestic-supply aquifer study unit, data were collected for the PBP in 2019. The PBP includes chemical analyses not generally available as part of regulatory compliance monitoring, including measurements of selected constituents at concentrations lower than human-health benchmarks and geochemical tracers to identify the source, movement, and age (time since recharge) of groundwater.

For more information

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

GAMA Project Chief

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California Water Science Center
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