GAMA
DOMESTIC WELL PROJECT
GROUNDWATER QUALITY DATA REPORT
TEHAMA COUNTY FOCUS AREA

California State Water Resources Control Board
Groundwater Protection Section
GAMA Program
Domestic Well Project
March 2009

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ACKNOWLEDGEMENTS

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ABBREVIATIONS AND ACRONYMS

DWR	California Department of Water Resources
SWRCB	State Water Resources Control Board
GAMA	Groundwater Ambient Monitoring and Assessment
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
NL	Notification Level
SMCL	Secondary Maximum Contaminant Level
µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
TDS	Total Dissolved Solids
VOCs	Volatile Organic Compounds

ABSTRACT

The State Water Resource Control Board (State Water Board) established the Groundwater Ambient Monitoring and Assessment (GAMA) Program in 2000. Private domestic wells in Tehama County were sampled in 2005 as part of GAMA's Domestic Well Project. Tehama County was selected for sampling due to the large number of domestic wells located within the county and the availability of well-owner data. A total of 223 wells were sampled by Water Board staff, primarily in the Los Molinos and Red Bluff areas.

Groundwater samples were tested by an accredited environmental laboratory for commonly detected contaminants such as bacteria indicators (total and fecal coliform), inorganic parameters (metals, major anions and general minerals), and volatile organic compounds (VOCs). A subset of groundwater samples were also tested for wastewater indicators and stable isotopes by Lawrence Livermore National Laboratory (LLNL).

Test results were compared to public water supply standards established by the California Department of Public Health (CDPH). Public drinking water standards referenced in this report include maximum contaminant levels (MCLs), secondary maximum contaminant levels (SMCLs), and notification levels (NLs). These water quality standards are used for comparison purposes only, since private domestic well water quality is not regulated by the State of California. Chemicals detected at concentrations above public drinking water standards included arsenic, chromium, and nitrate. Arsenic was the most commonly detected chemical (145 samples), and was detected above the MCL of 10 µg/L in 29 wells. Arsenic detections above the MCL were primarily located in the Los Molinos area. Chromium was detected above the MCL of 50 µg/L in one well, and nitrate was detected above the MCL of 45 mg/L in two wells.

Aluminum, iron, and manganese were detected above SMCLs. Aluminum was detected above the SMCL of 200 µg/L in six wells, iron was detected above the SMCL of 300 µg/L in 31 wells, and manganese was detected above the SMCL of 50 µg/L in 19 wells. Lead was detected in two wells at concentrations greater than the NL of 15 µg/L. Fifty six samples tested positive for total coliform bacteria, and three samples tested positive for fecal coliform bacteria.

INTRODUCTION

Groundwater is an important resource to the people of California. Groundwater supplies drinking water to up to 40% of Californians, and is an important source of irrigation and industrial supply water. Reliance upon this resource is expected to increase in the future, in part due to increased agricultural and industrial demand, drought, climate change, and population/land-use changes. Consequently, there are growing concerns regarding groundwater quality in California, and whether decreases in quality will affect the availability of this resource. Since the 1980s, over 8,000 public groundwater drinking water sources have been shut down – some due to the detection of chemicals such as nitrate, arsenic, or methyl tert-butyl ether (MTBE).

The State Water Board developed the Groundwater Ambient Monitoring and Assessment (GAMA) Program to address public concerns over groundwater quality. The primary objectives of the GAMA Program are to improve comprehensive statewide groundwater monitoring and to increase the public availability of groundwater quality information. The GAMA Program consists of four current projects:

- **Domestic Well Project**: A voluntary groundwater monitoring program that provides water quality information to private (domestic) well owners and provides the state with information on shallow groundwater quality. As of June 2009, this project has sampled five county focus areas: Yuba (2002), El Dorado (2003-2004), Tehama (2005), Tulare (2006), and San Diego (2008-2009). State Water Board staff sample the participants' wells at no cost to the owner.

- **Priority Basin Project**: A comprehensive, statewide groundwater monitoring program that focuses on public groundwater supply wells in high-use groundwater basins. These high-use basins contain more than 95% of all public groundwater supply wells. As of April 2009, this project has sampled over 1700 wells in over 90 different groundwater basins. The United States Geological Survey (USGS) is the project technical lead, with support from LLNL.

- **Special Studies Project**: Focuses on identification of pollutant sources and assessing the effects of remediation efforts in private domestic and public supply wells in California. LLNL is the project technical lead.

- **GeoTracker GAMA**: An innovative, map-based on-line query tool that allows public users to easily access groundwater quality data and information.

This Data Summary Report summarizes Domestic Well Project results from 223 domestic wells sampled in the Tehama County Focus Area collected during the spring and summer of 2005. Sampled well locations are shown in Figure 1.

Domestic Well Project

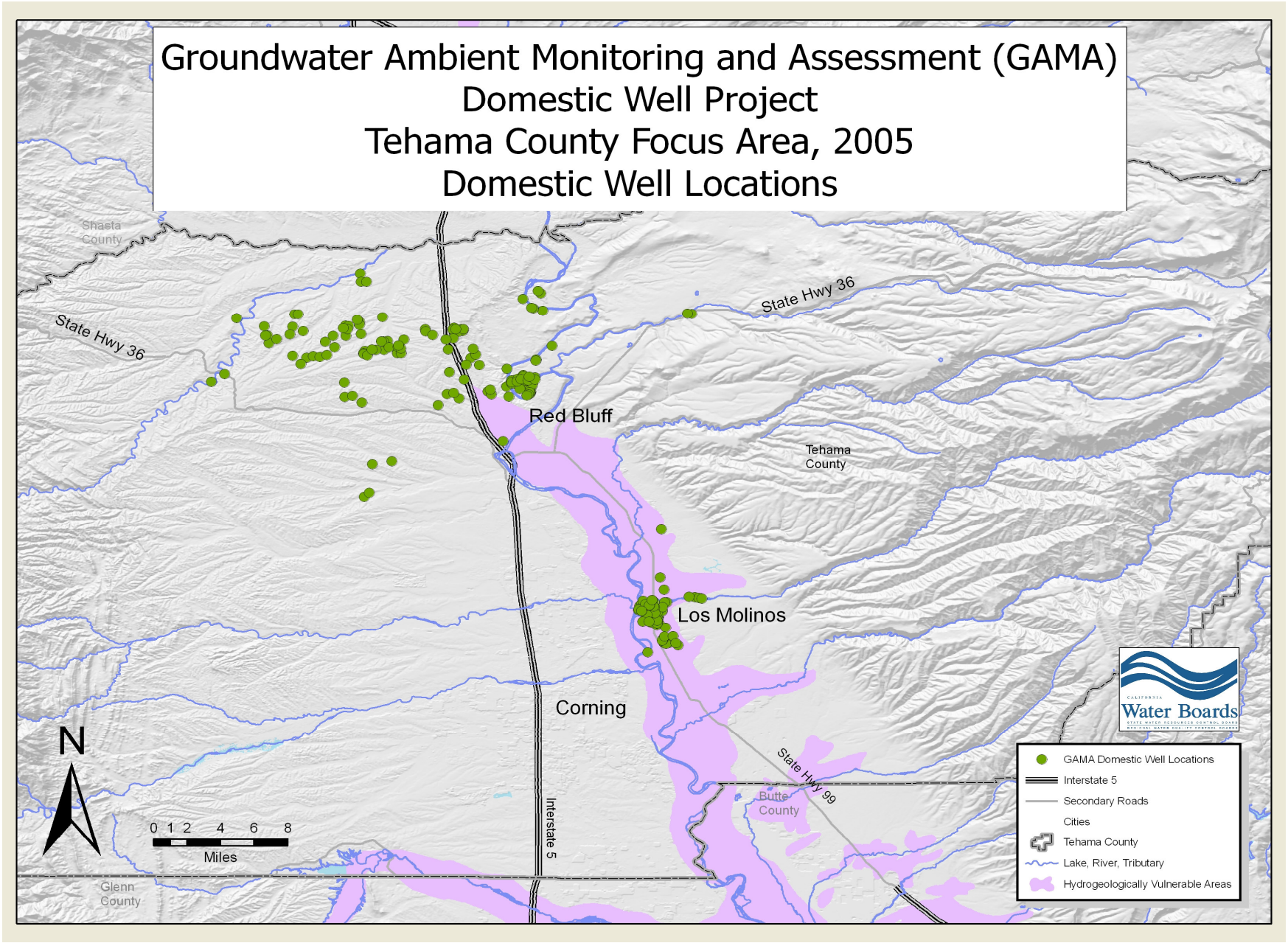
Domestic wells differ from public drinking water supply wells in several respects; domestic wells are generally shallower, are privately owned, supply a single household, and tend to be located in more rural settings where public water supply systems are not available. Based on data from the 1990 U.S. Census, more than 500,000 private domestic wells provide drinking water for more than one million Californians. There are more than 7,400 domestic wells in Tehama County alone (State of California, 1999). Because the California Department of Public Health (CDPH) does not regulate private domestic wells, well owners may not have an accurate assessment of their own well water quality.

Domestic well owners are responsible for ensuring the water quality of their domestic well. Domestic wells can produce very high quality drinking water. However, poor well construction or placement close to a potential source of contamination can result in poor domestic well water quality. In addition, chemicals from surface activities such as industrial spills, leaking fuel tanks, agricultural applications, leaking sewers, septic systems, and animal facilities can impact groundwater. Naturally-occurring chemicals can also be found at concentrations that are above public drinking water standards.

Domestic well water quality data collected by GAMA were compared to existing groundwater information and public supply well data to help assess California groundwater quality and identify issues that may impact private domestic well water. Test results were shared with the well owners in a summary letter from the State Water Board. A summary list of test results was also shared with State and local health officials to assist in well owner inquiries and concerns.

CDPH groundwater data from public supply wells sampled between 2004 and 2006 have also been included as part of the evaluation of results to better understand groundwater quality conditions in the area.

Figure 1. Locations of Sampled Domestic Wells



HYDROGEOLOGIC SETTING

Major Water-Bearing Formations

Tehama County is located in the northern Sacramento Valley section of California's Central Valley. Tehama County is bordered to the west by the California Coast Ranges and on the east by the Cascade Range. Topography consists of rolling foothills, generally flat valley land, and flat-topped buttes bisected by the Sacramento River and its local tributaries.

The California Department of Water Resources (DWR) Bulletin 118 identifies several water-bearing geologic formations in Tehama County, including the following:

- *Tehama Formation:* The Tehama Formation is generally comprised of sediments derived from the Klamath Mountains and Coast Ranges to the west deposited under floodplain conditions. The Tehama is located on or near the surface in western Tehama County and generally supplies water to shallow wells at the western margin of the Sacramento Valley. The Tehama Formation is the primary source of groundwater in the Red Bluff area. Although the formation is gradually covered by younger valley fill sediments, it remains an important water producer and supplies water to deep wells towards the center of the Sacramento River Valley.

- *Tuscan Formation*: The Tuscan Formation is primarily made up of volcanic gravels, mudflows, and eruptive material derived from the Cascade volcanics to the north and east. Located on the eastern side of the county (generally east of the Sacramento River), the Tuscan Formation generally supplies groundwater in deep wells in the central part of the county. The Tuscan Formation is gradually covered by younger valley fill sediments near the center of the Sacramento River Valley. The Tuscan Formation is the primary source of groundwater in the Los Molinos area.

- *Riverbank Formation*: The Riverbank Formation is made up of gravels, clay sands, and silts, and is younger than the Tehama and Tuscan Formations. Thickness of the Riverbank varies with location. Due to the variable thickness, stratigraphic location, and permeability the Riverbank Formation supplies few domestic wells.

- *Modesto Formation*: The Modesto Formation is made up of re-worked older sedimentary deposits, including the Tehama and Riverbank Formations. The Modesto supplies water to shallow wells in the valley portion of the county generally near the Sacramento River.

Well Construction Data

According to available DWR well-completion reports, approximately half of all wells drilled in Tehama County are completed between 125 and 150 feet below the surface. This suggests that the shallow aquifer system provides an adequate supply and quality for domestic use. The depths of wells sampled in Tehama County as part of the Domestic Well Project reflect this general distribution, as shown in Table 1 (well construction data was available for 144 of the 223 sampled wells). Table 1 shows two distinctive groups of wells. About half of the sampled wells are completed at depths less than 125 feet deep. The remaining wells were completed at depths greater than 125 feet deep, in some cases to depths exceeding 500 feet. Deeper wells are primarily located in the Cottonwood area, while shallower wells are primarily located in the Los Molinos and Bend areas.

Table 1: Domestic Well Depths

GAMA Domestic Well Project, Tehama County Focus Area

Total Well Depth (feet)	Number of Wells
0-24	0
25-49	3
50-74	10
75-99	39
100-124	29
125-149	8
150-174	5
175-199	4
200-224	6
225-249	1
250-274	3
275-299	5
300-324	9
325-349	4
350-374	7
375-400	1
>400	10

Note: Well construction data not available for all wells

METHODS

Well Selection

Tehama County was selected as a Domestic Well Project Focus Area due to the large number of domestic wells within the county and the availability of well owner data. The Tehama County Assessor's Office provided the State Water Board with an electronic database containing information on approximately 7,500 domestic wells. These data included well owner names, mailing addresses, and parcel map book numbers. Approximately 1,500 domestic well owners in Tehama County were mailed a pamphlet informing the domestic well owners about the GAMA well testing program and inviting them to participate. A total of 223 domestic well owners responded to the pamphlet and agreed to have their well tested.

Several factors affected the spatial distribution of wells that were sampled. Since the Domestic Well Project is voluntary, the location of sampled wells relied upon well-owner responses to the GAMA pamphlet. As a result, the locations of wells sampled for the Tehama County focus area are highly localized near the county's major population centers.

Sample and Data Collection

Well construction information was obtained from either well owners or DWR well completion reports (well logs). Observations at each well noted the location of nearby septic systems, large-scale agriculture, or livestock enclosures that could result in contamination of the well. Well locations were recorded using a Geographic Positioning Satellite (GPS) unit. Water temperature, pH, and specific electrical conductance were measured in the field. Field information was documented on a paper form and later entered into a computer database.

Groundwater samples were collected as close to the well head as possible. Most often the sample was collected from a faucet or spigot just before or after the pressure tank. All samples were collected in laboratory supplied pre-cleaned bottles, and were stored in an iced cooler until delivery to the lab. New nitrile gloves were worn by field staff during sample collection to minimize contamination during the sample handling process.

Field quality control trip blank and duplicate samples were collected at approximately 10 percent of the well locations. These samples help determine if contamination was introduced during sample collection, processing, storage, and/or transportation. All trip blank and duplicate data test results were within acceptable range criteria.

Sample Analysis

Groundwater samples were tested by Alpha Analytical Laboratories Inc. in Ukiah, California for the following:

- Bacteria (total and fecal coliform)
- Inorganics (metals, major anions and general minerals)
- Volatile organic compounds (VOCs)

In addition, selected groundwater samples were tested by LLNL for the following:

- Stable isotopes of oxygen in water
- Stable isotopes of nitrogen and oxygen in nitrate
- Wastewater indicators, including fecal sterols, caffeine, ibuprofen, DEET, antibacterial agents, and other compounds.

CDPH Public Groundwater Source Data

Although the Domestic Well Project collects samples from only private domestic wells, there are numerous public supply wells throughout Tehama County that are used for municipal water supplies. The CDPH requires routine water quality testing from these public supply wells, and data from these wells are publicly accessible through CDPH. Where available, CDPH public supply well data are plotted in figures along with domestic well data. When CDPH data are included in a map or figure, the public supply sources are clearly distinguished from domestic well data. Only CDPH well data collected from 2004-2006 are included in this report. When multiple results are available from a single CDPH source from 2004-2006, the highest detected value is plotted.

It is important to note that private domestic wells are usually much shallower in depth, and that the yield (or pumping volume) from domestic wells is significantly less than that of a public supply well (tens of gallons per minute versus thousands of gallons per minute). The use of CDPH data in these figures is strictly for comparison purposes only.

RESULTS

Detections Above a Drinking Water Standard

There are no Federal or State water quality standards that regulate private domestic well water quality. The Domestic Well Project has compared the test results to the following public drinking water standards: CDPH primary maximum contaminant levels (MCLs), secondary MCLs (SMCLs), and notification levels (NLs). The MCL is the highest concentration of a contaminant allowed in public drinking water. Primary MCLs address health concerns, while secondary MCLs (SMCLs) address aesthetics, such as taste and odor. NLs are health-based advisory levels for chemicals in public drinking water that have no formal regulatory standards.

Analytes that were detected in one or more wells above a drinking water standard:

- Total and Fecal Coliform Bacteria
- Nitrate (NO_3^-)
- Arsenic
- Chromium
- Lead
- Iron
- Aluminum
- Manganese

A summary of all analytes detected above a drinking water standard is outlined in Table 2. Detailed results of the domestic well sampling are summarized below.

Coliform Bacteria

Total coliform bacteria were detected in 56 wells (25% of total samples). Three of the wells with positive total coliform detections also tested positive for fecal coliform (1% of sampled wells). Figure 2 shows the distribution of detected total and fecal coliform bacteria in wells.

Table 2: Summary of Detections Above a Drinking Water Standard

GAMA Domestic Well Project – Tehama County Focus Area

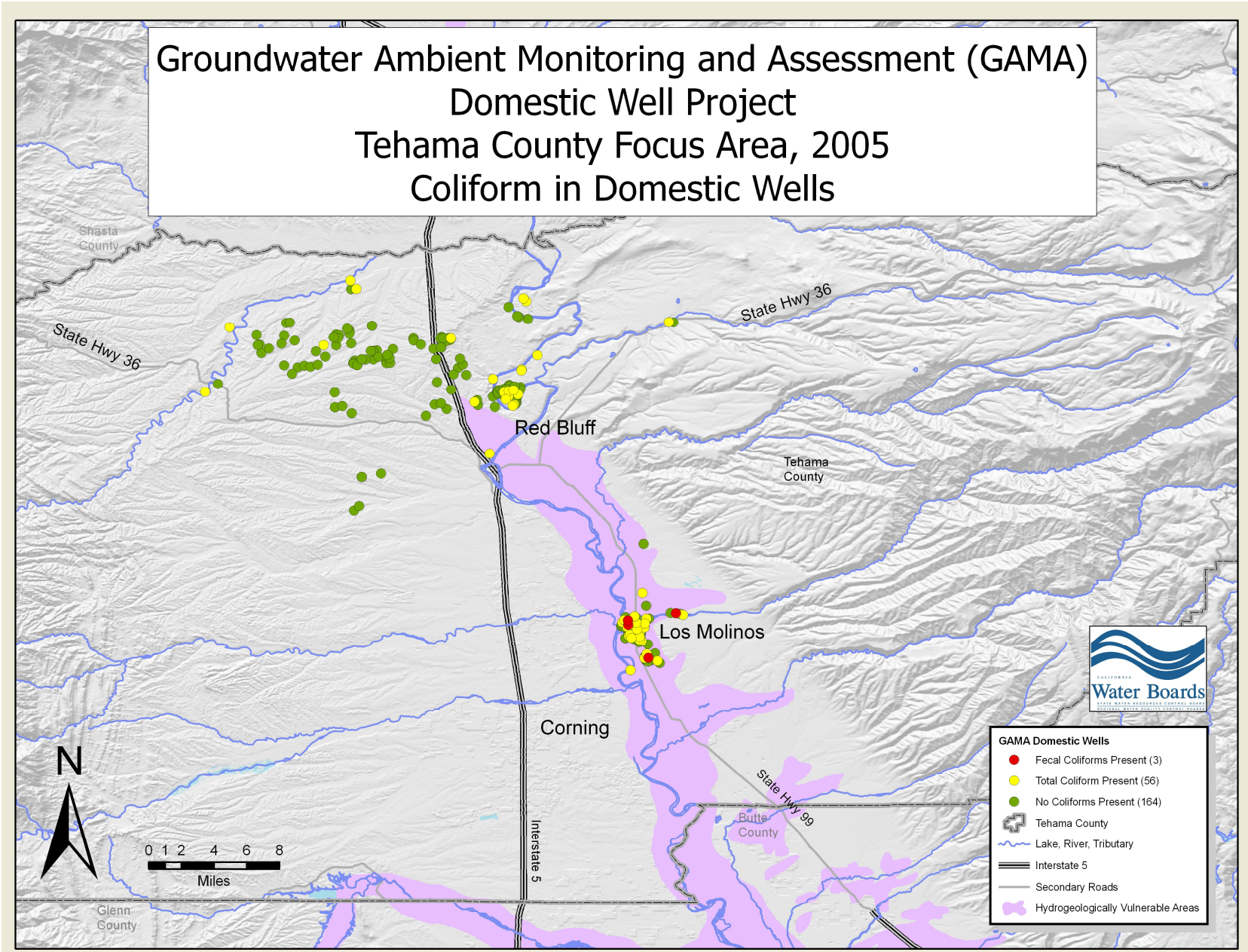
Total Number of Wells Sampled: 223

Compound	Number of Wells above Public Drinking Water Standards	Percentage	Ranges of detected values above Public Drinking Water Standards	Public Drinking Water Standards		
				MCL	SMCL	NL
Metals						
Arsenic	29	13%	10 - 25 µg/L	10 µg/L	--	--
Iron	31	14%	310 - 9700 µg/L	--	300 µg/L	--
Aluminum	6	2%	200 - 700 µg/L	1,000 µg/L	200 µg/L	--
Chromium	1	<1%	200 µg/L	50 µg/L	--	--
Manganese	19	8%	57 - 490 µg/L	--	50 µg/L	--
Lead	2	<1%	22 - 66 µg/L	--	--	15 µg/L
Nutrients						
Nitrate (NO_3^-)	2	<1%	49 - 60 mg/L	45 mg/L	--	--
Nitrite (N)	2	<1%	1.3 - 1.6 mg/L	1.0 mg/L		
Bacteria Indicators						
Total Coliform	56	25%	NA[3]	Present	--	--
Fecal Coliform	3	1%	NA[3]	Present	--	--

Notes:

1. CDPH Public Drinking Water Standards are used for comparison purposes only, since domestic well water quality is not regulated
2. µg/L = micrograms per liter, mg/L = milligrams per liter. A microgram is 1/1000th of a milligram.
3. Coliform are evaluated on a presence/absence criteria. No range can be determined.

Figure 2: Total and Fecal Coliform Results



General Minerals

General minerals detected in domestic well samples are summarized in Table 3. These naturally occurring minerals include measures of alkalinity, hardness, and total dissolved solids (TDS). There are no established regulatory levels for many general mineral analytes. Only foaming agents (MBAS) and TDS have SMCLs. MBAS, which are typically associated with the presence of detergents, were detected in only 1 sample at a concentration below the MCL. TDS, which is an estimate of the total concentration of all non-settleable (dissolved) components in water, were below the SMCL of 1000 mg/L in all 223 wells sampled.

All of the general minerals listed in Table 3, with the exception of foaming agents (MBAS), occur naturally in groundwater. Human activities can sometimes change the concentrations of these minerals in groundwater.

Table 3: General Minerals

GAMA Domestic Well Project, Tehama County Focus Area

Analyte	Range of Detected Values (mg/L)	Public Drinking Water Standard (mg/L)	Number of Wells Above Standard
Total Alkalinity (as $CaCO_3$)	49 - 260	NA	0
Bicarbonate	49 - 260	NA	0
Carbonate	42 - 70	NA	0
Calcium	3.1 - 64	NA	0
Magnesium	1.8 - 50	NA	0
Potassium	1 - 69	NA	0
Sodium	6.1 - 190	NA	0
Foaming Agents (MBAS)	0.14	0.5 SMCL	0
Hardness (Total) as $CaCO_3$	15 - 366	NA	0
pH, Laboratory	6.3 - 8.4	NA	0
Total Dissolved Solids (TDS)	91 - 600	1000 SMCL	0

Notes:
1. SMCL = Secondary Maximum Contaminant Level
2. mg/L = milligrams per liter
3. NA = Health or aesthetic standards are not available for this constituent

Major Anions

Major anions detected in domestic well samples are summarized in Table 4. Both nitrate (NO_3^-) and nitrite (NO_2) were detected at concentrations above a drinking water standard. Nitrate was detected in 208 samples at concentrations ranging from 1.1 to 60 mg/L, two of which were above the MCL of 45 mg/L (as NO_3). The distribution of nitrate in domestic wells and CDPH supply wells is shown on Figure 3. Nitrite was detected in two samples, both of which were above the MCL of 1.0 mg/L (as N).

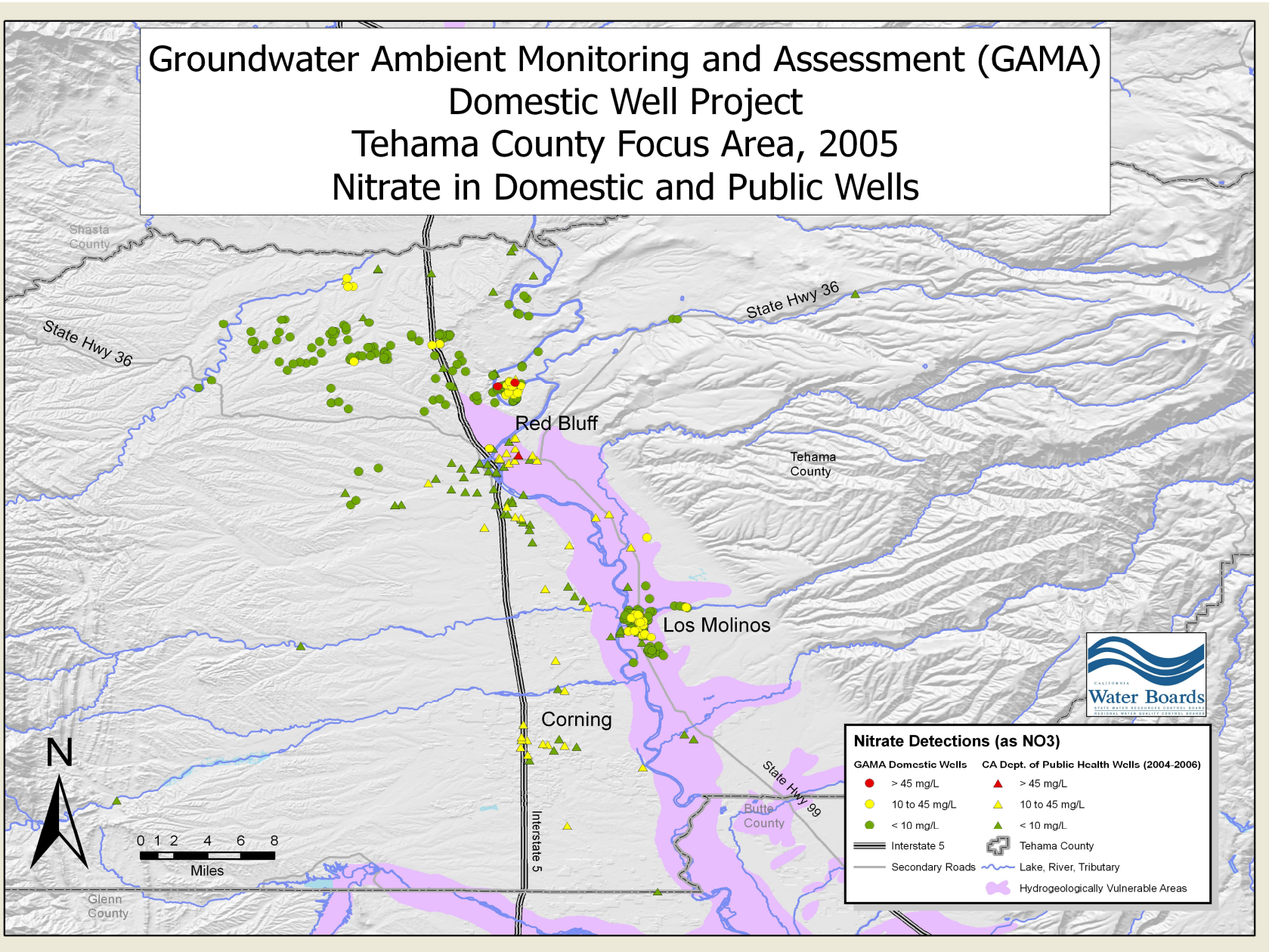
Table 4: Major Anions

GAMA Domestic Well Project, Tehama County Focus Area

Analyte	Range of Detected Values (mg/L)	Public Drinking Water Standard (mg/L)	Number of Wells Above Standard
Chloride	1.5 - 310	500 SMCL	0
Fluoride	0.1 - 0.34	2 MCL	0
Nitrate (as NO_3^-)	1.1 - 60	45 MCL	2
Nitrite (as N)	1.3 - 1.6	1 MCL	2
Sulfate	0.52 - 57	500 MCL	0

Notes:
1. MCL = Maximum Contaminant Level, SMCL = Secondary Maximum Contaminant Level
2. mg/L = milligrams per liter

Figure 3: Nitrate (as NO_3^-) Results



Metals

Metals detected in domestic well samples are summarized in Table 5. Six metals (aluminum, arsenic, chromium, iron, lead and manganese) were detected at concentrations above a public drinking water standard. A summary of all metals detected above a drinking water standard is provided below.

- Arsenic was detected in 133 wells at concentrations ranging from 2 to 25 µg/L. Arsenic was detected above the MCL of 10 µg/L in 29 samples. The distribution of arsenic in domestic wells is shown on Figure 4. Many of the wells with arsenic levels above the MCL were sampled in the Los Molinos area.

- Total chromium was detected in 40 samples at concentrations ranging from 10 to 200 µg/L. Chromium was detected in one sample at a concentration above the MCL of 50 µg/L.

- Lead was detected in 5 samples at concentrations ranging from 5 to 66 µg/L. Lead was detected in two samples at a concentration above the NL of 15 µg/L.

- Manganese was detected in 33 samples at concentrations ranging from 20 to 490 µg/L. Manganese was detected in 19 samples at a concentration above the SMCL of 50 µg/L.

- Iron was detected in 58 samples at concentrations ranging from 0.1 mg/L to 9.7 mg/L. Iron was detected in 31 samples at a concentration above the SMCL of 0.3 mg/L.

- Aluminum was detected in 20 samples at concentrations ranging from 50 to 700 µg/L. Aluminum was detected in six samples at a concentration above the SMCL of 200 µg/L.

Table 5: Metals

GAMA Domestic Well Project, Tehama County Focus Area

Analyte	Range of Detected Values (µg/L)	Public Drinking Water Standard (µg/L)	Number of Wells Above Standard
Aluminum	50 - 700	200 SMCL	6
Antimony	Not Detected	6 MCL	0
Arsenic	2 - 25	10 MCL	29
Barium	12 - 210	1,000 MCL	0
Beryllium	Not Detected	4 MCL	0
Cadmium	Not Detected	5 MCL	0
Chromium (Total)	10 - 200	50 MCL	1
Copper	20 - 150	1,000 SMCL	0
Iron	100 - 9,700	300 SMCL	31
Lead	5 - 66	15 NL	2
Manganese	20 - 490	50 SMCL	19
Mercury	Not Detected	2 MCL	0
Nickel	10	100 MCL	0
Selenium	Not Detected	50 MCL	0
Silver	Not Detected	100 SMCL	0
Thallium	1	2 MCL	0
Zinc	50 - 2,800	5,000 SMCL	0

Notes:

1. MCL = Maximum Contaminant Level, SMCL = Secondary Maximum Contaminant Level, NL = Notification level
2. µg/L = micrograms per liter

Figure 4: Arsenic Concentrations

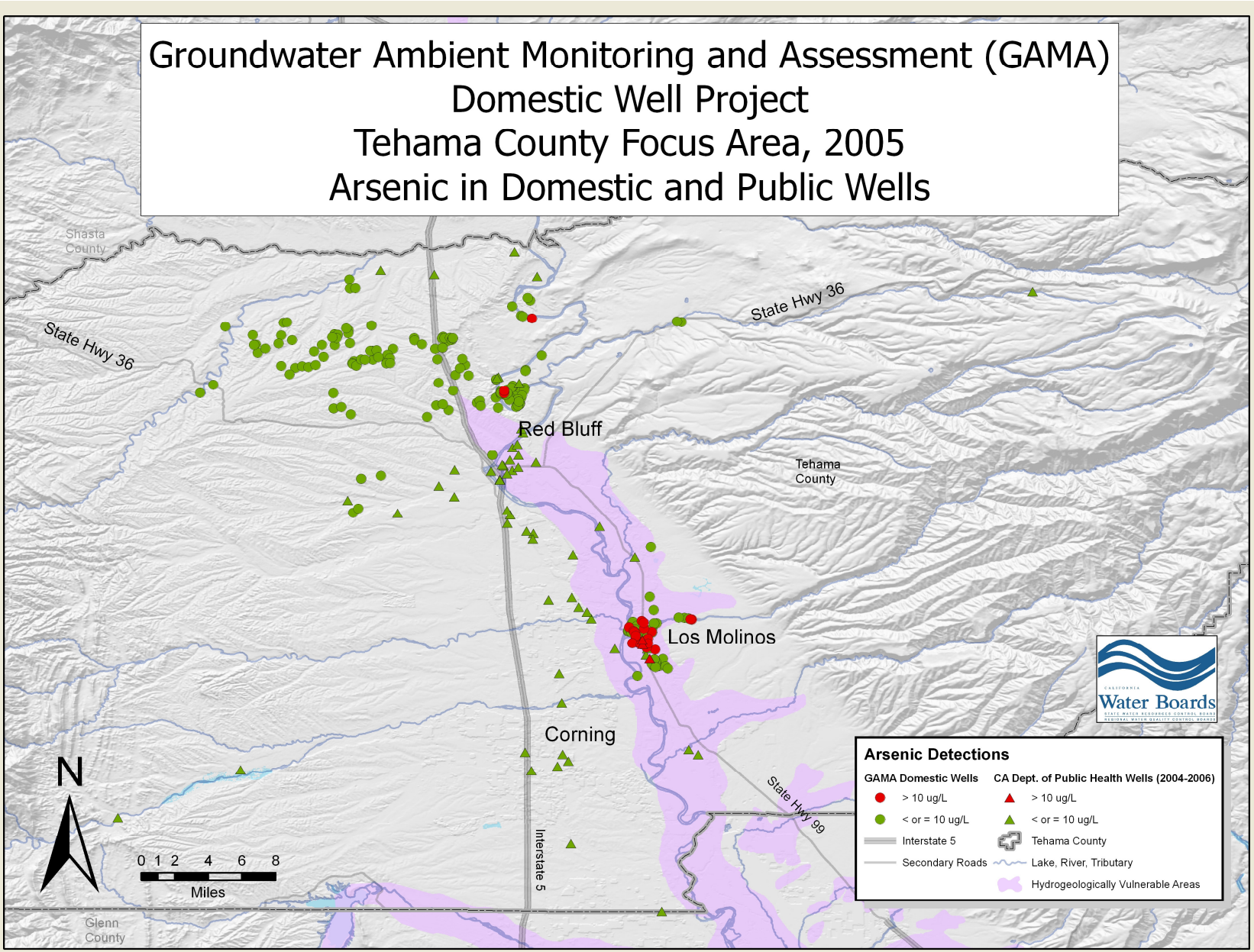
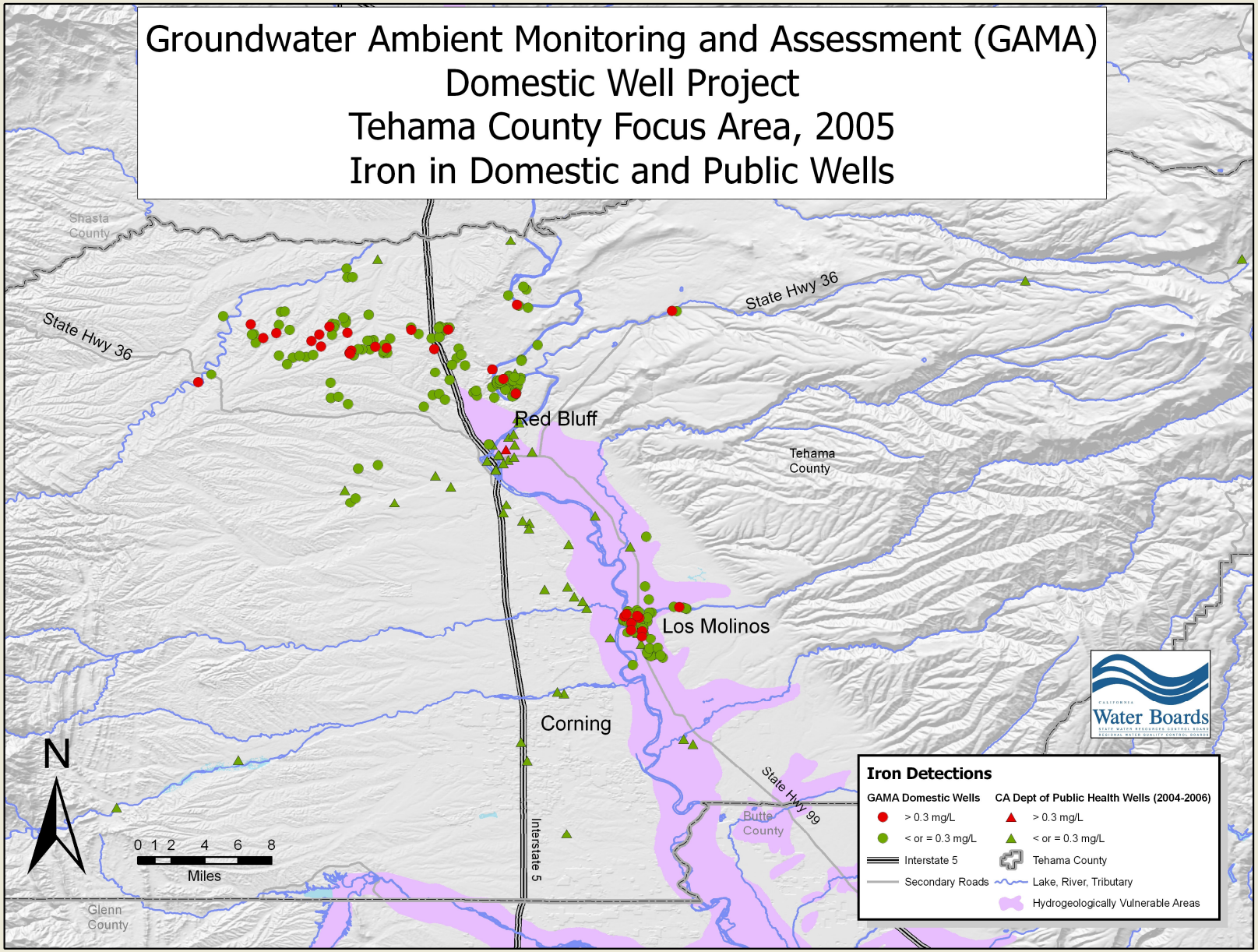


Figure 5: Iron Concentrations



Volatile Organic Compounds (VOCs)

VOCs detected in domestic wells are summarized in Table 6. VOCs were not detected above public drinking water standards in any of the domestic wells tested. Low-level concentrations of 5 VOCs were detected:

- 1,1,2-Trichloro-1,2,2-Trifluoroethane at a concentration of 0.52 µg/L in one well
- 1,1,2-Trichloroethane in three wells, with maximum concentration of 3.3 µg/L
- 1,3-Dichloropropane in three wells, with a maximum concentration of 0.72 µg/L
- Acetone at 14 µg/L in one well

Table 6: Volatile Organic Compounds (VOCs)
GAMA Domestic Well Project, Tehama County Focus Area

Analyte	Range of Detected Values (µg/L)	Public Drinking Water Standard (mg/L)	Number of Wells Above Standard
Acetone	14	NA	0
1,3-Dichloropropane	0.56 - 0.72	NA	0
1,1,2-Trichloroethane	2.3 - 3.3	5 MCL	0
1,1,3-Trichloro-1,2,2-Trifluoroethane	0.52	1,200 MCL	0

Notes:
1. MCL = Maximum Contaminant Level
2. µg/L = micrograms per liter
3. NA = Health or aesthetic standards are not available for this constituent

Wastewater Indicators

LLNL tested 35 samples for 13 wastewater indicator compounds, including caffeine, ibuprofen, DEET, triclosan, and other compounds. No wastewater indicators were detected in the Tehama County domestic well samples. A full description of the wastewater indicator results are in a summary report prepared by LLNL, and are available on the GAMA website (www.waterboards.ca.gov/gama/).

Isotopes

Oxygen isotopes in water, and both oxygen and nitrogen isotopes in nitrate, were analyzed from domestic well samples collected in Tehama County. Isotope results will be summarized and published in a separate report, and will be placed on-line at the GAMA website as they become available.

POSSIBLE SOURCES OF CONTAMINANTS IN DOMESTIC WELL WATER

Seven contaminants in the Tehama County Focus Area were detected above water quality standards. Four of these contaminants were detected in over 5 percent of the 223 sampled wells. Potential sources for these contaminants are discussed below. It is important to note that the focus of this sampling was not to pinpoint the source of contaminants found in groundwater. The following descriptions summarize data collected from groundwater across the country. The descriptions do not imply that a chemical detected in a domestic well comes from any single, specific source. The information is provided as a source for well owners.

Bacteria Indicators

Coliform bacteria are naturally present in the environment, and in general are harmless to people. However, some coliforms may cause illness in humans. The presence of coliforms is an indication that other harmful micro-organisms may be present. Fecal coliforms are found in human and animal wastes. Drinking water that contains coliform bacteria increases the risk of becoming ill.

Arsenic

Arsenic naturally occurs in soil, water, air, plants, and animals — and is widely distributed throughout the Earth's crust. Weathering of arsenic-containing rocks is the primary natural source of arsenic in the environment. The most significant human sources of arsenic in groundwater are mining of metal sulfides, pesticides, insecticides, cattle and sheep dips, and algaecides. Detections of arsenic (even at concentrations above the MCL of 0.01 mg/L) in the Central Valley may likely be natural in origin. Human exposure to arsenic can result in illness and even death. Long term exposure of arsenic has been linked to certain types of cancers.

Iron and Manganese

Iron and manganese have water quality standards associated with color, odor, and taste (SMCLs). Both metals naturally occur in soil and rocks, and most frequently enter the environment through natural weathering. Concentrations above SMCLs may lead to discoloration, metallic or bitter tasting water, and staining.

Piper Diagram

Basic groundwater geochemistry was evaluated using a Piper diagram (Figure 6) that illustrates ion concentrations and TDS for multiple water samples. Piper diagrams plot major ions in two base triangles. The total cations and anions are set equal to 100% and the data points in the two triangles are projected onto an adjacent grid. The main purpose of the Piper Diagram is to show clustering of data points to indicate water samples that have similar geochemical compositions.

Groundwater from wells located within the Cottonwood, Los Molinos, and parts of Red Bluff area is comprised of calcium-magnesium-bicarbonate ions. Groundwater from wells located northeast of Red Bluff (Bend area) indicates higher TDS concentrations and richer in sodium, potassium, and chloride. Sodium, potassium, and chloride are typically associated with water that has experienced significant evaporation resulting in enrichment of salts. Recharge of irrigation water and evaporation may be a possible contributing factor to the salinity increase detected in groundwater near the Bend area.

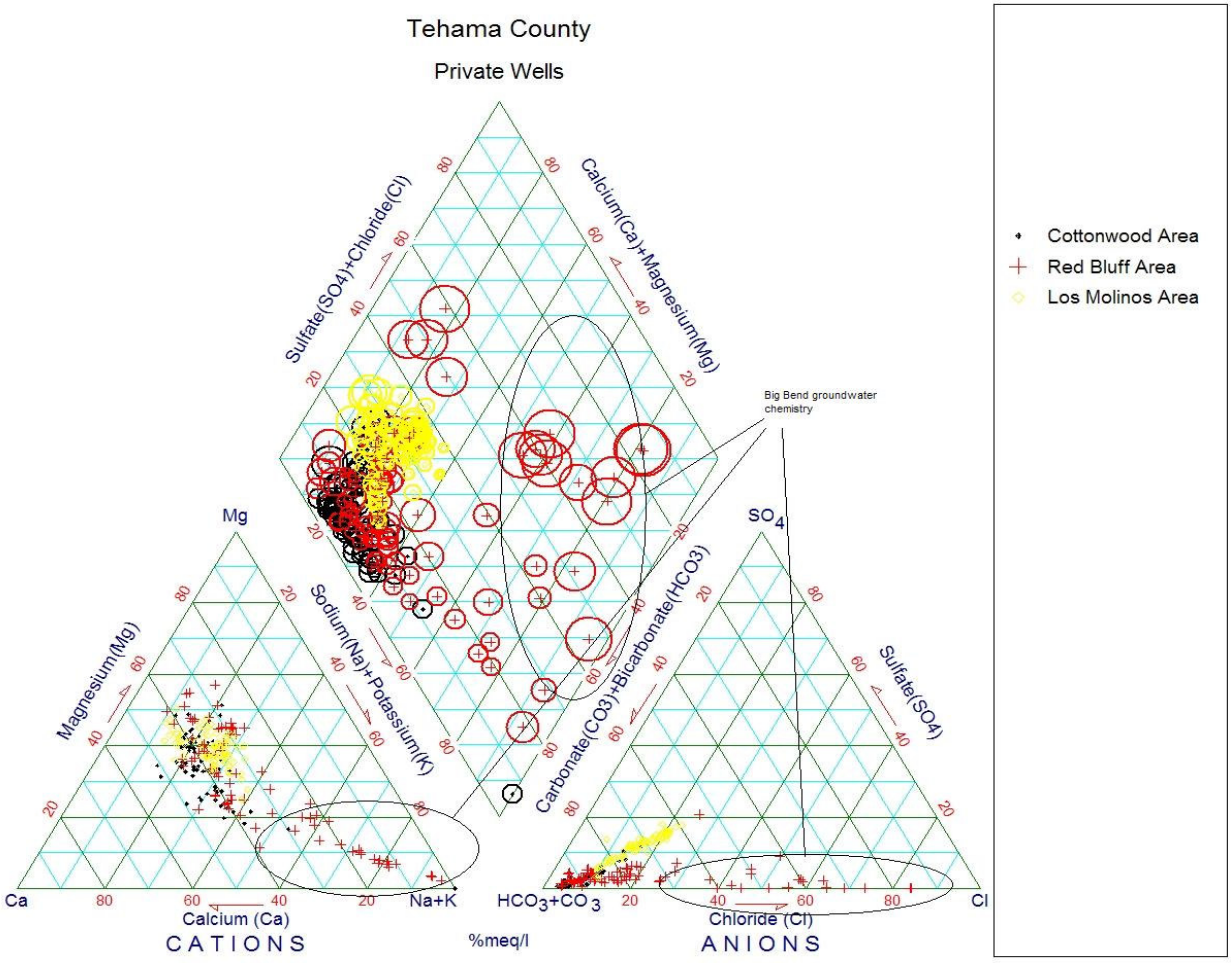


Figure 6: Piper Diagram of Groundwater Geochemical Composition

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