Alternative Water Supply Options for Nitrate Contamination in California's Tulare and Salinas Groundwater Basins

By

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B.S. (University of California, Davis) 2007
M.S. (University of California, Davis) 2011
THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

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2011

ACKNOWLEDGMENTS

Preparation of this Thesis was assisted by:

Acknowledgments:

Paul	Boyer	Self-Help Enterprises
Tony	Boren	Fresno Council of Governments
Beverly	Briano	Kern County Environmental Health
Kristine	Cai	Fresno Council of Governments
Holly	Canada	UCD – Graduate Student Researcher
Eugene	Cassady	Stockdale Annex Mutual Water Company
Thomas	Chamberlain	UCD – Undergraduate Student Assistant
Paul	Charpentier	Tulare County Department of Environmental Health – Water Program
Anthony	Chavarria	City of Firebaugh
Kathy	Chung	Fresno Council of Governments
Paul	Collins	CDPH Division of Drinking Water and Environmental Management
Rob	Coman	UCD – Information Center for the Environment
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Leslie	Cotham	Golden Living Center – Country View
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Laurel	Firestone	Community Water Center
Chione	Flegal	PolicyLink
Wayne	Fox	Fresno County Environmental Health
Anna	Fryjoff-Hung	UCD – Center for Watershed Sciences
Lynn	Gorman	Fresno County Department of Public Works and Planning
Kelly	Granger	Granger Water Specialties
Charles	Hemans	Tulare County Department of Environmental Health – Water Program
Samantha	Hendricks	Fresno Local Agency Formation Commissions
Charles	Hewitt	Monterey County Health Department – Drinking Water Protection Services
Cheryl	Higgins	UCD – Undergraduate Student Assistant
Allan	Hollander	UCD – Information Center for the Environment
Mimi	Jenkins	UCD – Civil and Environmental Engineering
Vivian	Jensen	UCD – Graduate Student Researcher
Katrina	Jessoe	UCD – Agricultural and Resource Economics
Chris	Johnson	Aegis Groundwater Consulting, LLC

Matt	Keeling	Central Coast Regional Water Quality Control Board
Sally	Keldgord	Kern County Environmental Health
Aaron	King	UCD – Center for Watershed Sciences
Tess	Lake	Seventh Standard Mutual Water Company
Harold	Leverenz	UCD – Department of Civil and Environmental Engineering
Betsy	Lichti	CDPH – Fresno District Engineer
Katherine	Lockhart	UCD – Graduate Student Researcher
Karl	Longley	CSU Fresno
Elena	Lopez	UCD – Center for Watershed Sciences
Jay	Lund	Civil and Environmental Engineering
Joe	McGahan	Summers Engineering
Josue	Medellin - Azuara	UCD – Civil and Environmental Engineering
Marti	Noel	Monterey County Health Department – Drinking Water Protection Services
Joe	Prado	Fresno County
Jim	Quinn	UCD – Information Center for the Environment
Jose	Ramirez	City of Firebaugh
Solana	Rice	PolicyLink
Clay	Rodgers	Central Valley Regional Water Quality Control Board
Michael	Rosberg	Water System Owner
Victor	Rubin	PolicyLink
Cheryl	Sandoval	Monterey County Health Department – Drinking Water Protection Services
Seth	Scott	Fresno County
Andrew	Tran	UCD – Graduate Student Researcher
Joshua	Viers	UCD – Center for Watershed Sciences/Information Center for the Environment
Jeff	Witte	Fresno County

ABSTRACT

Nitrate is California's most ubiquitous groundwater contaminant and has significant potential to harm human health. The Tulare Lake Basin and Salinas Valley were chosen as pilot study areas to study the population susceptible to nitrate contamination in groundwater, and identify the available short-term and long-term alternative water supply options. Farming practices on agricultural lands and dairies in these basins produce high levels of nitrate. The population served by the groundwater have a high risk of exposure to nitrate, and often cannot afford treatment or alternative water supply options. These factors combine to make the Tulare Lake Basin and Salinas Valley highly susceptible to health effects from nitrate in drinking water. This thesis estimates the population potentially susceptible to consuming nitrate in groundwater and examines the alternative water supply options available for each system type. The economic and financial costs are estimated for each water supply option and a least cost analysis is performed for the entire basin susceptible population.

Approximately 766,000 people in California's Tulare Lake Basin and Salinas Valley have drinking water supplies susceptible or potentially susceptible to nitrate groundwater contamination. Water users that are served by a community water system exceeding a nitrate threshold, or lacking historical nitrate records, account for about 675,000 people. The remaining 88,000 people are estimated to be connected to a self-supplied household or local small water system that is located in an area exceeding the nitrate threshold. Assuming unchanging and unabated basin-wide trends in nitrate groundwater levels, the susceptible community water system population is estimated to increase 80% by 2050.

The most promising options for communities connected to highly susceptible water systems are to consolidate with a larger system; consolidate with nearby smaller systems and regionalize into a larger system; install ion exchange community water treatment; drill a new well; blend sources; and as an interim solution, provide point-of-use treatment to households. There is significant potential for consolidation of systems. Solely based on system size and spatial proximity to surrounding systems, there is great possibility for smaller water systems to consolidate with larger water systems. Promising solutions for self-supplied households or local small water systems within a highly susceptible sub-area are to install a point-of-use reverse osmosis treatment system, or drill a new or deeper well.

The overall cost of providing nitrate-compliant drinking water to the Tulare Lake Basin and Salinas Valley is estimated to be about \$25 to \$30 million per year for the long-term. Roughly, \$18 to \$23 million per year is estimated to be needed for community water system users and about \$7 million is estimated to be needed for household self-supplied or local small water system users. To put this funding need in perspective, the overall costs correspond to \$33 to \$40 per year per susceptible person, \$6 to \$8 per study area irrigated acre per year, or \$125 to \$150 per ton of fertilizer applied.

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Abbreviations

AL	Action Level or Notification Level
CADWSAP	California Drinking Water Source Assessment and Protection Program
CDP	Census Designated Place
CDPH	California Department of Public Health
CWS	Community Water System
DAC	Disadvantaged Community
DWR	Department of Water Resources
USEPA	United States Environmental Protection Agency
GAMA	Groundwater Ambient Monitoring and Assessment
MCL	Maximum Contaminant Level
MHI	Median Household Income
NO_3	Nitrate
OEHHA	Office of Environmental Health Hazard Assessment
PHG	Public Health Goal
PICME	Permitting Inspection Compliance Monitoring and Enforcement
PWS	Public Water System
SB	Senate Bill
SDAC	Severely Disadvantaged Community
SV	Salinas Valley
SWRCB	State Water Resources Control Board
TLB	Tulare Lake Basin
WQM	Water Quality Management

Glossary

Action Level (AL)	The action level (also known as the notification level) is an advisory standard for state-regulated systems. If a water system exceeds the action level the systems must "notify the governing body of the local agency in which users of the drinking water reside" and it is recommended that the systems notify their customers about the occurrence and health concern of consumption of the contaminant. (CDPH)
Census Block	The smallest geographic unit used by the US Census for tabulating data collected from all households within a region. They are formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. (US Census)
Census Block Group	A cluster of census blocks and a subdivision of a census tract. Census block groups generally have between 600 and 3,000 people. On average there are 39 blocks in a block group. (US Census)
Census Tract	Small, relatively permanent statistical subdivisions of a county delineated for most metropolitan areas and other densely populated counties by local census statistical areas committees. Census tracts usually have between 2,500 and 8,000 persons and, when first delineated, are designed to be homogeneous with respect to population characteristics, economic status, and living conditions. (US Census)
Census Designated Place (CDP)	Areas delineated for each decennial census as the statistical counterparts of incorporated places. CDPs are created to provide date for settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state they are located. (US Census)
Community Water System (CWS)	A public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the area. (CDPH)
Disadvantaged Community (DAC) – Block Group	A block group that has a Median Household Income (MHI) of less than 80% of the State of California's Median Household Income.

Household Self-Supplied Water System	A water system that is not connected to a public water system assumed to be 1 to 2 dwelling units (or connections) and is considered a domestic well.
Local Small Water System	A water system with 2 to 4 connections.
Local Primacy Agency (LPA)	County environmental health jurisdiction that has applied for and was granted regulatory authority over small community and non-community water systems in their county. (CDPH)
Maximum Contaminant Level (MCL)	Enforceable drinking water regulations established to protect the public against consumption of drinking water contaminants that present a risk to human health. (USEPA)
Median Household Income (MHI)	The amount that divides the income distribution into two equal groups, half having income above that amount, and half having income below that amount. It is the sum of money received in the calendar year by all household members 15 years of age or older, including unrelated household members. (US Census)
Non-Transient Non-Community Water System (NTNC)	A public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year. (CDPH)
Permits, Inspection, Compliance, Monitoring, and Enforcement (PICME)	The PICME database maintained by the Drinking Water Program of the California Department of Public Health and contains information related to the regulation of public drinking water systems subject to the federal and California Safe Drinking Water Acts. (CDPH)
Public Water System (PWS)	A system for the provision of water for human consumption through pipes or other constructed conveyances that has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days out of the year. (CDPH)
State Small Water System (SSWS)	A system for the provision of piped water to the public for human consumption that serves at least five, but no more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.
Susceptibility	The potential for the residential population to consume drinking water above the nitrate MCL or AL (depending on system type).
Transient Non-Community Water	A non-community water system that does not regularly

System (TNC)	serve at least 25 of the same persons over 6 months per year. (CDPH)
Vulnerability	The potential for a system to deliver water with high nitrate levels. A function of the type and location of the system. Classified as higher, lower, or no vulnerability depending on the source of water and quantity of available sources.
Water Quality Management (WQM)	The WQM database contains one record for each CWS per quarter and year with average concentrations of nitrate as well as the frequency of sampling, the number of sampling stations, and the date of the last sample.

1 Introduction

Nitrate is the most common chemical contaminant in the world's aquifers and has significant potential to harm human health (Spalding and Exner, 1993). A 2002 report from Lawrence Livermore National Laboratory (LLNL, 2002) concluded that of all regulated contaminants in drinking water, nitrate contamination poses the greatest threat to California's drinking water supply. High nitrate levels in groundwater are primarily from use of fertilizers on agricultural land and land application of manure at dairies. On average, more than 80 pounds of nitrogen (N) per acre per year may leach into the groundwater from fertilizer application on California farms (Harter, 2009). Other nitrate sources include animal feed lots, wastewater discharges, and septic systems. California's extensive agricultural lands and dairies have greatly increased nitrate loads to groundwater over time. Based on California Department of Public Health (CDPH) statewide data collected since 1980, of the approximately 16,500 public drinking water sources sampled, nitrate levels exceeded the primary drinking water standard (Maximum Contaminant Level or MCL) at least once in 1,075 wells (CDPH, 2010). The 1988 Report on Nitrates in Drinking Water reported that 10 percent of the California samples in the USEPA database were above the MCL, with the highest density of contaminated wells in the Central Valley located close to the Highway 99 corridor, in cities, and near dairies or feedlots (SCWRCB, 1988). In the San Joaquin Valley, between 2005 and 2008, 92 of the 671 community water systems had at least one groundwater well with nitrate levels exceeding the MCL. These 92 community water systems serve more than a million residents (Balazs, 2010).

Groundwater nitrate concentrations exceeding 10 mg/L (as NO_3 or 2 to 3 mg/L as N) generally indicate contamination from human-related nitrate sources (Mueller, 1995). The MCL for nitrate was set by CDPH in 1994 at 45 mg/L as nitrate (NO_3). The MCL is set based on health risk, not occurrence level (CDPH, 2011). This is equivalent to the 1991 federally mandated MCL of 10 mg/L nitrate as nitrogen (N) (CA EPA, 1997). The Cal EPA's Office of Environmental Health Hazard Assessment (OEHHA) considers scientific and public health concerns when establishing their non-binding recommendations (Public Health Goals or PHGs). The CDPH considers health, economic cost, and technical feasibility when setting MCLs. In the regulatory literature nitrate concentrations in water may be reported in milligrams of nitrate per liter (mg/L of NO_3) or in milligrams of nitrate-nitrogen (mg/L of N) per liter. This report follows the convention of reporting in milligrams of nitrate per liter (as mg/L of NO_3).

This report examines the population susceptible to nitrate contamination in groundwater in the Tulare Lake Basin and Salinas Valley and estimates the overall cost for providing this population with alternative water supplies. The Salinas Valley and the Tulare Lake Basin were chosen as pilot study areas because community and household self-supplied water supplies in these basins produce relatively high levels of nitrate, and the population served by these supplies have a high risk of exposure, and often cannot afford treatment or alternative water supply options. These factors combine to make the population in the Salinas Valley and the Tulare Lake Basin highly susceptible to health effects from nitrate in drinking water.

To address nitrate groundwater contamination in the Salinas Valley and the Tulare Lake Basin, the 2010 susceptible population and available alternative water supply options are identified for recent and long-term conditions. First, a background on each basin and a map of the study area is presented. The area and population are reviewed for susceptibility classification. To quantify susceptible water users, the water supply system types are estimated and the susceptibility of groundwater sources and systems to groundwater nitrate contamination is defined. Each identified alternative water supply option is evaluated in terms of financial and economic costs, public health concerns, least cost management, and regulatory implications. Based on the estimate of susceptible water users and the costs and technical feasibility of alternative water supply options, alternatives are recommended for water systems types and sizes.

2 Study Area Background

2.1 Tulare Lake Basin (TLB)

The Tulare Lake Hydrologic region, as defined by DWR in the 2003 update of Bulletin 118, covers 8,000 square miles in the southern Central Valley of California (CA Department of Water Resources 2003).

Here, the Tulare Lake Basin Study Area is defined as only the areas within the larger DWR-defined Tulare Lake Hydrologic Region that are a part of the San Joaquin Valley Groundwater Basin. The 8,045 square miles of underlying basin area (CA Department of Water Resources 2003) can be defined by the following DWR Bulletin 118 Groundwater Sub-Basins: 5-22.08 (Kings), 5-22.09 (Westside), 5-22.10 (Pleasant Valley), 5-22.11 (Kaweah), 5-22.12 (Tulare Lake), 5-22.13 (Tule), 5-22.14 (Kern County), and the southern tail of 5-22.07 (Delta-Mendota) (Figure 1). The Tulare Lake Basin portion of the study area includes the Central Valley basin ports of Fresno, Kings, Kern, and Tulare counties (Figure 2).

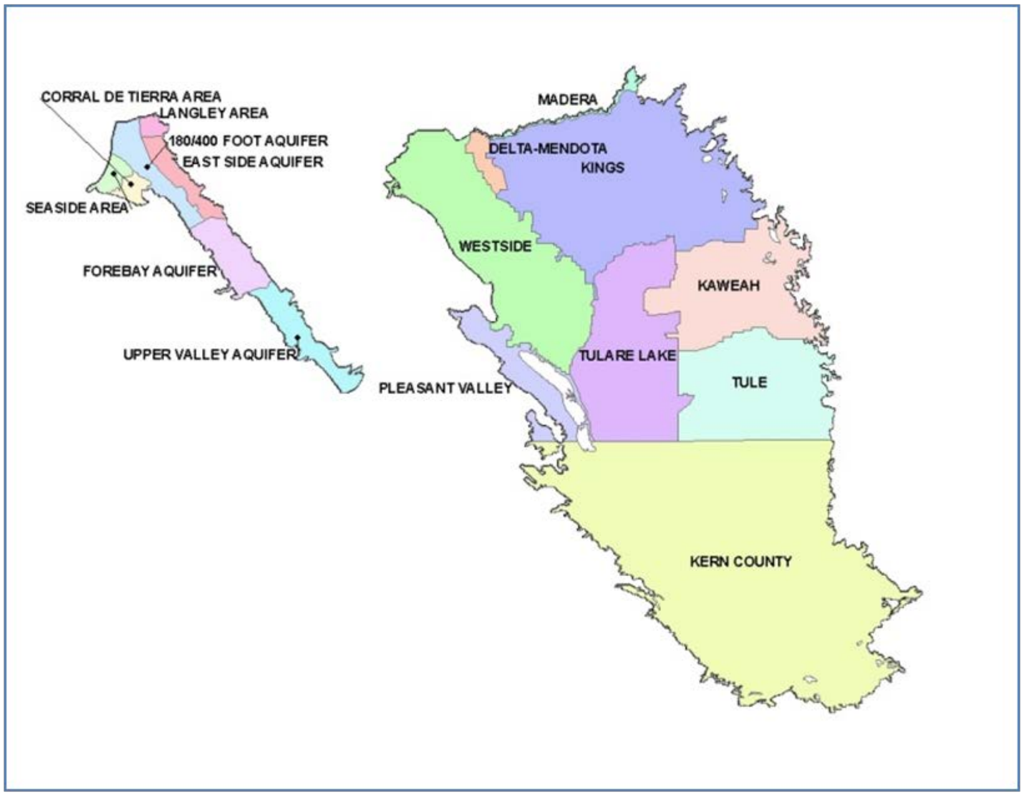
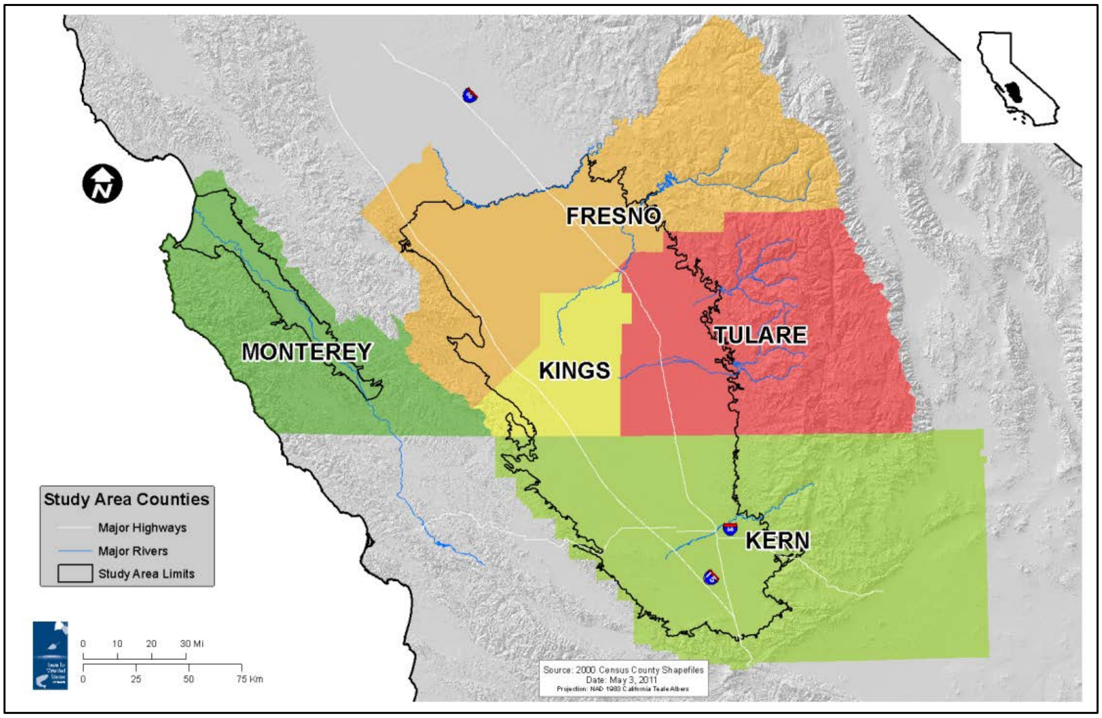


Figure 1. Bulletin 118 Groundwater Basins in the Study Area



Source: 2000 Census County Shapefiles
Date: May 3, 2011
Projection: NAD 1983 California Teale Albers

Figure 2. Salinas Valley and Tulare Lake Basin Counties

The population of 1.8 million people living in the Tulare Lake Basin[1] in 2000 grew to an estimated 2.25 million by 2010. The Basin has a Mediterranean climate with hot, dry summers and cool, moist winters. Average rainfall varies from seven inches in central and western parts of the Basin to 13 inches in eastern parts of the Kaweah and Kern County Sub-Basins (CA Department of Water Resources 2003). The Basin's largest city (Fresno) depends almost entirely on local groundwater (CA Department of Water Resources 2003). Fresno, Tulare, Kern, and Kings Counties are first, second, fourth, and eighth among California's top agricultural producing counties with gross production values of $5.37 billion, $4.05 billion, $3.61 billion, and $1.76 billion for 2009 (CDFA, 2009). There are approximately 3.4 million acres of irrigated land in the Tulare Lake Basin; production values are $1,579, $1,191, $1,062, and $518 per irrigated acre, for each county respectively.[2]

In 2000, 11% of the population, or over 200,000 people, lived in areas classified as rural. The other 1.6 million people lived in areas classified as urban[3].

2.2 Salinas Valley (SV)

With a total drainage area of 5,000 square miles, the Salinas Valley (SV) watershed is the largest southern California coastal basin (Justin and Kenneth 2005). It is bordered by the San Joaquin Valley and the Pacific Ocean. Boundaries for the SV for this thesis follow DWR Bulletin 118

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[1] The total population living in the Tulare Lake Basin is based on summarizing population values listed in the 2000 US Census blocks (www.census.gov). This is an overestimation of the total population within the study area because blocks extend beyond study area boundaries.

[2] California Department of Water Resources, Land Use Classification: Irrigated acre totals

[3] This designation uses 2000 census blocks. It follows the 2000 US Census method of defining urban versus rural on the basis of population density: an urbanized area or an urban cluster consists of: 1) core census block groups or blocks that have a population density of at least 1,000 people per square mile and 2) surrounding census blocks that have an overall density of at least 500 people per square mile (US Census Bureau 2009).

Groundwater Sub-Basins: 3-4.01 (180/400 Foot Aquifer), 3-4.02 (East Side Aquifer), 3-4.04 (Forebay Aquifer), 3-4.05 (Upper Valley Aquifer), 3-4.08 (Seaside Area), 3-4.09 (Langley Area), and 3-4.10 (Corral de Tierra Area) (Figure 1) and cover a total drainage area of 650 square miles. The Paso Robles area of the SV watershed is not included in this study. The SV, as considered here, is entirely within Monterey County (Figure 2).

Climate features warm, dry summers and cool, moist winters. In Monterey, the average annual temperature is 57˚F and average annual precipitation is 20 inches (mostly during the winter and early spring) (Justin and Kenneth 2005). Precipitation in the entire Salinas Valley increases with both latitude and altitude (Justin and Kenneth 2005). The Salinas Valley depends almost entirely on local groundwater for all water supplies, and the SV supports one of the most productive agricultural industries in California.[4] Monterey is third among California's top agricultural producing counties with a gross production value of $4.03 billion for 2009 (CDFA, 2009). The Salinas Valley has approximately 200,000 acres of irrigated land with an average production value of $20,150 per irrigated acre.[5] As of 2006, crop production was roughly 83 percent of the total nitrate load to groundwater.[6]

In 2000, 7% of the population, or approximately 22,600 people, were classified as living in rural areas. The other 300,000 people were classified as living in urban areas.[7]

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[4] Monterey County Water Resources Agency (MCWRA), UC Coop. Ext., and Irrigation Training and Research Center (ITRC). Irrigation and Nutrient Management Conference and Trade Fair 1996. CDFA Contract # 95-0419.

[5] California Department of Water Resources, Land Use Classification: Irrigated acre totals

[6] MCWRA, UC Coop. Ext., and Irrigation Training and Research Center (ITRC). Irrigation and Nutrient Management Conference and Trade Fair 1996. CDFA Contract # 95-0419.

[7] This designation uses 2000 census blocks. It follows the 2000 US Census method of defining urban versus rural on the basis of population density: an urbanized area or an urban cluster consists of: 1) core census block groups or blocks that have a population density of at least 1,000 people per square mile; and

3 Susceptible Water Users

This section reviews the existing California drinking water supply systems within the basins, and summarizes current threats to groundwater quality in the basins in the context of the established nitrate threshold (MCL or action level). A discussion of susceptible water users is provided, defining susceptibility and vulnerability. To identify susceptible water users within the Salinas Valley and the Tulare Lake Basin, all public data pertaining to water systems and water quality were collected and analyzed. Self-supplied households, or domestic well locations, were estimated on a land parcel level. The population on local small or state-small water systems was deduced from the basin total population and domestic well estimates found from parcel use level estimation. The methods and data used for estimating susceptible water users are discussed in Section 3.3.1.

3.1 Drinking Water Supply Systems

Water systems are defined by the period of water service, the number of people served, and the number of connections. A public water system (PWS) distributes water for human consumption to 15 or more service connections or regularly serves at least 25 people daily for at least 60 days of the year (CDPH, 2008). PWS include a wide range of system types, both residential and non-residential. A community water system (CWS) is a PWS that serves at least 15 residential connections all year or regularly serves at least 25 residents all year (CDPH, 2008). In addition to CWSs, PWSs include non-transient non-community (NTNC) and transient non-community (TNC) systems. A NTNC PWS serves drinking water to a stable non-residential population of more than

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2) surrounding census blocks that have an overall density of at least 500 people per square mile (US Census Bureau 2009).

25 people; these systems are often schools and places of business (CDPH, 208). A TNC PWS serves areas such as campgrounds or restaurants that serve a changing population of 25 or more people, 60 or more days per year (CDPH, 2008). A state-small water system (SSWS) is not a PWS and pipes water to five to 14 connections, and does not regularly serve drinking water to more than an average of 25 people daily for at least 60 days of the year (CDPH, 2008). Systems with two to four service connections are referred to as local small systems. Systems with less than two (or less than five) connections are self-supplied households often referred to as domestic wells.

Water system regulations depend on water system type. PWSs and CWSs are state-regulated, SSWSs are county-regulated, and local small and household self-supplied systems are largely unregulated, unless a County ordinance requires well monitoring when well property is sold. Monterey County regulates their local small water systems and requires them to comply with Title 22 of the California Code of Regulations and the Monterey County Code (MCHD, 2011). PWSs and CWSs are regulated by the state and must adhere to the National Primary Drinking Water Regulations under the Safe Drinking Water Act.

Most counties are designated Local Primacy Agencies (LPAs) and are responsible for regulating community water systems with up to 199 connections. Tulare County, Kings County and Monterey County are all LPAs.[8] Fresno County relinquished LP authority in 2007. LPAs are also responsible for regulation or oversight of SSWSs (5-14 connections). County-regulated systems serving five to 14 connections are not explicitly covered by the Safe Drinking Water Act, but they may still be required to treat by a variety of other contractual or development permit terms,

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[8] CDPH: Provisions of Section 116330 of the California Health and Safety Code

local/county ordinances, or anti-pollution laws; however, monitoring or procedures to implement these requirements may not be in place. County-regulated water systems are subject to tort law if they fail to protect the water delivered to consumers.

3.2 Water Quality Threats

Once the water quality of an aquifer has been degraded, the aquifer may no longer be considered a drinking water source without treatment. Threats to groundwater quality can be point or nonpoint source pollution. Point sources are easier to identify than nonpoint sources because they originate from specific locations and are typically discharged from pipes. Nonpoint sources occur from pollutants over an area, such as irrigated runoff or infiltration from agriculture. Examples of point sources of contamination include leaking underground septic systems and discharge from wastewater treatment plants. Nonpoint contamination typically comes from agriculture, mining, dairies, feedlots, and urban stormwater. Contaminants enter aquifers directly from surface water, improperly built groundwater wells, and surface water infiltrating through the soil. The primary constituents of concern within California's groundwater are pesticides, nitrate, perchlorate, arsenic, volatile organic compounds (VOCs), microbial agents, and salts (DWR 2003). Contaminated groundwater can also affect the quality of surrounding surface water.

To protect the public from harmful constituents in groundwater and surface water, Congress passed the Safe Drinking Water Act (SDWA) of 1974 to require regular testing of drinking water supplies, set standards for contaminant concentrations, and schedule for development of new standards (EPA, 2011). The SDWA also requires the Office of Environmental Health Hazard Assessment (OEHHA, within Cal EPA) to adopt Public Health Goals (PHGs) (Ca EPA, 1997). PHGs represent the official level of a contaminant that can be consumed daily for a lifetime without imposing a health risk. The PHGs are based entirely on public health considerations and are used by the California Department of Public Health (CDPH) to establish state MCLs. PHGs are developed for chemical contaminants based on the best available toxicological data in the scientific literature.

The PHG for nitrate is 45 parts per million (ppm), which is equivalent to California's current drinking water standard (MCL) of 45 mg/L (as NO_3). Water systems that are currently non-compliant with the state MCL must distribute public notifications to all consumers of potential health risks from consumption of their water. California's drinking water regulations have also established an action level (AL) for nitrate, which is half of the MCL (22.5 mg/L as NO_3) and is also known as the notification level. If the AL is exceeded for contaminants listed in the CDPH drinking water standards, the water system must follow monitoring and reporting requirements specific to the contaminant. When the AL is exceeded for nitrate, systems must switch from annual monitoring and reporting to quarterly monitoring and reporting and they must include a health information notice in the consumer confidence report (CCR) discussing public health concerns from consumption of nitrate.[9] If a water system exceeds the AL the system must "notify the governing body of the local agency in which users of the drinking water reside" and it is recommended that the systems notify their customers about the occurrence and health concern of consumption of the contaminant.[10]

A summary of the state and federal agencies involved in protecting and improving California's drinking water quality appears in Table 1.

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[9] Title 22: California Regulations Related to Drinking Water:§64432.1 (a) and §64482 (b)
[10] Health and Safety Code §116455: Local Government Notification

Table 1. California's Drinking Water Quality Responsibilities*

Department	**Key Water Quality Responsibilities**
California Department of Public Health (CDPH)	▪ Enforces federal and state SDWAs ▪ Ensures the quality of the state's drinking water
California Department of Toxic Substances Control	▪ Ensures monitoring and remediation at toxic groundwater sites
California Office of Environmental Health Hazard Assessment	▪ Performs health-risk assessments related to setting drinking water standards
California Public Utilities Commission	▪ Ensures reliable service to regulated water utility customers
California State Water Resources Control Board (SWRCB) and California Regional Water Quality Control Boards	▪ Protects the quality of the state's surface water and groundwater

* From POLICY MATTERS: The Water We Drink: What is California Doing to Ensure its Safe Water is Safe?: A review of the state's drinking water program and how the water we drink is monitored for safety. By California Senate Office of Research (May, 2011).

3.3 Susceptible Water Users

Susceptible water users are those that could be potentially harmed or affected from consuming drinking water containing contaminants, or by costs related to such contamination. Susceptibility can be classified or defined in a variety of ways. Here, susceptibility is defined in the context of residential consumption of drinking water and the potential for that water to be above the nitrate MCL or AL (based on system type). The residential users examined in this thesis are connected to community, state-small, local small and self-supplied water systems. Previous studies refer to nitrate susceptible populations from a human health perspective, such as subpopulations with a history of immunostimulatory conditions or lacking nitrosation inhibitors in the colon (De Roos et al. 2003). In this study susceptibility is not defined by a health-based parameter. Balazs et al. (2011) suggested a susceptibility measure based on system water quality and the total number of raw water sources within a community water system. They categorized community water systems by considering three levels of source water quality: 1) low (< 22.5 mg NO_3/L), 2) medium (22.5 mg NO_3/L to 44.9 mg NO_3/L), or 3) high (≥ 45 mg NO_3/L) (Balazs et al., 2011). Balazs and others then estimated the total population potentially exposed based on the population served by these individual community water systems (according to CDPH's Permitting Inspection Compliance Monitoring and Enforcement Database (PICME)). For this report, a similar definition for susceptible water users is used.

Here, susceptibility is estimated by examining the water system type, the population served by each water system, and the recent raw source water and delivered source water quality (if available). Specifically this report defines "susceptible population" as the number of individuals who:

1) are served by a multiple source CWS that has reported at least one delivered water nitrate MCL exceedance in the past five years, or
2) are served by a single source CWS or SSWS that has reported at least one raw water nitrate AL exceedance in the past five years, or
3) are on domestic wells, local small, or state-small water systems (not in PICME) in an area (Thiessen polygon) where a raw source water AL exceedance has been detected (from 1989-2010), or
4) are served by a CWS or State-documented state-small water system (reported in PICME) lacking nitrate water quality data.

Additionally, the Annual Compliance Reports (ACRs) from CDPH were used to find systems in violation of the nitrate MCL from 2004 to 2008, to provide a true regulatory violator estimate of the susceptible population and for comparison with the exceedance susceptible population estimate.

To estimate the population susceptible to nitrate groundwater contamination in the study area the vulnerability is first estimated by delineating system type and that vulnerability is then confirmed by evaluating historical nitrate water quality data. In other words, the status of susceptibility is found from estimating and confirming the vulnerability of each water system in the study area.

Vulnerability describes the intrinsic potential for a system to inadvertently deliver water with high nitrate levels based on the type of system and the number of water sources within the system. First, the vulnerability is estimated:

- Lower vulnerability is assigned to community water systems (water systems with > 15 connections) that have more than one source of water (i.e., more than one well).
- Higher vulnerability is assigned to all other water systems (community water systems with one well, and state-small, local small, and household self-supplied water systems).
- No vulnerability (to groundwater contamination) is assigned to water systems that are solely supplied by surface water.

Next, the likelihood for a system to encounter adverse water quality conditions (with or without addressing these in the treatment process) is estimated to confirm the vulnerability and determine the susceptibility. The vulnerability is confirmed by examining the water quality history documented for that system, or, if that information is not available, the historical ambient groundwater quality in the vicinity of the source or system. After confirming the vulnerability of a system, the susceptibility is ranked as:

- Low susceptibility if there has been no recent exceedance of a nitrate threshold.

- High susceptibility if there has been at least one recent exceedance of a nitrate threshold.
- Unknown susceptibility, if a community water system has no water quality data available.

The highly susceptible population in this study is considered to be the population served by systems ranked as being of high or unknown susceptibility. The rest of the population is considered to be of low susceptibility to nitrate contamination in groundwater.

3.3.1 Methods

The methods used to estimate the total study area population, the population estimated to rely on domestic wells or local small water systems, and the total population susceptible to nitrate contamination is discussed in this section. Figure 3 illustrates how the degree of vulnerability and overall susceptibility for the study area population in year 2010 was assessed.

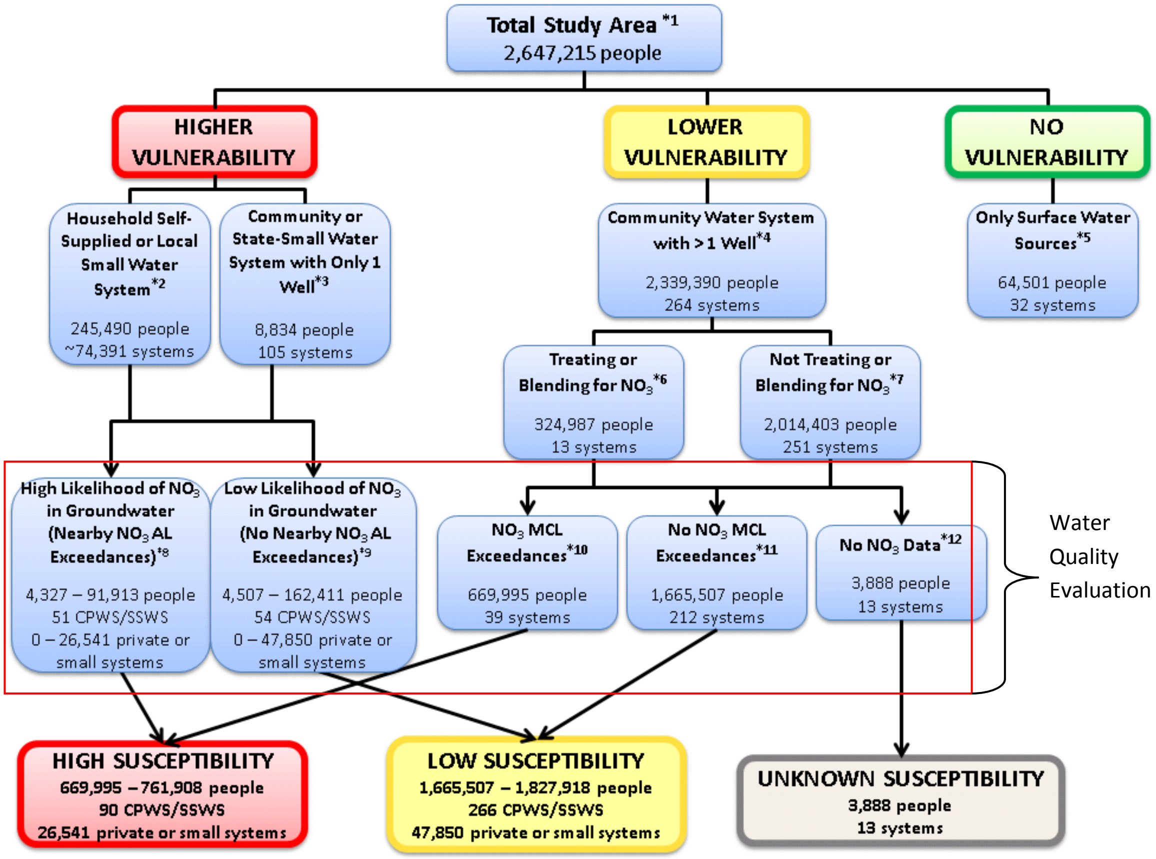

Figure 3. Characterization of Susceptible Populations Based on Estimated Vulnerability and Water Quality Data for the Study Area[11]

The methodology used for creating the susceptibility chart and chart footnotes are further discussed in the Appendix (Section 11.1.1).

The total population within the delineated Tulare Lake Basin and Salinas Valley was estimated using the 2010 Census, California Department of Finance 2010 population estimates, each county's Local Agency Formation Commission, and CDPH PICME data. Once the study area population was found, the PICME population numbers were summarized and recorded, and an analysis of the difference used to estimate the number of households supplied by domestic

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[11] Due to different sources of data, the summation of the top row does not exactly equal the total study area population. All population and connection information is approximate.

wells, and local small water systems. This estimation method is inherently imprecise as to absolute populations due to data limitations and inconsistencies, including data coverage (i.e., block groups versus county boundaries), population values listed in PICME that are rounded up and tend to exceed the actual population served, and systems within the study area boundaries that may serve households just outside. The domestic wells analysis estimated the number and location of domestic wells using land parcel use codes and the DWR land use class designations. The total number of dwelling units affiliated with each parcel was used to develop population estimates and the parcel locations used to estimate residential susceptibility. It was assumed that 3.3 people reside within in one dwelling unit, and parcels with 4 or fewer dwelling units (dus) were considered self-supplied (1-2 dus) or local small (3-4 dus) water systems. Residential parcels within city limits or water system boundaries were excluded from the count of self-supplied households.   The 1990 Census block group household self-supplied data (the number of households that are self-supplied) were compared to the parcel household self-supplied analysis on a county level, to verify the method used here (discussed further in Section 3.4.2.1).

3.3.1.1 Vulnerability

The estimated vulnerability of a system is rated based on the type of system. A household self-supplied, local or state-small water system (not already in PICME) has higher vulnerability since they lack multiple sources. A community water system with multiple sources has less vulnerability and a system using only surface water has no vulnerability to nitrate in groundwater. The CDPH Water Quality Management (WQM) and PICME database provided all community water system data and some state-small water system information to identify system type, locate sources, and determine nitrate levels in raw and distributed water for the vulnerability and susceptibility assessments. The domestic wells were located based on the method discussed above. Vulnerability is further discussed in Section 3.4.

The vulnerability of a system is confirmed based on the presence or likelihood of nitrate contamination in groundwater near the source well(s). For community water systems estimated as having lower vulnerability, the chosen nitrate threshold for confirming the vulnerability was the MCL because of frequent testing on community water systems. If the distributed (or delivered) water (found in the WQM database) for a system exceeded the nitrate MCL at least once from 2006 to 2010, the vulnerability of the system is confirmed to be lower and the system is classified as having high susceptibility. The systems recorded as distributing water less than the MCL are classified as having low susceptibility. The community or state-small water systems with no nitrate water quality data are labeled as having an unknown susceptibility, but is included in the total highly susceptible population estimate (further discussed in Section 3.6).

For higher vulnerable community water systems (systems with only one well), and for state-small, local small, and household self-supplied water systems the chosen nitrate threshold for confirming the vulnerability was the more conservative AL because data on delivered water quality are generally unavailable for these systems. The AL was chosen as the threshold for likelihood since CDPH has defined it as an advisory standard for state-regulated systems. For single source community or state-small water systems the WQM data were used to determine if the raw source water was greater than 22.5 mg/L (the AL), and therefore rated to be high susceptibility systems, or alternatively, were less than the AL and rated to be low susceptibility systems. For the local small and self-supplied household water systems without nitrate data, the highest nitrate level in the nearest well (from the UC Davis “CASTING” database) was used to estimate whether or not the source exceeded the AL.

All groundwater wells with nitrate water quality data within the study area were compiled into a comprehensive wells database (“CASTING”) that includes nitrate concentrations from 1989 to

2010.[12] Information from the CASTING database was used to evaluate the likelihood of a household self-supplied or local small water system being at risk of nitrate contamination. Each well within the database that was less than 300 feet[13] in depth was used to geographically seed the creation of a Thiessen polygon or proximal zone. Thiessen polygons represent areas where any location within the polygon is closer to its associated well than any other well.[14] Since the true raw source water quality in most of the domestic and local small wells is unknown, the nearest CASTING raw well water quality datum is used to estimate the susceptible population. The well of a self-supplied or local small system, based on the parcel location, is assumed to have a high likelihood of contamination if the centroid of the parcel is within a Thiessen polygon whose CASTING well nitrate water quality data has a maximum nitrate concentration value greater than the AL, and the system is given a high susceptibility rating. Alternatively, a self-supplied or local small water system well is assumed to have a low likelihood of contamination if it is within a Thiessen polygon with a CASTING groundwater nitrate concentrations less than or equal to 22.5 mg/L, and the system is given a low susceptibility rating. This method does not account for the direction of groundwater flow and the actual nitrate concentrations at the true well depth, but provides a reasonable estimate of the population of domestic well and local small water system consumers potentially at risk of drinking nitrate contaminated water on a geographic basis. The locations of state-small water systems not contained in PICME could not be identified, and thus the population served by these systems was not considered further.

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[12] UC Davis CASTING wells database SBX2 1Ca Nitrate Project: Technical Report 4: Groundwater Nitrate Occurrence in the Tulare Lake Basin and Salinas Valley (UCD, 2011)

[13] Assumed as the average depth for household self-supplied wells.

[14] ArcGIS Resource Center.

Other properties of these systems and sources are found in the PICME database. CDPH has assessed each active well in PICME at least once, identifying potential contamination activities in "protection zones" around the well, as well as vulnerability from well construction and subsurface geology, where known. The estimated and confirmed vulnerability and susceptibility will be further discussed in Sections 3.3.1, 3.4 and 3.5

Figure 4 and Figure 5 show the 2010 population susceptibility assessment for the Tulare Lake Basin and Salinas Valley, respectively.

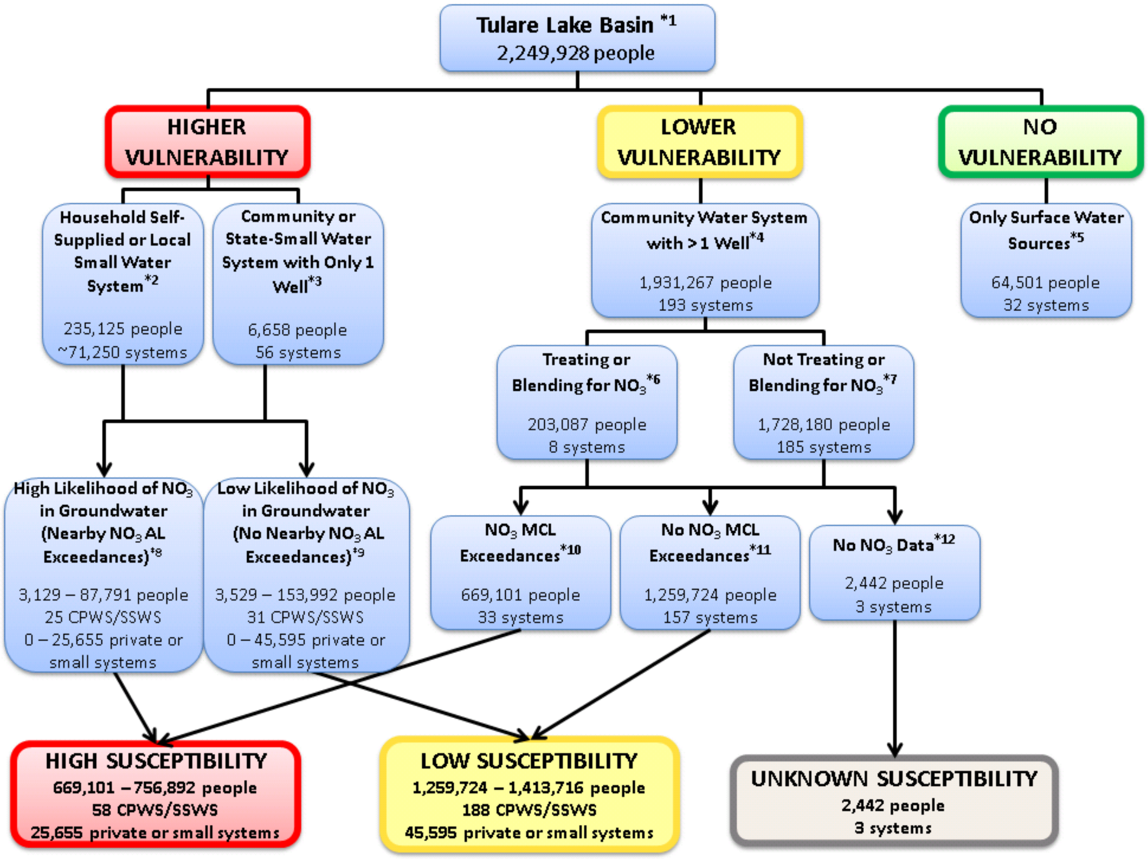

Figure 4. 2010 Population and Susceptibility Characterization for the Tulare Lake Basin Based on Estimated Vulnerability and Water Quality Data

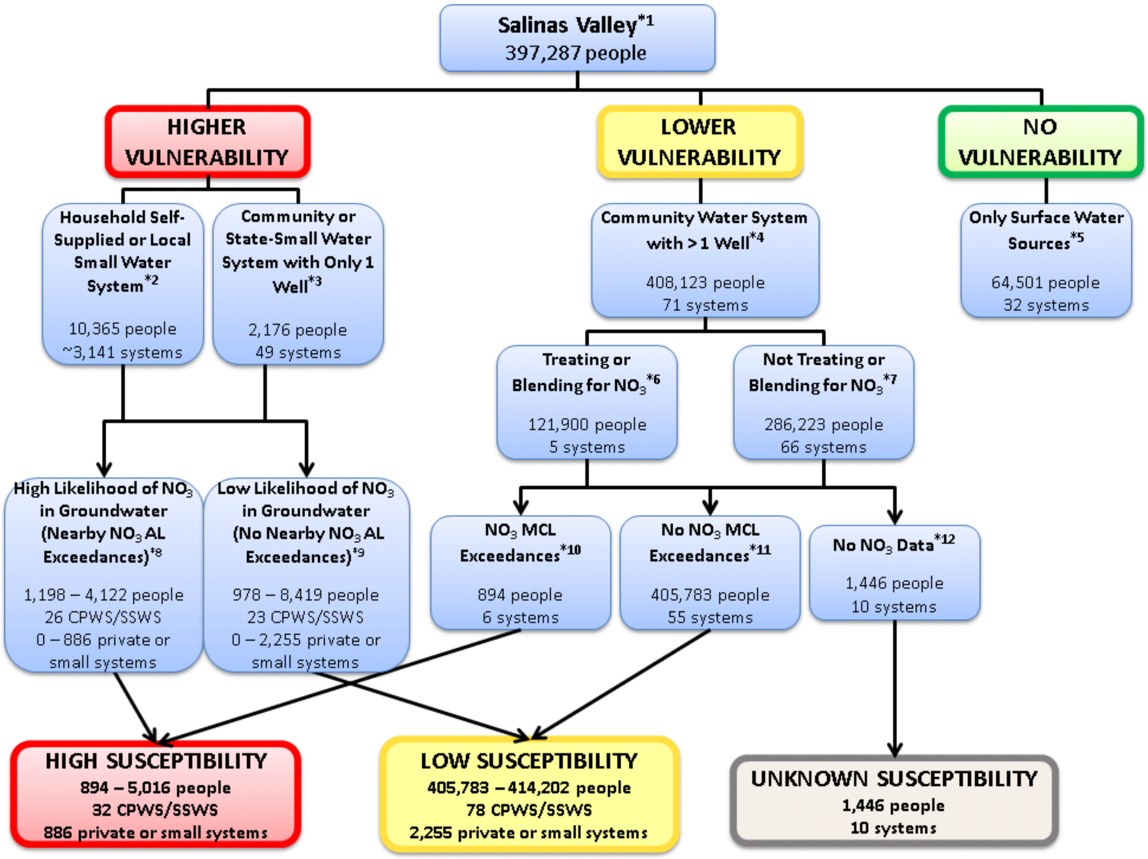

Figure 5. 2010 Population and Susceptibility Characterization for the Salinas Valley Based on Estimated Vulnerability and Water Quality Data[15]

3.4 Vulnerability of Water Users

Vulnerability of water users is based on a system's ability to protect against nitrate contamination. The vulnerability classification of population describes the potential for delivering high nitrate water to users and is a function of system type. All households are categorized into four residential drinking water supply systems: a household self-supplied system, a local small system, a state-small system, or a community water system.

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[15] Due to different sources of data, the summation of the top row does not exactly equal the total study area population. All population and connection information is approximate. See Methods section for detailed explanations.

In most counties, state-small systems receive little monitoring or regulatory attention, and are typically considerably more vulnerable to ambient pollution than are CWSs. Community water systems must adhere to the state MCLs for all drinking water contaminants, so households on these systems should have less vulnerability to nitrate contamination. However, community water systems having only one well have the potential to be more vulnerable since blending cannot be used as a relatively inexpensive solution.

Lower vulnerability exists for regulated CWSs that have more than one well and the opportunity to blend. Systems that rely completely on surface water have no vulnerability to delivering groundwater contaminated with nitrate, though they may be vulnerable to other pollutants.

While the study area population can be exposed to nitrate contamination if they consume drinking water from non-transient non-community or transient non-community public water systems, this report only addresses vulnerability from community water systems or water systems that directly serve residences. It is assumed that the non-community systems adequately warn their users if nitrate contamination is a concern; since users are not permanent, they are able to either avoid use or provide themselves with clean drinking water from another source. Approximately 382 non-transient, non-community water systems serve about 190,000 people in the study area. These 382 systems are non-residential and serve the same people for at least 6 months, such as schools and businesses. Approximately 318 transient non-community water systems serve about 150,000 people in the study area. These 318 systems are non-residential and serve a changing population for at least 60 days per year, such as restaurants, hotels, stores and campgrounds.

According to CDPH's drinking water system database, PICME, 401 active community and state-small water systems exist in the study area basins (281 in the Tulare Lake Basin and 120 in the Salinas Valley). These systems supply water to about 2.4 million people. The 371 CWSs are supplied by 3,829 sources and the 30 SSWSs supplied by 31 sources. Of the 3,860 sources overall, 3,682 are groundwater; the remaining 178 are surface water. The state-small water systems in PICME do no t account for all state-small water systems in the study area. The 30 systems were collected into PICME as part of AB 1403 and are further referred to as state-documented state-small water systems (CDPH, 2011).

Figure 6 breaks down the number of state-small and community water systems by their USEPA size categories[16], in PICME and the study area. According to PICME, the Tulare Lake Basin has 8 state-small and 219 community water systems serving very small and small systems (< 3,300 people). About 81% of Tulare Lake Basin water systems are very small or small and serve 89,125 people (4% of the Tulare Lake Basin population). The Salinas Valley has 22 state-small and 87 community water systems serving very small and small systems. About 89% of the Salinas Valley water systems are very small or small and serve 23,215 people (6% of the Salinas Valley population). Figure 7 and Figure 8 show the number of PICME state-small and community water systems treating or blending raw water within each USEPA size category in the Tulare Lake Basin and Salinas Valley.

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[16] USEPA system size definitions are: (1) very small serves 25-500 people; (2) small serves 501-3,300 people; (3) medium serves 3,301-10,000 people; (4) large serves 10,001-100,000 people; and very large serves greater than 100,000 people (USEPA 2010). Available at: http://water.epa.gov/infrastructure/drinkingwater/pws/factoids.cfm.
Very small in this graph includes some of the SSWSs so the population ranges from 15-500.

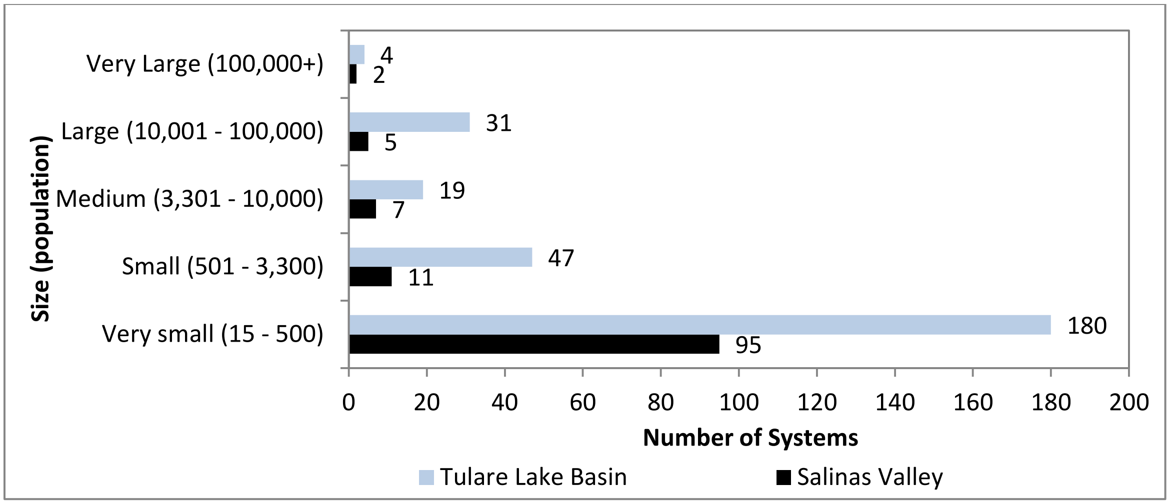

Figure 6. The Size Distribution (by Population Served) for All State-Small (State-documented) and Community Water Systems in the Study Area

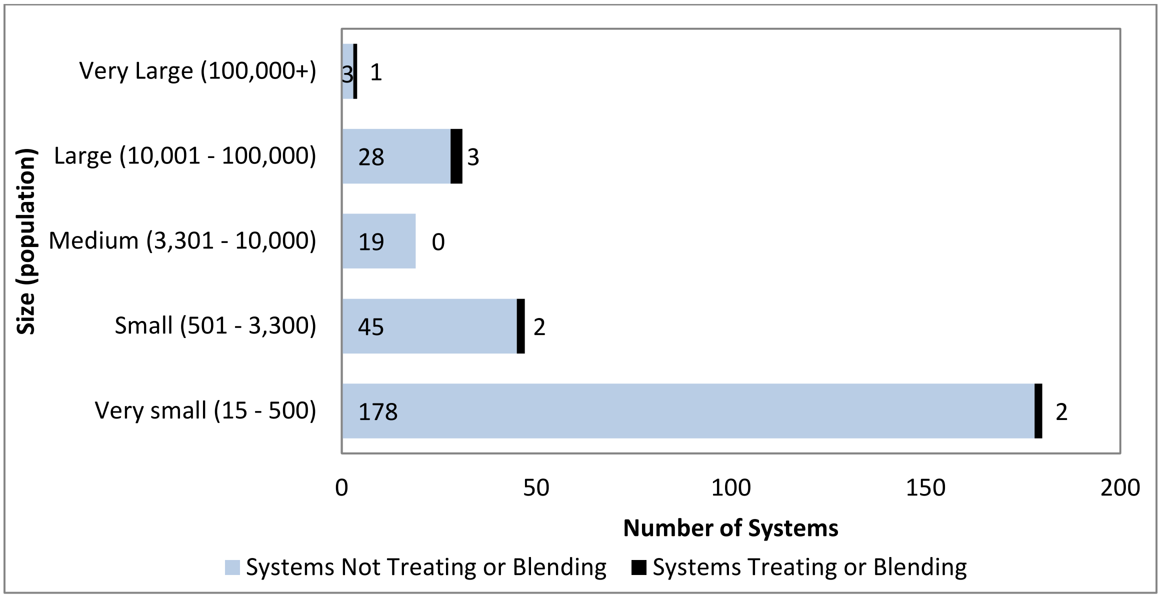

Figure 7. All State-Small (State-documented) and Community Water Systems Treating or Not Treating for Nitrate in the TLB

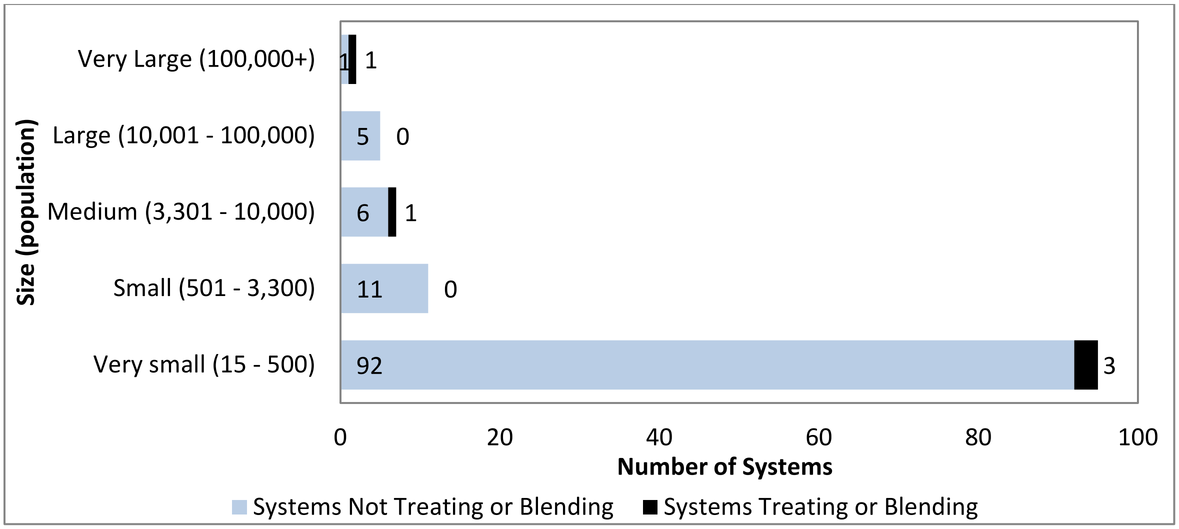

Figure 8. All State-Small (State-documented) and Community Water Systems Treating or Not Treating for Nitrate in the SV

3.4.1 Low Vulnerability

Theoretically, a CWS should not deliver water exceeding the nitrate MCL since they must adhere to the SDWA standards (see Section 3.5.1). Where possible, high-nitrate sources can be blended with low-nitrate sources to reduce delivered nitrate levels to a compliant level, although daily monitoring and operations may not always identify an exceedance. Because of the strict regulations and guidelines and the availability of alternate sources, CWSs with more than one well are considered lower vulnerability systems. This lower vulnerability population is quantified in Figure 4 and Figure 5 for the Tulare Lake Basin and Salinas Valley, respectively.

The lower vulnerability community water systems include both systems treating for nitrate and not treating for nitrate. Currently within the study area, only thirteen water systems treat for nitrate (eight in TLB and five in SV) and eight of these systems treat by blending with lower-nitrate sources (five in TLB and three in SV). Tables of these systems are presented below for the Tulare Lake Basin (Table 2) and the Salinas Valley (Table 3), and their size distribution is shown in Figure 7. These systems were identified from inventories of counties in the study area, CDPH, and responses to *The Survey of Nitrate Treatment Systems* (discussed in the SBX2 1 California Nitrate Project: *Water Treatment Report;* Jensen & Darby, 2011).

Table 2. Community Water Systems Treating for Nitrate in the Tulare Lake Basin

System Number	System Name	Treatment Type or Blending	Number of Sources	Connections	Population
1000359	Fresno County Service Area #32/Cantua Creek	Blending	4	81	230
1510006	East Niles CSD	Blending	29	7,406	25,500
1510013	City of McFarland	Ion Exchange	15	2,220	12,138
1510055	California Water Service – North Garden	Blending	36	7,035	26,860
5400935	California Water Service – Mullen Water Company	Ion Exchange	2	44	139
5410012	Strathmore PUD	Blending	8	471	1,904
5410016	California Water Service – Visalia	Ion Exchange	190	40,530	133,749
5410801	Porterville Development Center	Blending	10	89	2,567
	TULARE LAKE BASIN TOTAL		**294**	**57,876**	**203,087**

Table 3. Community Water Systems Treating for Nitrate in the Salinas Valley

System Number	System Name	Treatment Type or Blending	Number of Sources	Connections	Population
2700534	Colonial Oaks	Blending	5	66	198
2700656	Moro Cojo Mutual Water Agency	Blending	5	19	67
2701926	Moro #9	Blending	5	70	210
2710010	California Water Service – Salinas	Ion Exchange	126	25,451	114,840
2710851	Salinas Valley State Prison	Reverse Osmosis	8	2,069	6,585
SALINAS VALLEY TOTAL			**151**	**27,680**	**121,945**

Of the total 401 active systems, 264 have more than one source, serving 2.3 million people and have a lower vulnerability to nitrate contamination in groundwater. Of these, 193 systems are in the Tulare Lake Basin and serve 1.9 million people. The remaining 71 are in the Salinas Valley and serve 400,000 people. The susceptibility level of these lower vulnerability systems is discussed in Section 3.5.

3.4.2 High Vulnerability

Households not served by a state-regulated CWS, are considered highly vulnerable because county-regulated systems and individual household wells are usually neither monitored nor treated. If the groundwater source of these households experienced an increase in nitrate levels (above existing elevated levels), these households would not be protected from nitrate contamination. This highly vulnerable population is quantified in Figure 4 and Figure 5 for the Tulare Lake Basin and Salinas Valley, respectively. The highly vulnerable systems are classified as:

1. Household Self-Supplied or Local Small Water Systems (see Section 3.4.2.1)
2. Community Water Systems with only one well or State-Small Water Systems (see Section 3.4.2.2)

3.4.2.1 Household Self-Supplied or Local Small Water Systems

The 1990 Census spatial data was used with the 2010 Census spatial data, DWR land use class designation, and the land parcel use code information, to estimate the current 2010 population on household self-supplied systems. Any parcels within city limits or water system boundaries were excluded.

Unlike more recent census data, the 1990 Census asked a sample population about their water systems. These data were collected at the household level and summarized in Attribute H23 of the 1990 Census.[17] Census block groups (for which data are reported) tend to be of small area in urban regions, but relatively large in rural regions so land use parcel code data for was used

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[17] Per the 1990 Census definitions, a source that supplies water to five or more housing units is considered a “Public system or private company”. This includes any wells that supply water to five or more housing units. If the source serves four or fewer housing units, it is classified as: an “Individual drilled well”, an “Individual dug well”, or “Some other source”. The last distinction, “Some other source”, includes springs, creeks, rivers, lakes, cisterns, etc. (US Census Bureau, 1999).

instead for estimating self-supplied household and local small water system densities. Then a comparison of the 2010 self-supplied household estimates and the 1990 Census block group numbers is performed. The self-supplied and local small water system population found from parcel use codes and DWR land use designation is estimated in Table 4.

The estimated location of these household self-supplied and local small water systems is shown in Figure 9. The total number of domestic wells in the study area portion of Kern County is limited as its parcel use code zoning differs from other counties. In Kern County more parcels are zoned as having 100 plus dwelling units (i.e., apartment complexes and condominiums) than having single dwelling units. The underestimation of self-supplied households in Kern County might be balanced out by the overestimation of self-supplied households in Fresno County. Approximately 235,125 people are on self-supplied household or local small water systems in the Tulare Lake Basin and 10,365 in the Salinas Valley (Table 4).

This total population served by self-supplied household and local small water systems has a higher vulnerability to nitrate contamination in the groundwater. The US Census estimates 7.6% of residents lived in rural areas in California between 2006 and 2008.[18] Using the counties' rural area definition,[19] an estimated 13% of California residents lived in rural areas in 2009. The self-supplied and local small water system population estimate based on the parcel code and DWR land use data falls within these rural percentage estimates, accounting for 9.2% of the total

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[18] V. Manual Perez (Chair). Assembly Committee on Jobs, Economic Development and the Economy: *Fast Facts on California Rural Communities* (June 2010). Rural areas contain population densities of less than 500 people per square mile. US Census Bureau. "Census 2000 Urban and Rural Classification". http://www.census.gov.geo/www/ua/ua_2k.html. Accessed July 13, 2010.

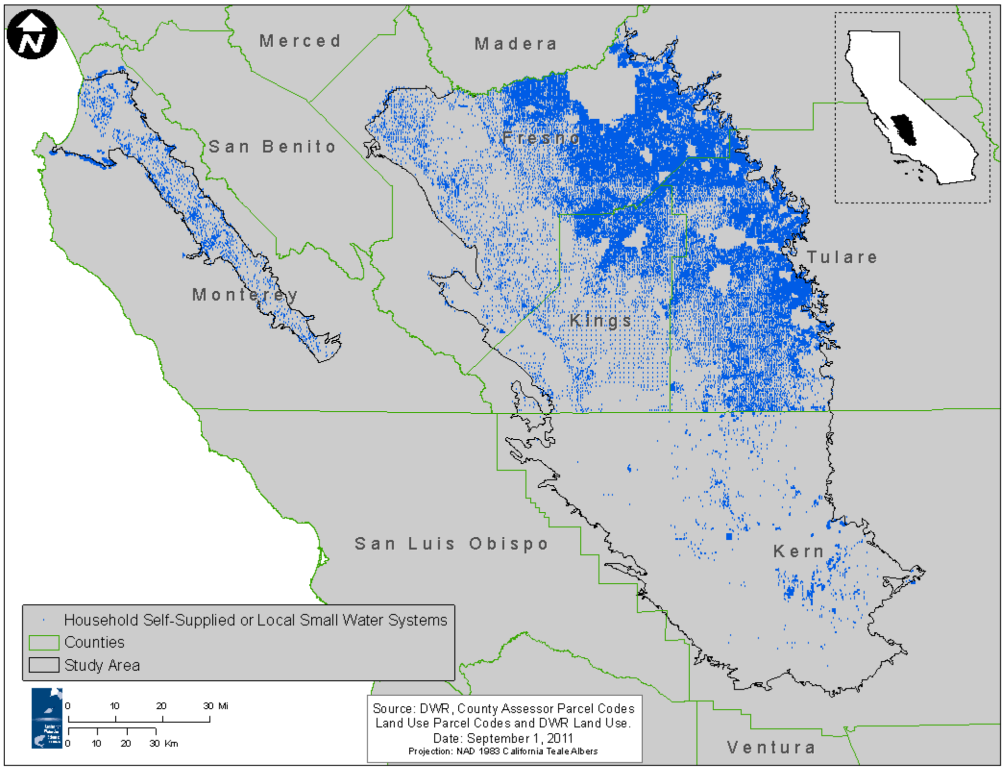
[19] Counties with 80% or greater rural land mass are generally considered rural.

study area population. The susceptibility for this population is examined in Sections 3.5.1.1 and 3.5.2.1.

Table 4. 2010 Estimated Self-Supplied and Local Small Water System Population within the Study Area Based on the Parcel Use Code and DWR Land Use Designation[1]

Basin	Domestic Wells	Population Served by Domestic Wells
Tulare Lake Basin	71,250	235,125
Salinas Valley	3,141	10,365
STUDY AREA TOTAL	**74,391**	**245,490**

[1] Domestic Wells = Household self-supplied and local small water systems. These are all well systems with fewer than four connections, classified as such, based on the number of residential dwelling units on a parcel and its location outside of water system and city boundaries.



Source: DWR, County Assessor Parcel Codes Land Use Parcel Codes and DWR Land Use.
Date: September 1, 2011
Projection: NAD 1983 California Teale Albers

Figure 9. Estimated Locations of Household Self-Supplied and Local Small Water Systems

Since the basin boundaries do not correspond with Census or County delineations there is no existing data to effectively compare the domestic well analysis on a basin level, so a comparison on a county level is performed. Table 5 shows the results from applying this land parcel use code method on a county-level, but only regards domestic wells or parcels zoned as having one dwelling unit, located outside of city and water system boundaries. For Fresno, Kings, Monterey and Tulare Counties, the 2010 estimated population is at most one and a half times greater than the 1990 Census block group population. Kern County's 2010 estimate is a little over four times greater than the 1990 Census, which can be attributed to the inclusion of vacant parcels or the lack of water system boundaries outside of the study area and into the outer parts of the county. Since parcel use codes are from the County assessors they are not a true count of people actually living on the parcel, but are zoning values for distinguishing the number of people that can live there.

Table 5. 1990 Census v. 2010 Estimated Domestic Well (Single Dwelling Unit) Population by County

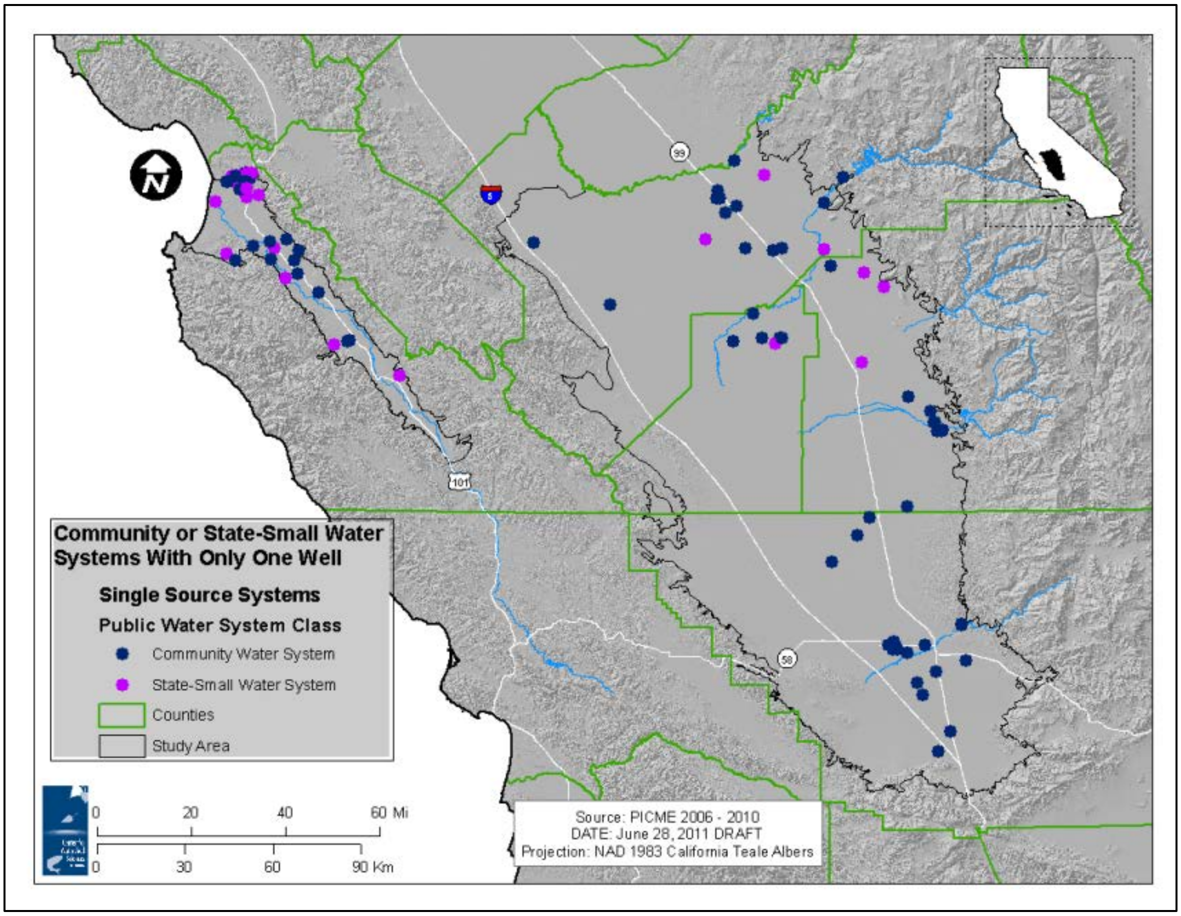
County	**1990 Census Block Group Population[1]**	**2010 Residential Code Population Estimate (Parcel Use Code)[2]**
Fresno	110,022	126,968
Kern	40,742	167,274
Kings	15,975	23,354
Monterey	34,528	37,927
Tulare	68,511	91,219

[1] The sum of the 1990 Census Category H0230002 (an "individual drilled well") and H0230003 (an "individual dug well") is the domestic well block group population.

[2] Residential parcels with 1 dwelling unit estimated from County parcel land use codes.

3.4.2.2 Community or State-Small Water Systems with Only One Well

There are 105 CWSs or SSWSs in the study area with only one well as a source of drinking water (Figure 10). These systems are highly vulnerable because they cannot blend with other clean water sources if their source becomes contaminated. The 56 and 49 single source systems in the Tulare Lake Basin and Salinas Valley serve 6,600 and 2,000 people, respectively. Of the 56 one-well systems in the Tulare Lake Basin, 49 are CWSs and 7 are SSWSs. Of the 49 one-well systems in the Salinas Valley, 27 are CWSs and 22 are SSWSs. Quantifying the susceptibility of these systems is discussed in Section 3.5.



Source: PICME 2006 - 2010
DATE: June 28, 2011 DRAFT
Projection: NAD 1983 California Teale Albers

Figure 10. Community or State-Small Water Systems with Only One Well

3.4.3 No Vulnerability

There are 32 community water systems in the study area that are recorded in PICME as only having surface water sources (Figure 11). These surface water sources are inherently much less vulnerable to nitrate contamination overall and have essentially no vulnerability to nitrate contamination in groundwater. The surface water source for most of these 32 systems is from the Friant Kern Canal and the Coastal Branch of the California Aqueduct. All 32 surface water systems are in the Tulare Lake Basin.

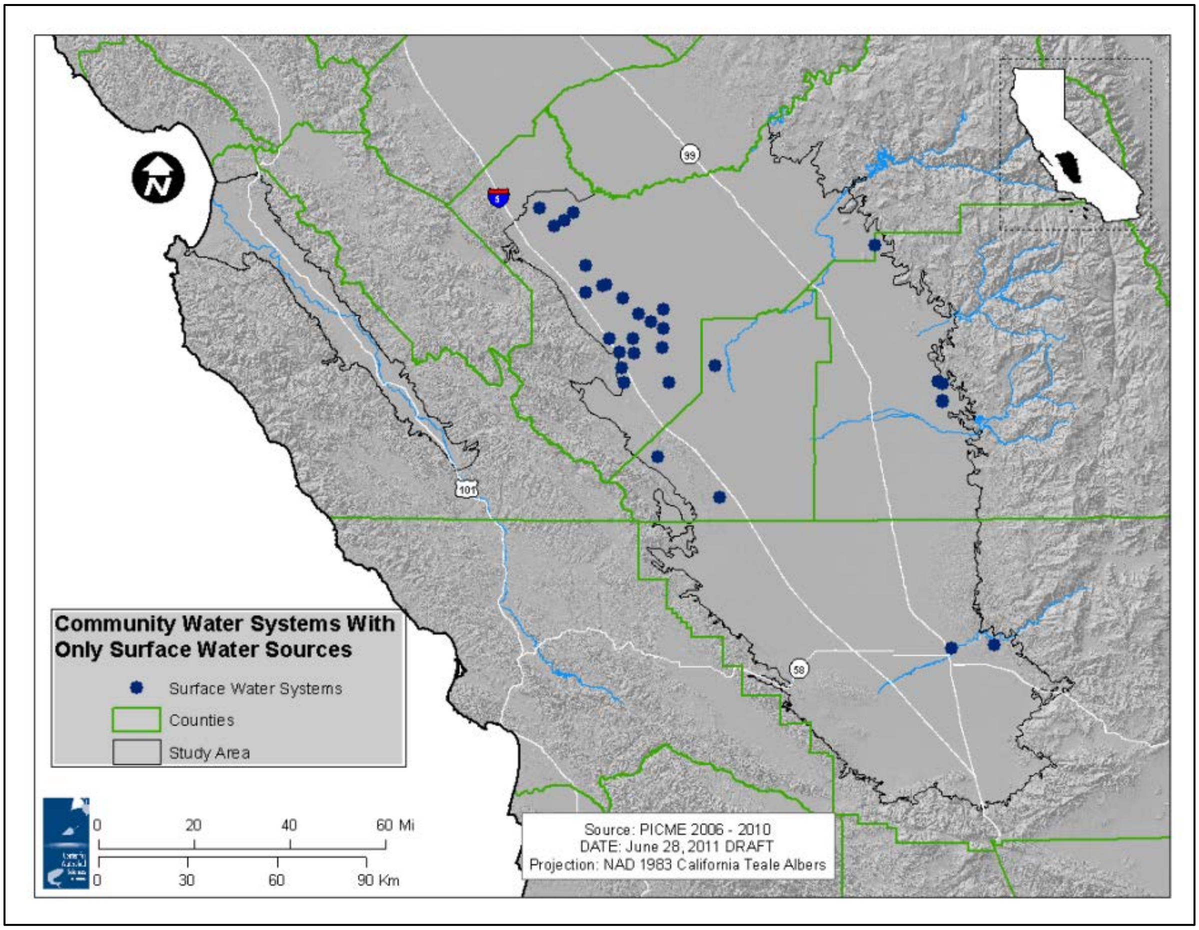


Figure 11. Community Water Systems with Only Surface Water Sources

3.5 Level of Susceptibility to Drinking Water Users

The level of susceptibility to drinking water users is found from confirming the vulnerability using the probability or likelihood that each type of system will deliver nitrate contaminated water to its users (evaluating the water quality data). The level of susceptibility is based on the spatial and historical incidence of nitrate in delivered or raw water.

Figures 3-5 summarize the susceptibility classification within the study area.

3.5.1 High Susceptibility Water Systems

Household self-supplied, local small, state-small and community water systems that have recently exceeded one of two nitrate thresholds at least once are defined as high susceptibility systems. As previously mentioned, the nitrate threshold used to classify susceptibility varies by system type, depending on its availability of delivered water quality data. High susceptibility systems are as follows:

1. Household self-supplied or local small water systems in sub-areas characterized in the CASTINGS database as having a nitrate concentration exceeding the nitrate AL in shallow (<300 feet) groundwater (see Section 3.5.1.1)
2. Community and state-small water system with only one well and that have PICME WQM records of at least one raw source water nitrate AL exceedance since 2006 or lack water quality data (see Section 3.5.1.2)
3. Community Water Systems with more than one well and have PICME WQM records of at least one delivered water nitrate MCL exceedance since 2006 (see Section 3.5.1.3)
4. Community Water Systems violating the nitrate MCL at least once from 2004 to 2008 (as a comparison to Community Water Systems with a single well or with more than one well exceeding the MCL – see Section 3.5.1.4)

3.5.1.1 Household Self-Supplied or Local Small Water Systems with a High Likelihood of Nitrate Groundwater Contamination

Figure 12 shows the maximum raw source water nitrate concentration from 1989 to 2010 in wells less than 300 feet deep. Household self-supplied or local small water systems with a high likelihood of current nitrate groundwater contamination are systems within a Thiessen polygon with raw water nitrate concentrations exceeding the action level (22.5 mg/L as NO_3). Figure 13 shows all estimated household self-supplied and local small water systems within low vulnerability Thiessen polygons.

Table 6 provides the population estimated to be served by a high susceptibility system relative to the total basin domestic well population. Approximately 88,000 people are served by high susceptibility self-supplied or local small water systems.

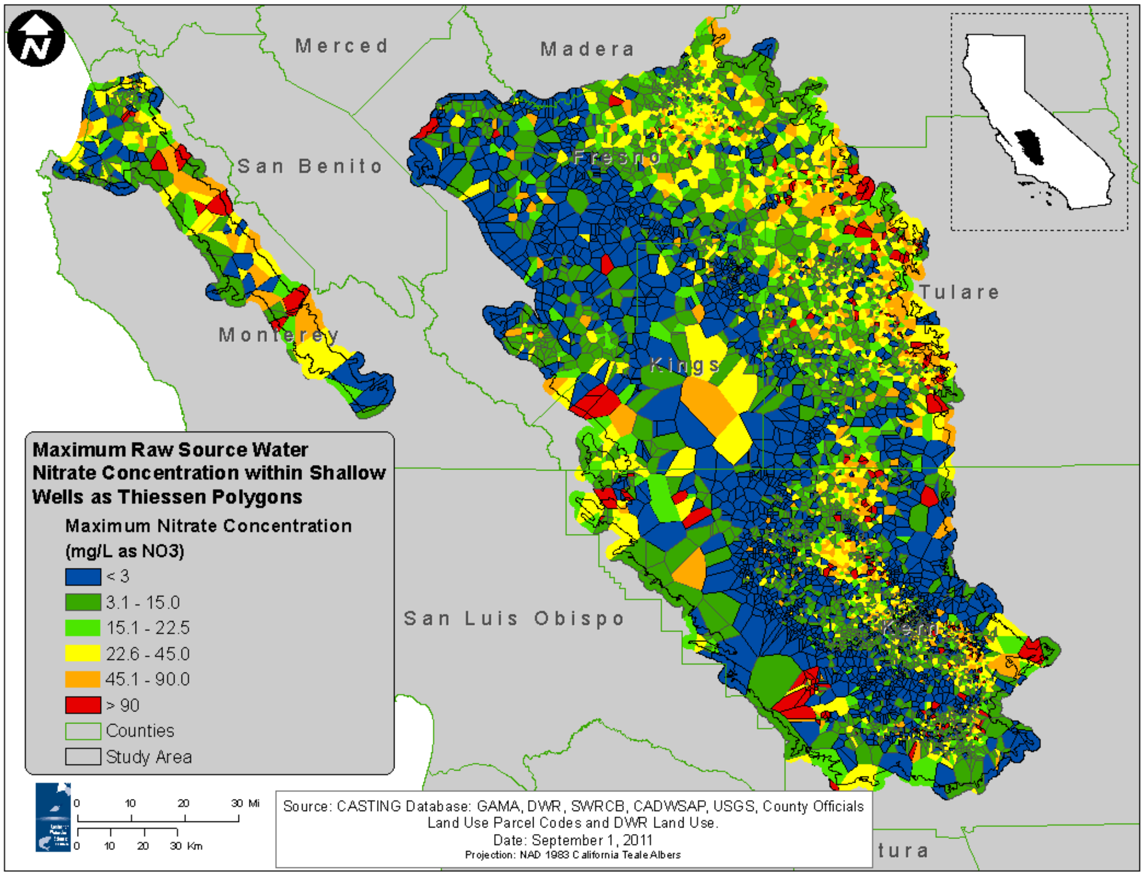
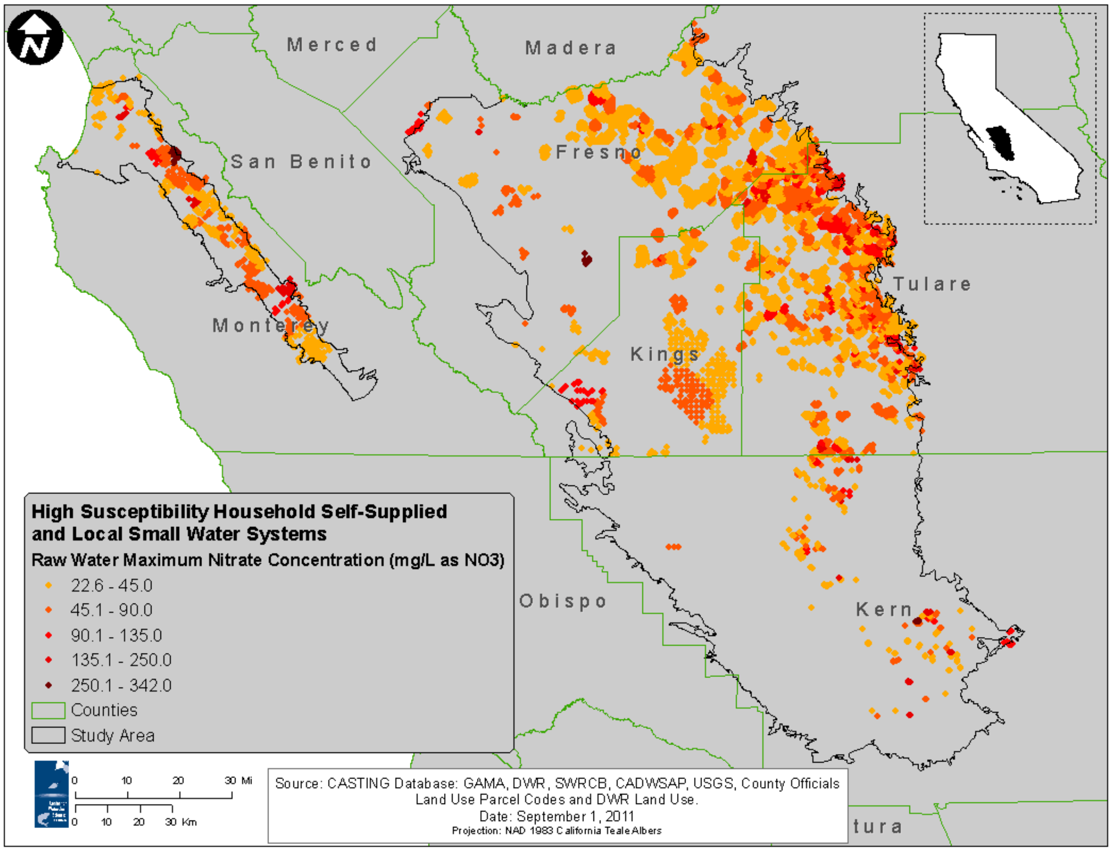


Figure 12. Maximum Raw Source Water Nitrate Concentration within Shallow Wells (≤ 300') as Thiessen Polygons (CASTING: 1989-2010)



Source: CASTING Database: GAMA, DWR, SWRCB, CADWSAP, USGS, County Officials
Land Use Parcel Codes and DWR Land Use.
Date: September 1, 2011
Projection: NAD 1983 California Teale Albers

Figure 13. Household Self-Supplied and Local Small Water Systems Thiessen Polygons Showing Maximum Nitrate Concentration Greater than the AL (CASTING: 1989-2010)

Table 6. 2010 Estimated Self-Supplied Household and Local Small Water System Population Served by High Susceptibility Water Systems

Basin	**Domestic Well Population**[1]	**Population Served by High Susceptibility Water Systems**[2]	**% of Domestic Well Population**
Tulare Lake Basin	235,125	84,662	36%
Salinas Valley	10,365	2,924	28%
STUDY AREA TOTAL	**245,490**	**87,586**	--

[1] Domestic Wells = Household self-supplied and local small water systems estimated from the DWR and parcel use code evaluation. These are all well systems with fewer than five connections, classified as residential dwelling units and located outside of water system and city boundaries.

[2] Low vulnerability population are served by systems with a high likelihood of nitrate contamination, these systems are within a Thiessen polygon that has a maximum raw water nitrate concentration greater than 22.5 mg/L (as NO_3).

3.5.1.2 Community and State-Small Water Systems with Only One Source and Recorded Raw Water NO3 AL Exceedances or No Water Quality Data

The active community and state-small water systems in PICME that have only one source and either:

1) have PICME WQM raw source water data that exceeded the AL for nitrate since 2006, or
2) are lacking water quality data

are considered to have a high likelihood of nitrate in groundwater and are defined as high susceptibility water systems. Of 105 single source systems in the study area, 51 have a high likelihood of nitrate in groundwater. Using these single-source-AL-exceedance systems the population is quantified in Table 7. If applicable, the highest recorded nitrate measurement per system was used to create conservative estimates. The 4,300 people served by these 51 systems are included in the high susceptibility estimate.

Table 7. Single Source Systems with a High Likelihood of Nitrate in Groundwater

Basin	**High Susceptibility Single Source CWSs[1]**	**Population[2]**
Tulare Lake Basin	25	3,129
Salinas Valley	26	1,198
STUDY AREA TOTAL	**51**	**4,327**

[1] Low vulnerability within single source CWSs are any systems with no nitrate concentration data or systems with raw source water exceeding the action level for nitrate from 2006 to 2010 (WQM, 2010).
[2] The population served by these systems (PICME, 2010).

3.5.1.3 Community Water Systems with Recorded Delivered Water NO3 MCL Exceedances

Nitrate measurements from PICME for all community and state-small water system sources in the study area were mapped. These measurements were taken between January 1st, 2006 and July 13th, 2010. Figure 14 shows a map of WQM raw nitrate data from all sources in the study area.

To estimate the high susceptibility population from low vulnerability systems (or confirm that the systems are low vulnerability), all active and pending CWSs and SSWSs (with multiple sources) within CDPH's WQM database were evaluated to determine delivered water nitrate levels. Approximately 15% of the 264 Active/Pending and Community/State-Small Water Systems (with multiple sources) in the study area delivered water that exceeded the nitrate MCL at least once from January 1st, 2006 to July 15th, 2010 (see Figure 15). This includes 39 systems serving 670,000 people (35% of the entire population being served by CWS/SSWSs) and suggests potential consumption of water with nitrate levels exceeding the public health standards. Figure 14 shows the locations of these exceeding systems.

Of these 39 systems, three currently blend and one treats with ion exchange (according to the Survey of Nitrate Treatment System responses within the study area). According to PICME, four other systems are treating, but the type of treatment or reason for treating is not disclosed (i.e., they may be under LPA jurisdiction).

Figure 16 shows the system size breakdown (based on established EPA size categories) for the same systems shown in Figure 15 that delivered water above the nitrate MCL. About 80% of the systems (serving a total of 13,800 people) exceeding the MCL are very small and small systems (serve less than 3,300 people). These smaller systems find it difficult to comply with the drinking water standards because they lack economies of scale of larger treatment systems and they have a small rate payer base to fund capital expenses (discussed further in Section 4.2.4).

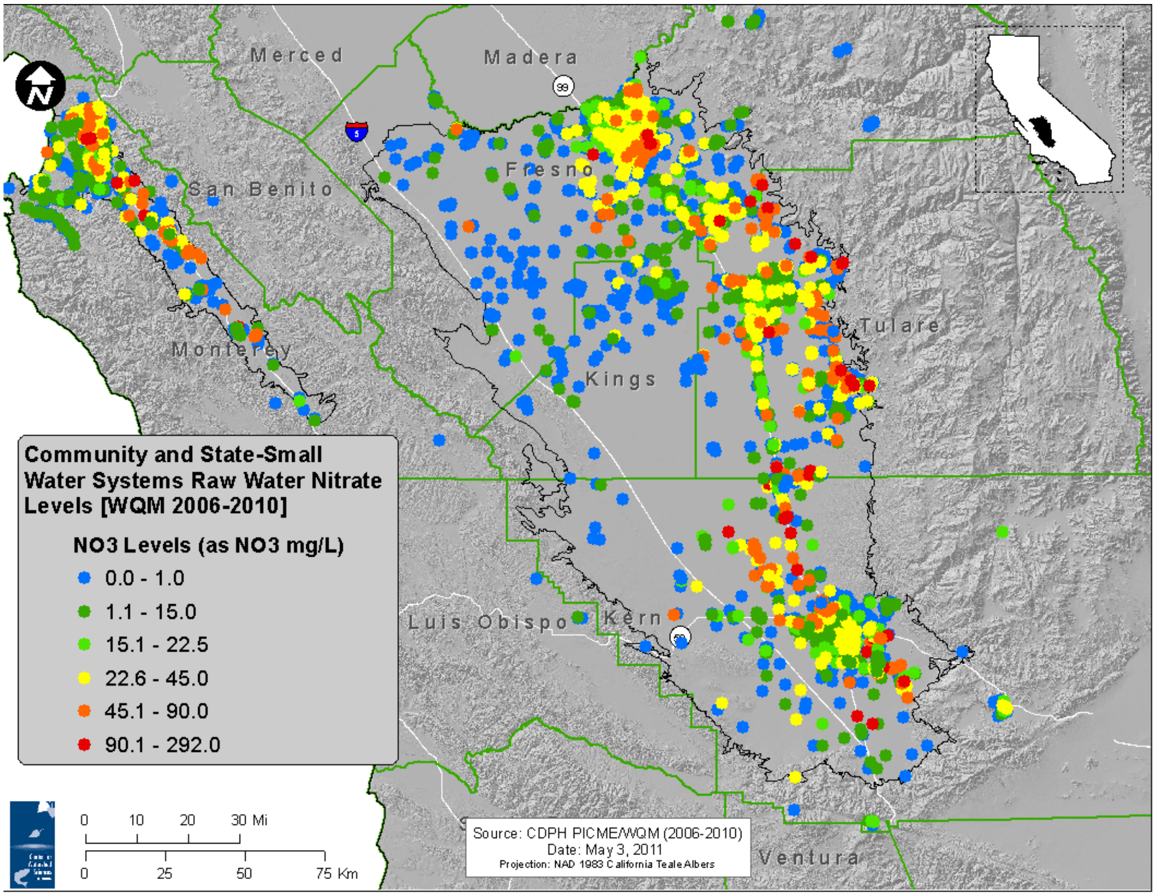


Figure 14. Maximum Raw-level Nitrate Records in Community and State-Small Water Systems Since 2006

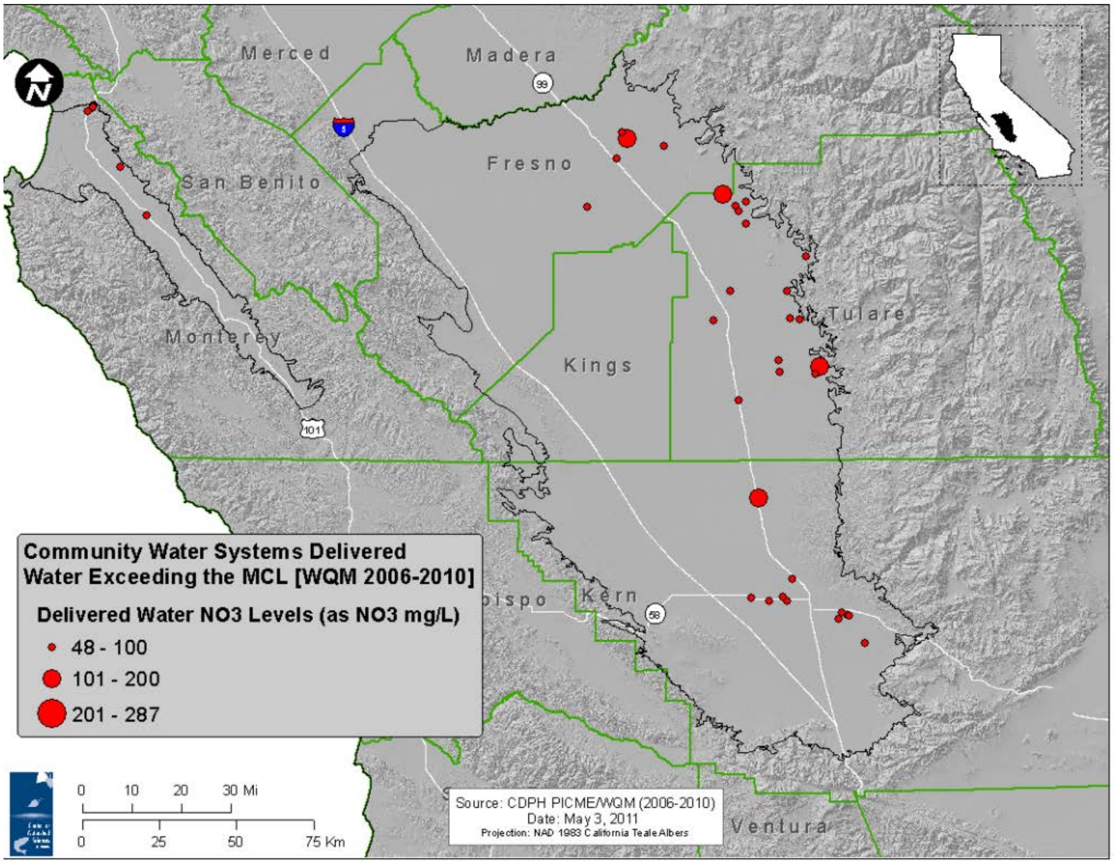


Figure 15. Community Water Systems with Delivered Water Exceeding the MCL at Least Once (2006-2010) (The highest recorded NO3 measurement per system is shown.)

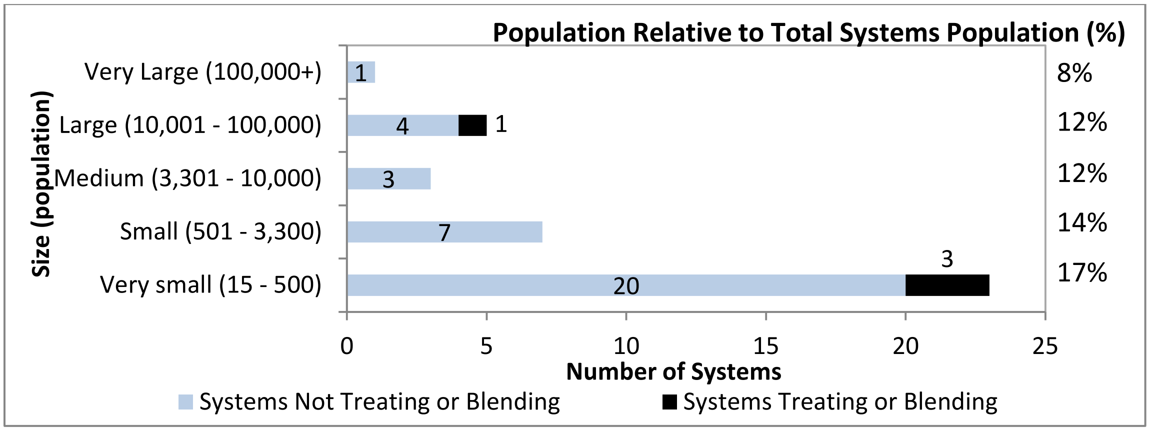


Figure 16. System Size Distribution (by Population Served) of the State-Small or Community Water Systems Exceeding the MCL [CDPH 2006-2010]

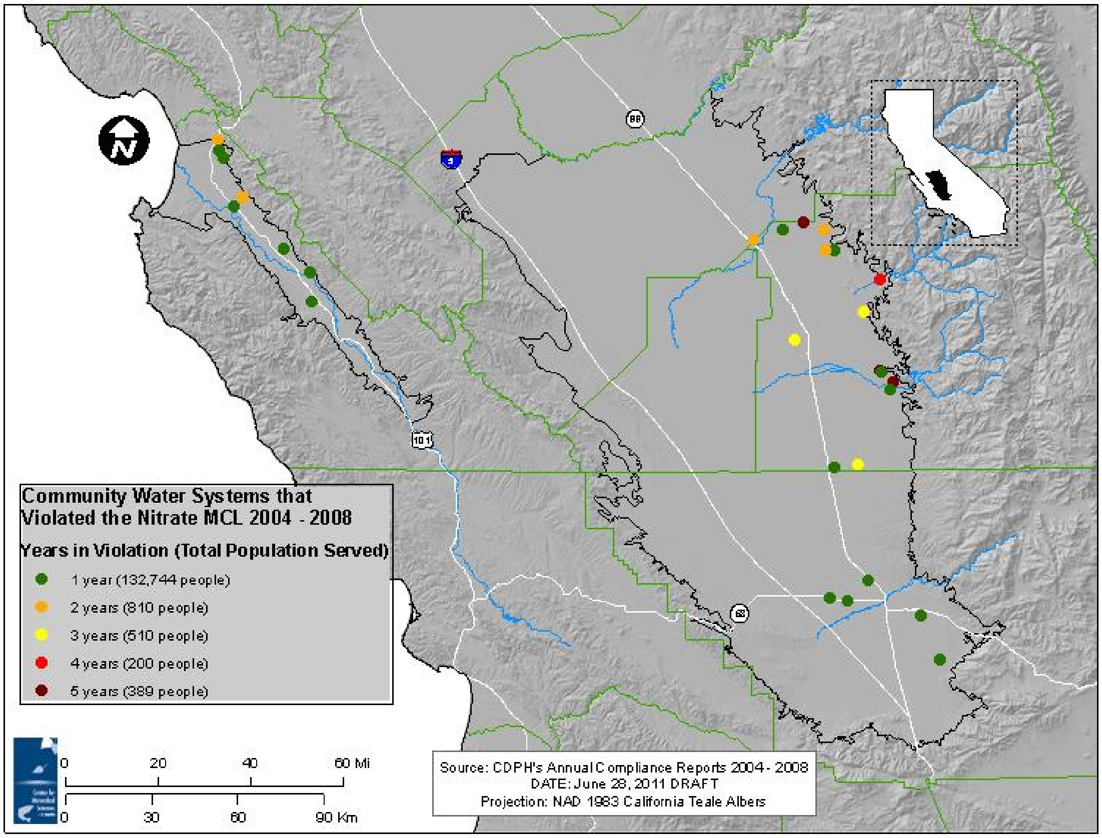
3.5.1.4 High Susceptibility Water Systems Evaluated as Violations (versus Exceedances)

An alternative to evaluating high susceptibility as system exceedances is to evaluate high susceptibility based on system violations (per CDPH regulatory language). Systems can sometimes err in reporting contaminant concentrations, and CDPH requires a second lab sample when an MCL is exceeded to verify the accuracy of the original sample. This comparison can only be performed for community water systems that must submit annual compliance reports (ACRs) to CDPH. The CDPH ACRs were used to identify the CWSs violating the nitrate MCL. A violation of the nitrate MCL is when the MCL is exceeded in two consecutive exceedance reports (CDPH, 2011). When the MCL for nitrate is exceeded once, a secondary, follow-up source sample is required and must be analyzed by an approved CDPH laboratory within 24-hours of notification of the first result. The two results are averaged and if the average exceeds the MCL or if the system fails to collect a confirmation sample, the system is in violation of the nitrate MCL and must contact their regulating agency (the CDPH field office or the local primacy agency) by phone or in writing within 24 hours (CDPH, 2011). The regulating agency then consults with the system to determine the best solution for protecting public health, and the long-term feasibility of complying with the MCL. The regulating agency also helps the system set up a monitoring and reporting schedule to proceed with for as long as the agency deems necessary. Since the violation of nitrate is a Tier 1 violation, systems must notify customers of the violation within 24 hours and continue communication until the regulator says not to.

For comparison, it was desired to obtain annual compliance reports for all systems in the Tulare Lake Basin and Salinas Valley from 2006 to 2010, however, 2008 is the last year that is publicly accessible. To be consistent, a five year span evaluation based on ACRs from 2004 to 2008 was used to quantify the number of community water systems violating the MCL. Twenty six community water systems (Table 8) violated the nitrate MCL within the Tulare Lake Basin and Salinas Valley, five in Kern, eight in Monterey, thirteen in Tulare, and zero in Kings and Fresno counties. The total population served by violating systems is about 130,000 (Table 8) and is about 640,000 people less than the total population served by multiple source community water exceedance systems (mentioned in the community water system exceedance discussion in the previous section, Section 3.5.1.3). This population difference is from the difference in evaluating systems based on an exceedance versus violation. For a system to violate the nitrate MCL, the average of two consecutive samples must be greater than the MCL. For a system to exceed the nitrate MCL, only one sample must be greater than the MCL. CDPH has established the violation definition to avoid any discrepancy in monitoring or reporting at the system or lab level. A conservative approach is taken here when observing the susceptibility based on exceedances rather than violations. The community water systems in violation of the nitrate MCL are shown in Figure 17, highlighting the total years in violation between 2004 and 2008.

Table 8. Community Water Systems in Violation of the Nitrate MCL (2004-2008)

County	System Number	System Name	Years in Violation	Population
Kern	1500373	SEVENTH STANDARD MUTUAL	1	110
	1500494	WILSON ROAD WATER COMMUNITY	1	72
	1500544	ENOS LANE PUBLIC UTILITY DISTRICT	1	250
	1500584	GOOSELAKE WATER COMPANY	1	80
	1510001	ARVIN COMMUNITY SERVICES DIST	1	14,500
			KERN TOTAL POPULATION	**15,012**
Monterey	2700665	OAK HEIGHTS W & R CO INC	2	105
	2701036	APPLE AVE WS #03	1	60
	2701904	SAN JERARDO COOP WS	2	249
	2702409	EL CAMINO WC INC	1	90
	2702439	WOODLAND HEIGHTS MWC	1	57
	2702466	SAN VICENTE MWC	1	90
	2710010	CWSC SALINAS	1	111,135
	2710851	SALINAS VALLEY STATE PRISON	1	5,400
			MONTEREY TOTAL POPULATION	**117,186**
Tulare	5400523	EL MONTE VILLAGE M H P	1	100
	5400550	SEVILLE WATER CO	1	400
	5400567	TOOLEVILLE WATER COMPANY	3	300
	5400616	LEMON COVE WATER CO	4	200
	5400651	BEVERLY GRAND MUTUAL WATER	5	108
	5400663	FAIRWAYS TRACT MUTUAL	5	250
	5400666	WATERTEK - GRANDVIEW GARDENS	1	350
	5400735	RODRIGUEZ LABOR CAMP	3	110
	5400805	SOULTS MUTUAL WATER CO	3	100
	5401003	EAST OROSI CSD	2	106
	5401038	AKIN WATER CO	1	50
	5402047	GLEANINGS FOR THE HUNGRY	5	31
	5403043	YETTEM WATER SYSTEM	2	350
			TULARE TOTAL POPULATION	**2,455**
			STUDY AREA POPULATION VIOLATING THE NITRATE MCL (2004-2008)	**134,653**



Source: CDPH's Annual Compliance Reports 2004 - 2008
DATE: June 28, 2011 DRAFT
Projection: NAD 1983 California Teale Albers

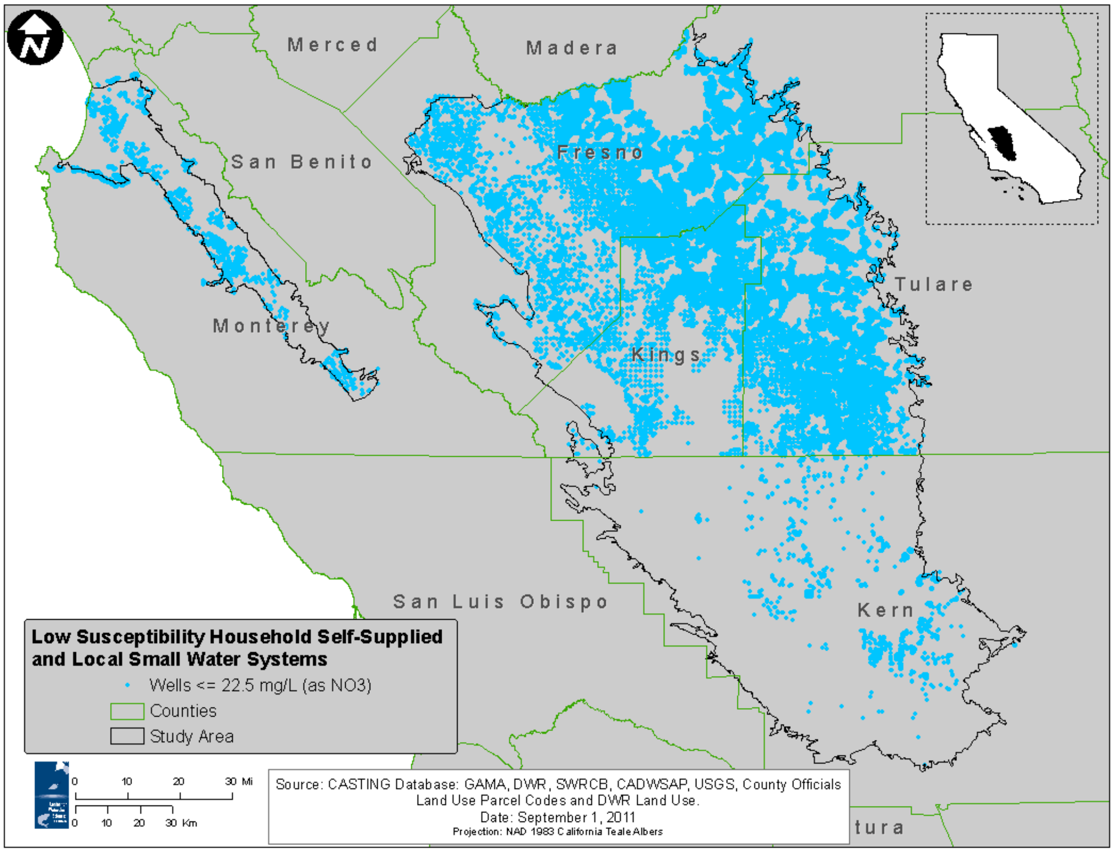
Figure 17. Community Water Systems in the Study Area in Violation of the Nitrate MCL 2004 to 2008

3.5.2 Low Susceptibility Water Systems

Low susceptibility water users (Figure 3) are on systems estimated to have a higher vulnerability with a low likelihood of nitrate contamination in the groundwater, or on systems estimated to have a lower vulnerability (CWSs with more than one well) with no recorded nitrate MCL exceedances since 2006. These low susceptibility water systems serve an estimated 1.31 to 1.47 million people in the study area, suggesting this population is not currently susceptible to consumption of nitrate-contaminated drinking water within their residences.

3.5.2.1 Household Self-Supplied or Local Small Water Systems with a Low Likelihood of Nitrate Groundwater Contamination

Household self-supplied or local small water systems are assumed to have a low likelihood of current nitrate groundwater contamination when they fall within a Thiessen polygon that has raw water nitrate concentrations less than or equal to the AL (22.5 mg/L as NO_3). Figure 18 shows all estimated household self-supplied and local small water systems within low-nitrate Thiessen polygons. Table 9 provides population estimates for persons supplied by low susceptibility systems relative to the total basin domestic well population. The estimated 158,000 people served by self-supplied household and local small water systems are included in the low susceptibility population estimate. This does not necessarily imply that these systems are all of low susceptibility.



Source: CASTING Database: GAMA, DWR, SWRCB, CADWSAP, USGS, County Officials Land Use Parcel Codes and DWR Land Use.
Date: September 1, 2011
Projection: NAD 1983 California Teale Albers

Figure 18. Household Self-Supplied and Local Small Water System Wells within a Thiessen Polygon of a Tested Well with Max Nitrate Concentration Less Than the Action Level (CASTING: 1989-2010)

Table 9. 2010 Estimated Population Served by Low Susceptibility Self-Supplied Household and Local Small Water Systems

Basin	Domestic Well Population[1]	Population Served by the Low Susceptibility Water Systems[2]	% of Domestic Well Population
Tulare Lake Basin	235,125	150,463	64%
Salinas Valley	10,365	7,441	72%
STUDY AREA TOTAL	**245,490**	**157,904**	**--**

[1] Domestic Wells = Household self-supplied and local small water systems. These are all well systems with fewer than four connections, classified as residential dwelling units and located outside of water system and city boundaries.

[2] The population served by low susceptibility water systems. These systems have a low likelihood of nitrate contamination, these systems are within a Thiessen polygon that has a maximum raw water nitrate concentration less than or equal to 22.5 mg/L (as NO_3).

3.5.2.2 Community or State-Small Water Systems with Only One Source and No Recorded Raw Water NO3 AL Exceedances

The active community and state-small water systems in PICME that have only one source and have not exceeded the AL for nitrate since 2006 are considered to have a low likelihood of nitrate in the groundwater and are defined as low susceptibility systems. These systems are measured against the nitrate AL since the delivered water quality could not be estimated in PICME. Of the 105 single source systems, 54 have a low likelihood of nitrate in groundwater. The population of these single-source-non-AL-exceedance systems is given in Table 10. The highest recorded nitrate measurement per system was used to create conservative estimates. The 4,500 people served by these 54 systems are included in the low susceptibility estimate.

Table 10. Single Source Systems with a Low Likelihood of Nitrate in Groundwater

Basin	Low Susceptibility Single Source CWSs[1]	Population[2]
Tulare Lake Basin	31	3,529
Salinas Valley	23	978
STUDY AREA TOTAL	**54**	**4,507**

[1] Single source community water systems that have a low susceptibility are single source systems with maximum source (raw water) nitrate concentrations that are less than 22.5 mg/L (as NO_3) (WQM, 2010).

[2] The population served by these systems (PICME, 2010).

3.5.2.3 Community Water Systems without Recorded NO3 MCL Exceedances

There are 212 multiple source CWSs in the study areas with recorded PICME nitrate data having no nitrate MCL exceedances from 2006 to 2010. The population of these multiple-source-non-

MCL-exceedance systems is given in Table 11. The 1.7 million people served by these 212 systems are included in the low susceptibility estimate.

Table 11. Community Water Systems with a Low Likelihood of Nitrate in Groundwater

Basin	**Low Susceptibility Multiple Source CWSs[1]**	**Population[2]**
Tulare Lake Basin	157	1,259,724
Salinas Valley	55	405,783
STUDY AREA TOTAL	**212**	**1,665,507**

[1] Community water systems with more than one source that are low susceptibility have maximum delivered nitrate concentrations less than or equal to 45 mg/L (as NO_3) (WQM, 2010).

[2] The population served by these systems (PICME, 2010).

3.5.3 Unknown Susceptibility Water Users

The WQM dataset is incomplete for 13 multiple source community water systems that are included in PICME (serving 3,900 people) and are lacking nitrate measurement data. There are 3 and 10 systems in the Tulare Lake Basin and Salinas Valley, serving about 2,450 and 1,450 people, respectively. These systems have an unknown susceptibility level, but are assumed to be highly susceptible to nitrate in groundwater contamination, and will be included in the higher susceptibility water users total in the following section. This report assumes the lack of nitrate data is from the absence of monitoring and reporting, however, the data could be in the process of being incorporated into WQM. Figure 19 shows the distribution of system sizes for the multiple source water systems with no nitrate measurement data. Eleven of these community water systems are county-regulated and may have nitrate data within their respective County health departments.

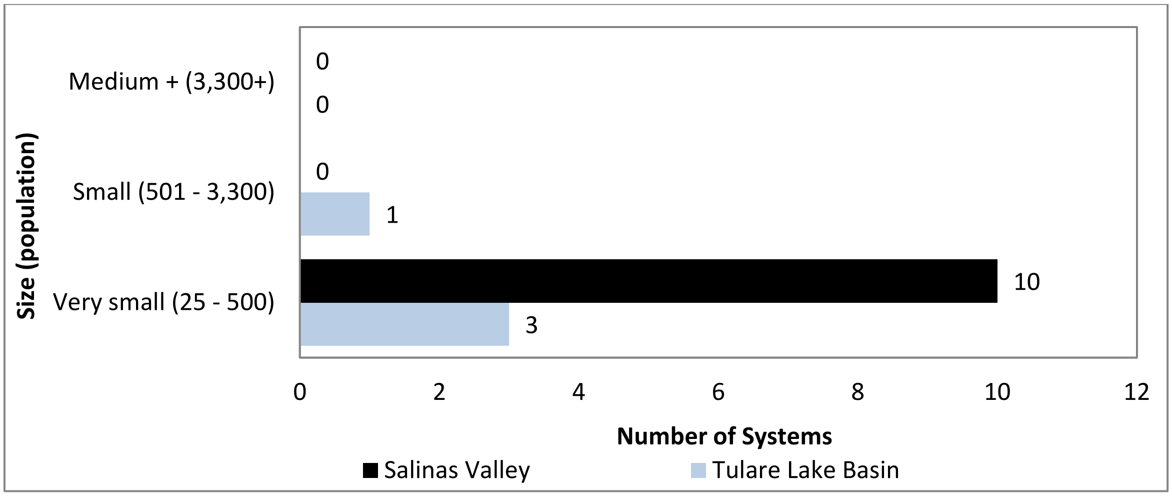


Figure 19. System Size Distribution (by Population Served) of the Community Water Systems without Water Quality Information [CDPH 2006-2010]

3.6 Major Findings on Susceptible Water Users

The population connected to each water system type and their estimated and confirmed vulnerability, and susceptibility is summarized below.

Vulnerable and susceptible populations include:

- An estimated 246,000 people on self-supplied and local small water systems (about 9% of the total study area population).
    - This population is served by systems with high vulnerability.
    - About 88,000 people, or 36% of the household self-supplied and local small water system population, are within Thiessen polygons with a maximum nitrate concentration exceeding the AL, having high nitrate contamination susceptibility.
    - The other 158,000 people are considered to be served by systems in areas of low nitrate contamination susceptibility.
- An approximate 8,800 people on single source state-small and community water systems (less than 1% of the study area population).

    - This population is served by systems with high vulnerability.
    - Approximately, 2,000 people, or 22% of the single source state-small and community water system population, are served by a system with a maximum recorded (raw source water) nitrate level exceeding the AL or are lacking nitrate data, and have high nitrate contamination susceptibility.
    - Approximately 2,350 people, or 27% of the single source state-small and community water system population, are served by a system having no recorded nitrate data, and have high nitrate contamination susceptibility.
    - The other 4,500 people are considered to be served by systems with low nitrate contamination susceptibility.
- An estimated 2.3 million people are on multiple source community water systems (about 88% of the study area population).
    - This population is served by systems with low vulnerability.
    - Approximately, 670,000 people, or 29% of the multiple source community water system population, have a maximum recorded (delivered water) nitrate level exceeding the MCL, and have high nitrate contamination susceptibility.
    - Approximately, 3,900 people (less than 1% of the multiple source community water system population), have no recorded nitrate data, and have high nitrate contamination susceptibility.
    - The other 1.7 million people are served by systems with low nitrate contamination susceptibility (about 77% of the population).

A summary of the existing susceptible water systems and the population served is shown in Table 12 (refer to Figure 3 for a visual representation of this information). Approximately

762,000 people are served by water systems that have higher susceptibility (29% of the study area population), 1.8 million are served by water systems that have lower susceptibility (69% of the study area population), and 64,000 have no susceptibility (2% of the study area population) to nitrate groundwater contamination.

Table 12. Assessment of Susceptible Water Users in the Study Area

		Population Served		
System Description	**Susc.[1]**	**Salinas Valley**	**Tulare Lake Basin**	**Total Study Area**
Total Basin Population[2]		**397,287**	**2,249,928**	**2,647,215**
Household Self-Supplied or Local Small Water Systems[3]		**10,365**	**235,125**	**245,490**
Max NO_3 AL Exceedance[3a]	H	2,924	84,662	87,586
Max NO_3 AL Non-Exceedance[3b]	L	7,441	150,463	157,904
Single Source State-Small or Community Water Systems[4]		**2,176**	**6,658**	**8,834**
Max NO_3 AL Exceedance or No WQM Data[4a]	H	1,198	3,129	4,327
Max NO_3 AL Non-Exceedance[4b]	L	978	3,529	4,507
Surface Water Community Water Systems[5]	No	0	64,501	64,501
Multiple Source Community Water Systems[6]		**408,123**	**1,931,267**	**2,339,390**
Treating or Blending for NO_3[7]		121,945	203,087	325,032
Not Treating or Blending for NO_3[8]		286,178	1,728,180	2,014,358
Max NO_3 Distributed Water MCL Exceedance[9]	H	894	669,101	669,995
Max NO_3 Distributed Water MCL Non-Exceedance[10]	L	405,783	1,259,724	1,665,507
No NO_3 Data[11]	H	1,446	2,442	3,888
TOTAL HIGHER SUSCEPTIBILITY POPULATION[12]		6,462	759,334	765,796
TOTAL LOWER SUSCEPTIBILITY POPULATION[13]		414,202	1,413,716	1,827,918
TOTAL NO SUSCEPTIBILITY POPULATION[14]		0	64,501	64,501

[1] Susceptibility – Levels: High (H), Low (L), and No.

[2] The total basin population. Estimated from US Census and California Department of Finance data, spatially verified in ArcGIS.

[3] Population on household self-supplied and local small water systems estimated using Parcel Use Codes from County Assessors and DWR land use classification. Household Self-Supplied Water Systems are any residential parcels zoned as having 1-2 dwelling units, located outside of city and water system boundaries. Local Small Water Systems are any residential parcels zoned as having 3-4 dwelling units, located outside of city and water system boundaries. Assumed 3.3 people per dwelling unit.

[3a] Population on household self-supplied and local small water systems located within Thiessen polygons that have a nitrate concentration greater than the Action Limit (22.5 mg/L as NO_3). Nitrate concentrations are from DWR, CDPH, USGS, SWRCB, and all study area counties.

[3b] Population on household self-supplied and local small water systems that are located within Thiessen polygons that have a nitrate concentration less than the Action Limit (22.5 mg/L as NO_3).

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[4] Population on single source state-small or community water systems from CDPH's PICME database.

[4a] Population on single source state-small or community water systems with a maximum raw water nitrate concentration (PICME WQM, 2006-2010) greater than the Action Limit (22.5 mg/L as NO_3) or without nitrate data in WQM.

[4b] Population on single source state-small or community water systems with a maximum raw water nitrate concentration (PICME WQM, 2006-2010) less than the Action Limit (22.5 mg/L as NO_3).

[5] Population on community water systems serving only surface water sources (PICME 2006-2010).

[6] Population on community water systems with more than one source (PICME 2006-2010).

[7] Population on community water systems with more than one source treating or blending for nitrate (Drinking Water Treatment Chapter – Nitrate Treatment Systems Survey and systems approved for treatment by CDPH).

[8] Population on community water systems with more than one source not treating or blending for nitrate, those systems that did not respond to the Nitrate Treatment Systems Survey and CDPH does not have treatment information on.

[9] Population on community water systems with more than one source with delivered water exceeding the nitrate MCL (45 mg/L as NO_3) (PICME WQM 2006-2010).

[10] Population on community water systems with more than one source with delivered water less than the nitrate MCL (45 mg/L as NO_3) (PICME WQM 2006-2010).

[11] Population on community water systems with more than one source with no nitrate water quality data (PICME WQM 2006-2010).

[12] Total Higher Susceptibility Population = 3a + 4a + 9 + 11

[13] Total Lower Susceptibility Population = 3a + 4a + 10

[14] Total No Susceptibility Population = 5

3.7 Health and Socioeconomic Disparities

This report estimates the susceptibility as a qualitative likelihood of exposure; however, a more common definition of susceptibility to nitrate contamination is based on the health and socioeconomic status of an individual. The following discussion is not meant to change this report's definition of susceptibility or the susceptible population estimate shown, but acknowledges the population that is highly susceptible to health and financial effects, and much more difficult to quantify. There are two highly susceptible subgroups with susceptibility defined as a health and financial status instead of an expected likelihood of consuming contaminated water. These two categories are:

1. **Pregnant women or infants under six months** are more susceptible to higher levels of nitrates in drinking water. This is a direct public health concern.

2. **Residents of disadvantaged unincorporated communities** have a more difficult time paying for both the capital and on-going operations and maintenance (O&M) costs of point-of-use or community-wellhead treatment options if local nitrate contamination becomes a problem. This is primarily a financial impact and financial feasibility concern.

3.7.1 Pregnant Women and Infants

The number of pregnant women and infants within each basin was estimated using the Department of Finance data on a county level. This overestimates the highly susceptible population since the boundaries of each county are not fully within the study area boundaries. Roughly 84,500 and 14,100 pregnant women and infants live in the Tulare Lake Basin counties and Monterey County, respectively (CaDoF, 2010). However, the location of these pregnant women and infants is unknown, making it difficult to determine if they are currently drinking nitrate contaminated water and not allowing for incorporation into the susceptibility chart. Applying the estimated total higher susceptibility percentage (28% and 45% for the Salinas Valley and Tulare Lake Basin - discussed in the previous section), approximately 3,900 and 6,400 pregnant woman and infants within Monterey and Tulare Lake Basin counties are highly susceptible to health problems from consuming nitrate-contaminated water. Again, the difference in basin boundaries and county boundaries makes this a conservative estimate (or an overestimation).

3.7.2 Disadvantaged Communities (Disadvantaged Unincorporated Communities)

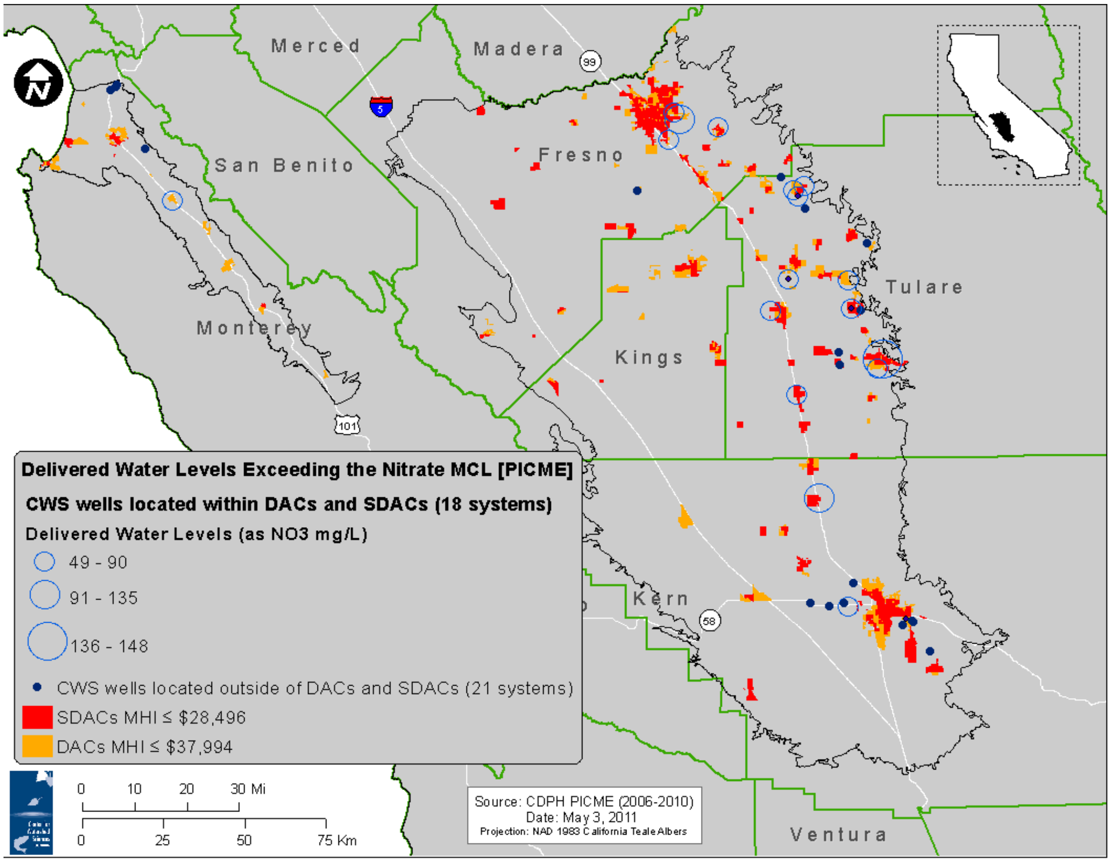
Title 22 of the CA Code of Regulations defines a disadvantaged community (DAC) as a community whose median household income (MHI) is less than or equal to 80% of the statewide

MHI. The MHI for CA was $47,493 in 2000, so for this report, any community with an MHI less than $37,994 will be considered a DAC.

DACs that are unincorporated often lack central water and sewer services. These disadvantaged unincorporated communities (DUCs) are highly susceptible to nitrate contamination because they may lack a safe water source and are less able to buy bottled water or treat with point-of-use systems if their water source becomes contaminated with nitrate. Since these areas have a large concentration of families with low incomes, community solutions to nitrate treatment or alternative water supply also would be difficult.

Impoverished communities within the Tulare Lake Basin and Salinas Valley are shown in Figure 20, along with the delivered water quality of multiple source CWSs (WQM data from 2006 to 2010). Severely disadvantaged communities (SDACs) have a MHI of less than 60% of the statewide MHI (less than $28,496), and are severely impoverished areas within the study area. Some DACs include areas known as Census Designated Places (CDPs), or unincorporated areas, that implies Figure 20 is representative of some DUCs. CWSs with delivered water quality exceeding the nitrate MCL within severely disadvantaged and disadvantaged communities are shown in hollow blue circles, with those outside of severely disadvantaged and disadvantaged communities shown in blue points. About 52% of the multiple source systems that have delivered water exceeding the nitrate MCL are located within the severely disadvantaged and disadvantaged communities.

Figure 21 shows a scatter plot that relates the median household income of the water system (water systems located within Census block groups are attributed with block group MHI values) with the maximum raw source water nitrate level. Systems are shown as being in an incorporated (non-CDP) or unincorporated (CDP) area. Any system above the red MCL line and to the left of the blue 80% MHI line have a source that has exceeded the nitrate MCL at least once since 2006, and is located in a disadvantaged community. There are 51 community water systems (serving about 714,000 people) in the study area with a raw source exceeding the nitrate MCL; 40 systems (serving about 379,000 people) are located in a disadvantaged community and 11 systems are located outside of a disadvantaged community. Thirteen of the 40 exceeding systems are CDPs (serving about 167,000 people) and 27 are non-CDPs (serving about 212,000 people). Of all 328 systems shown in Figure 21, 12% are exceeding systems within a disadvantaged community and only 3% are exceeding systems outside of a disadvantaged community.



Source: CDPH PICME (2006-2010)
Date: May 3, 2011
Projection: NAD 1983 California Teale Albers

Figure 20. The Relationship between DACs and SDACs and Delivered Water Levels in Multiple Source CWSs

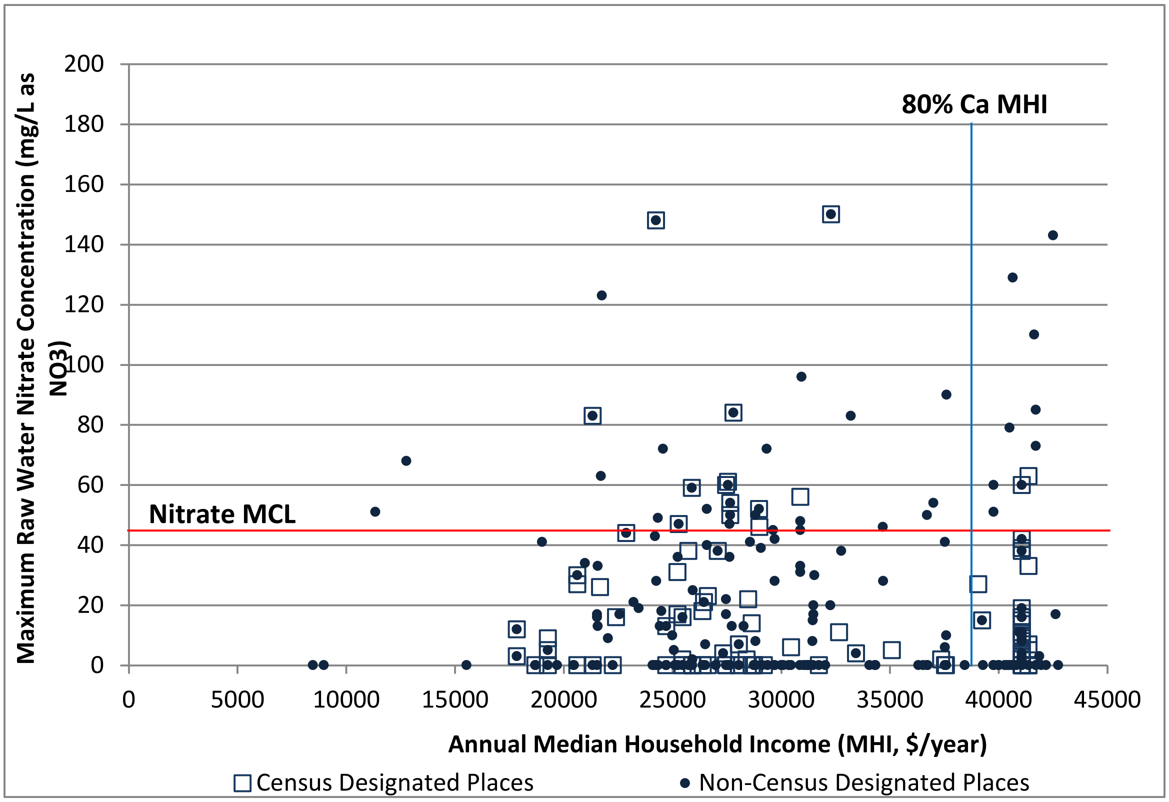


Figure 21. The Maximum Raw Source Water Nitrate Concentration for State-Small or Community Water Systems with MHI Data (WQM 2006 – 2010 and 2000 Census)
{**Note: Census Designated Place = Unincorporated Place and Non-Census Designated Place = Incorporated Place}

Disadvantaged unincorporated communities are smaller communities that are often either not connected to a public water system or are connected to very small systems. The smaller water systems lack technical, managerial and financial capacity to maintain an expensive water treatment facility or to provide alternative water supplies to their customers. Small water systems are typically responsible for more water quality violations and have difficulties successfully operating and maintaining their systems (Washington Department of Health, 2009).

3.8 Trends of Susceptible Populations in Time

Legacy nitrate contamination of groundwater will expand in spatial extent in the future and increase the at-risk population. By 2050, the total study area population is projected to grow to about 5.8 million people, with about 5.3 million people in the Tulare Lake Basin, and a little over 500,000 people in the Salinas Valley (California Department of Finance, 2010).

3.8.1 Accumulating nitrates and population changes

Current groundwater nitrate contamination is largely a legacy problem, as contamination persists, percolates, and spreads in groundwater decades after nitrogen is applied to the soil. In some places, source loading from decades ago is just now reaching the Tulare Lake Basin and Salinas Valley aquifers and nitrate discharges today may not be seen in drinking water wells for decades. Nitrate accumulates in groundwater; given the extent of contamination there is little evidence to suggest that nitrate concentrations in deep groundwater will decrease without intervention (denitrification is very minor in the environments of this study). As the area's population increases, more people in small and household water systems will face health and cost consequences from nitrate contaminated groundwater.

The Pacific Institute comment on the Central Valley Draft Environmental Impact Report for the Irrigated Lands Regulatory Program discussed the need to recognize increasing groundwater nitrate levels (Pacific Institute, 2010). Their regression analysis on Kern County wells monitored by the Groundwater Ambient Monitoring and Assessment (GAMA) Program and observed trends in nitrate levels found that a third of the well locations' nitrate levels are increasing, and the number of wells exceeding the MCL will likely double over the next ten years (Pacific Institute, 2010). The USGS National Water-Quality Assessment (NAWQA) Program has collected well data across the nation since 1991 and has observed increasing nitrate concentrations in groundwater over the last 15 years. NAWQA discovered increasing nitrate levels in aquifers underlying agricultural areas correlated with oxygenated conditions and well-drained soils (Nolan et al., 1997). As the population increases and agricultural land is converted to residential property, risks from nitrate-laden groundwater will increase, requiring more aggressive and expensive treatment.

The long-term trends for nitrate concentrations were found for public supply wells over the past 40 years. The average annual change in nitrate concentration was found for all public supply wells with at least two nitrate records listed in WQM.

Table 13 shows the mean change in nitrate concentration, and the confidence intervals for public supply wells in the Tulare Lake Basin, Tulare County, and Salinas Valley. Based on these annual trends for nitrate in public supply wells, the total number of community water systems that will have raw source water exceeding the MCL by 2035 and 2050 is estimated in Table 14 (CDPH's WQM Database from 1970s to current). This is the predicted susceptible population if no remediation or abatement of source application occurs. This analysis only examines the increasing nitrate trend of the existing community water systems and is applied to the maximum raw source water. The susceptible population is estimated to be approximately 1.9 million people by the year 2050. Approximately 79% of the existing community water systems' sources could exceed the MCL for nitrate by 2050. This estimate does not consider any treatment implementation or distribution of alternative water supplies and ignores water system population increases.

Table 13. Long-term Trends for Nitrate Concentrations in Public Supply Wells*

	Mean Change [mg/L-yr]	**Confidence Interval -95%**	**Confidence Interval +95%**
Tulare Lake Basin {Tulare County} Public Supply Wells, 1970s – current	0.27 {0.41}	0.17 {0.22}	0.36 {0.59}
Salinas Valley Public Supply Wells, 1970s – current	0.53	0.31	0.77

*The nitrate trend for all public supply wells listed in CDPH's CADWSAP (WQM) database from 1970s to current.

Table 14. Estimated Time for CWS Sources to Exceed the NO_3 MCL and Total Affected Population

Time For Maximum Recorded Raw NO_3 Level to Reach the MCL	**Total Number of Affected CWSs**	**Total Affected Population**	**Percent of Total CWSs Population (Study Area)**
0 Years (2010)	77	1,363,657	57%
25 Years (2035)	114	1,836,732	76%
40 Years (2050)	127	1,903,300	79%

3.8.2 Drinking water system regulatory changes

Tightening drinking water regulations and increasing trends in nitrate concentrations will likely make it more difficult for small local suppliers to comply with regulations for nitrates, arsenic, and other contaminants. With drinking water regulations expected to become more stringent in the future, more water systems will be forced to implement state-of-the-art treatment facilities and monitor more frequently with online monitoring tools. Systems must be prepared to comply with more complex regulations while simultaneously continuing to comply with existing regulations. Compliance will be difficult as nitrate levels increase over time. Small systems lacking the technical, managerial, and financial capacity for operating and maintaining a treatment facility will struggle with future regulations. The lack of resources should motivate smaller systems to regionalize and consolidate with bigger systems, where possible, or to consult assistance programs for financial, technical and institutional help.

4 Alternative Water Supply Options

Alternative water supplies and nitrate treatment for drinking water are presented and discussed in this section, including the latest technologies, limiting factors, and capital and O&M costs, with a goal of identifying promising options. Guidelines are developed for selecting promising water supply options and evaluating solution design and costs as a function of source water quality, system size, and system location. The discussions are based on an inventory and analysis of nitrate management strategies and treatment options available to the study area population, identifying concerns for each option, including financial and economic aspects. The alternative water supply options available for the susceptible population are considered and costs are estimated in Section 5. Alternative water supply and nitrate management options are grouped into three categories: improving the existing water source, providing alternative supplies, and relocating households (Table 15). Several ancillary activities also improve the performance of some water supply alternatives. Although each system requires its own engineering analysis, cost estimates are discussed in Section 5.

Table 15. Alternative Water Supply Options

OPTION
IMPROVE EXISTING WATER SOURCE
Blending
Drill Deeper Well
Drill a New Well
Community Supply Treatment
Household Supply Treatment
ALTERNATIVE SUPPLIES
Switch to Treated Surface Water
Piped Connection to an Existing/New System
Regionalization and Consolidation
Trucked Water
Bottled Water
RELOCATE HOUSEHOLDS
ANCILLARY ACTIVITIES
Well Water Quality Testing
Dual System

4.1 Improve Existing Water Source

Several source improvements via non-treatment and treatment options can reduce water source nitrate levels to comply with regulatory standards. Non-treatment options include blending and drilling a deeper or new well. Both can be limited by well characteristics, available sources, and financial resources. Treatment options for community water systems include ion exchange, reverse osmosis, biological denitrification and chemical denitrification. Household treatment options include ion exchange and reverse osmosis at the point-of-use or point-of-entry.

4.1.1 Blending

Blending dilutes a source with higher nitrate levels with a lower nitrate source to produce nitrate compliant water, while still using the contaminated water source. Blending can be used as a stand-alone option or as a step before chemical or biological treatment. Blending typically takes advantage of the differing nitrate concentrations typically found among wells with different locations, districts and depths. Older wells tend to be shallower, and therefore have often higher nitrate concentrations. Blending requires at least one nitrate compliant source and cannot occur in systems with only one well, unless additional water is brought from outside.

Blending is considered a form of treatment because water systems are required to monitor and operate the blending process as a permitted treatment facility with a certified operator (CDPH 2011). The nitrate compliant source must be field monitored daily using continuous online nitrate analyzers to ensure complete mixing and blending water quality, collecting monthly samples to certify a source is uncompromised, consistently distributing nitrate compliant water (CDPH 2011). The compliance point for a blending system shifts from the source water in the well to the blended sampling point (or point-of-entry distribution system) (CDPH 2011). Water may be blended from several groundwater wells or systems can blend groundwater with purchased treated surface water. Daly City blends their high nitrate wells with cleaner water from SFPUC (CDPH 2011).

According to CDPH, blending is only acceptable as “a treatment process if one of the blended sources exceeds a primary MCL” (CDPH - Div. 4 Ch. 13 Operator Certification). If a water system decides to blend their sources to comply with drinking water regulations, they must contact CDPH and coordinate with them to create a Blending Program and receive permission to blend. Blending requires two wells to continually operate, ensuring that one is always a low-nitrate source. A blending system must have an operator certified as Grade T2. If the low-nitrate blend water becomes compromised with high nitrate, a system automatically loses blending privileges. The maximum blend concentration allowed by CDPH is less than or equal to 40 mg/L (as NO_3).

Within the study area, eight CWSs use blending alone to reduce nitrate in delivered water. Blending is typically the first choice and least expensive option when a nitrate compliant source is available. Estimated costs for blending are presented in Section 5.1.1.

4.1.2 Drilling a Deeper or New Well

The nitrate plume slowly follows general groundwater movement down from the surface to the saturated zone. For self-supplied households, sometimes it is possible to avoid or defer nitrate contamination by drilling deeper wells. This is often considered a temporary solution because any nitrates contaminating the original well can eventually infiltrate to the deeper well unless any of the following conditions are met:

- a strong-chemically reducing aquitard zone capable of denitrifying downward seeping groundwater separates the current screen level from the target screen level;

- a semi-impermeable layer separates the deeper well from the nitrate contamination; or
- the new well screen is much deeper (several hundred feet) below the current screen level *and* the well is properly sealed to the depth of the well screen.

A deeper aquifer protected by a clay layer could prevent nitrate-contaminated water from entering the new wells withdrawal zone. Depending on the local hydrogeology, source capacity may decrease with deeper wells – however, this is typically not an issue for small production household wells or wells with few connections. Other water contaminants (such as arsenic) may emerge at new depths. Jensen and Darby found an increase in the incidence of arsenic MCL exceedance with well depth (Jensen & Darby, 2011). New wells might be a feasible option for communities while they await long-term solutions, such as connection with larger systems, a new treatment system, or groundwater remediation. Drilling a deeper or new well takes less time than some construction or remediation projects. Owners or systems with new wells should test their well frequently.

Drilling a new or deeper well should employ an experienced well driller who is educated on the local hydrogeology. The driller should be familiar with the nitrate distribution and groundwater gradient at the desired well location. The main costs of drilling a new or deeper well will be drilling and pumping costs; both increase with the depth to uncontaminated water. Well modification may limit the screened interval, to capture a region of nitrate-free groundwater. A packer/plug can be installed to restrict withdrawal from nitrated contaminated regions and installation can occur without removing pumps (BESST Inc., 2008).

A new well should be drilled more than about 30 meters (100 feet) from potential sources of pollution or contamination (such as septic fields). To avoid pollution or contamination it may be necessary to drill a new well up to two miles from the existing well. Drilling a well has many costs including drilling a pilot test well and drilling the (larger diameter borehole for the) production well, installing the well, filter pack, borehole seals, and surface completion, equipping the site, testing for sediment and water quality, well development, installation of storage and distribution systems, and planning, consulting, and engineering services.

A community water supply well can cost from about $300,000 to $1 million, depending on depth and capacity (Darby & Newkirk, 2010). Kettleman City Community Services District estimated the costs for drilling a pilot test well to be about $320,000 (KCCSD, 2011).

To estimate the costs for drilling a deeper well, a USEPA BID document was used along with a quote from an experienced hydrogeologist. Costs for drilling a deeper or new well are presented in Sections 5.1.2 and 5.1.3.

Mettler Community Water District, in Kern County, drilled a 700 foot well at a capacity to serve 146 residents and it was estimated to cost $284,000. In 2009, a well comparable in size and depth was built by Plainview Mutual Water Company, in Tulare County, to serve 800 residents and it was estimated to cost $339,000. Ducor Community Service District, also in Tulare County, spent close to $725,000 on a 1,400 foot well for 850 residents. These cost estimates do not include the contingency, escalation, and design costs, that can add an additional 30% to the construction costs. (Self-Help Enterprises, 2011)

4.1.3 Community Treatment

If an existing CWS supply exceeds the MCL for nitrate, community treatment should be considered based on the population served, quantity of water distributed, and technical and managerial capacity. The EPA has approved ion exchange, reverse osmosis, and electrodialysis as potable water treatment methods for nitrate removal (Jensen & Darby, 2011). These three processes remove nitrate ions from the contaminated water and concentrate them into waste brines. The most common nitrate treatment method in the United States is ion exchange. Alternatively, denitrification methods do not transfer the nitrate to concentrated brine, but convert the nitrate to a reduced nitrogen form, such as nitrogen gas. Full-scale denitrification methods have not been applied in the United States, but chemical denitrification has been used at the pilot-scale level in the US (Jensen & Darby, 2011). Europe has applied biological denitrification for potable water at full-scale (Jensen & Darby, 2011).

The most appropriate treatment for nitrate contamination can be influenced by influent nitrate concentrations (Jensen & Darby, 2011). Table 16 lists several scenarios for influent nitrate level and water system characteristics, with considerations listed for each option.

Table 16. Influence of Nitrate Concentration on Treatment Selection[1]

Option	Practical Nitrate Range	Considerations
Blend	10 - 30% above MCL	Dependent on capacity and nitrate level of blending sources.
Ion Exchange	Up to 2X MCL	Dependent on regeneration efficiency, costs of disposal and salt usage. Brine treatment, reuse, and recycle can improve feasibility at higher nitrate levels.
Reverse Osmosis	Up to > 2X MCL	Dependent on energy use for pumping and number of stages. May be more cost effective than IX for addressing very high nitrate levels.
Biological Denitrification	Up to > 2X MCL	Dependent on the supply of electron donor. May be more cost effective than IX for addressing high nitrate levels.

[1] Based on contact with vendors and environmental engineering consultants. Excerpt from The SBX2 1 California Nitrate Project: *Drinking Water Treatment Report* (Jensen & Darby, 2011).

The estimated costs for use of ion exchange and reverse osmosis are presented in Section 5.1.4. Since the most recent EPA Cost Estimating Manual is from 1979, collected cost information for arsenic treatment was used for a more up to date comparison of ion exchange treatment (EPA, 2000).

Communities with dual plumbing systems, separating drinking and cooking uses from other water uses, can greatly reduce treatment quantities and costs, and reduce production of waste brines requiring disposal. However, dual plumbing systems increase capital and maintenance costs and may raise regulatory issues.

Any CWS implementing treatment should consider using remote monitoring and management technology to lower operating and maintenance expenses. A remote telemetry or supervisory control and data acquisition (SCADA) system would be very beneficial to small systems lacking resources to support qualified operators on-site. Small water systems are more expensive and challenging to manage well and SCADA allows an operator to supervise several systems remotely. A SCADA system allows real time control of system operation and maintenance of water quality by using a central computer to control mechanical processes and collect data from sensors. Emergency responses are quick with instant notification of critical system events or episodes automatically sent to the operator. The data acquisition component allows utilities to provide statistics on water quality and usage for budget planning, water quality compliance, system improvement, and targeted system expansions. A SCADA system can alert operators of changes in water quality requiring their assistance or to modify system operation through preprogrammed control functions not needing operator assistance. A SCADA and Programmable Logic Controller (PLC) control system for a 900 gpm surface water treatment plant costs about $75,000 (Kettleman City CSD, 2011).

Based on the EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment, approximate minimum costs for SCADA are represented for various system sizes in Section 5.1.4.

4.1.4 Household Treatment

An alternative to a community treatment is a household water treatment device either at “whole house” (point-of-entry) or “point-of-use” locations. Point-of-entry (POE) solutions removes nitrate (through reverse osmosis or anion exchange) for the entire house (usually only indoor uses). Point-of-use (POU) solutions for nitrate commonly use reverse osmosis for kitchen taps (New Hampshire Department of Environmental Services, 2010). Since nitrate is not a concern for non-drinking uses (e.g., showering), a POU system that treats drinking and cooking water is more economical than a POE system. POU systems have greater potential public health risks because residents may consume water from bathroom taps mistakenly. In general, reverse osmosis is the cheapest nitrate treatment at the household level (Mahler, 2007).

Certification to the relevant ANSI/NSF standard by an ANSI accredited third party certifier ensures the safety and performance of the residential treatment systems (Jensen & Darby, 2011). Currently there is only one relevant ANSI/NSF standard for nitrate reduction: NSF 58 - Reverse osmosis drinking water treatment systems (NSF, 2009). POU devices that claim to reduce a drinking water contaminant must be certified by CDPH.[20] CDPH's Certified Residential Water Treatment Devices directory lists approved water treatment devices to reduce nitrate. "Under counter" systems reduce nitrates through reverse osmosis or reverse osmosis with carbon. "Counter top" systems reduce nitrate through reverse osmosis and granular activated carbon, with either mechanical or adsorptive processes (CDPH, 2009b).

POU treatment requires separation of drinking and cooking water supplies from other water uses and potentially increases public health risk, but is much less expensive than treating all household water use to remove nitrate, and similarly generates much less waste brine. For a reverse osmosis system, piping from the device and faucet plumbing must be lead-free. This

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[20] California Department of Public Health (CDPH) pursuant to Chapter 8.5, Part 1, Division 5 of the Health and Safety Code.

precaution is needed because reduction of the water's alkalinity can increase corrosiveness and leach lead (New Hampshire Department of Environmental Services 2010).

The average rated service flow for the certified residential nitrate treatment devices in the CDPH directory is about 20 gallons per day (gpd), with some devices as low as 7.6 gpd and some as high as 35.5 gpd (CDPH, 2009a). The average human uses 0.8 gpd for cooking and drinking (NAS report, 2004), so these flow rates are appropriate for most family sizes.

While the residential water treatment devices in the CDPH directory are certified to remove nitrate in drinking water, there is a limit to their effectiveness. For example, many of the reverse osmosis with carbon treatment systems manufactured by Kinetico Incorporated are only acceptable for nitrate levels below 27 mg/L (measured as nitrogen) (CDPH, 2009a). However, treatment also can potentially remove other contaminants of concern, such as arsenic.

The estimated cost of a reverse osmosis POU device is discussed in Section 5.1.5.

4.2 Connect to Alternative Water Supplies

Alternative water supplies include connecting to a better quality water system, trucking potable water from a better source, and purchasing bottled or vended water. A piped connection to a better quality water system can take three forms: connecting to an existing system, connecting to a newly developed system, and consolidating several small systems into

Kettleman City Community Services District is proposing switching from their contaminated groundwater (arsenic and benzene) to a surface water treatment plant. The County of Kings and Tulare Lake agricultural users are allocating some of their State Water Contract (900 acre-feet per year). The estimated cost for a surface water treatment plant is $6.6 million. The plant would supply 1.3 mgd of surface water to 1,500 people. An increase in residential rates is limited to $2.21 per month (1.94% of the MHI). The annual O&M will be subsidized by Kings County.

a larger regional system. Trucked water would most likely occur for remote, very small communities and businesses. Bottled or vended water use is simple and effective for isolated households or small businesses, albeit at some cost and inconvenience.

4.2.1 Switch to Treated Surface Water

A piped connection to an existing surface water treatment system becomes promising if a community is reasonably near a well-functioning system. The costs for connecting to an existing surface water treatment system, such as the Central Valley Project (CVP) or State Water Project (SWP), would include the pipeline costs for the installed distribution pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, utility interference, and the fees for each connection to buy into capacity(varies within each system – the City of Davis charges about $9,000 for a residential ¾" meter connection to their system).[21]

> Cutler and Orosi are two unincorporated communities in Tulare County located less than a mile from each other, and less than a mile from a smaller community, East Orosi. Cutler and Orosi each have their own water systems that are contaminated with DBCP and nitrate. The Alta Irrigation District has just completed the first stage of a feasibility study for treating Friant Kern Canal surface water to supplement Cutler and Orosi's contaminated groundwater sources. The project is estimated to cost approximately $17 million in capital costs and approximately $500,000 in annual operating costs. (CWC, 2011)

The costs of such connections and treatment might also be large, per unit, given sometimes poor quality of the water for drinking water (Chen et al., 2010). Although the quantities of water use would not be large, legal and contracting issues will arise. Operating characteristics of irrigation systems that are often drained for maintenance off-season also are likely to pose challenges for rural community drinking water supplies. To prepare for surface water operating

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[21] City of Davis Public Works Division personal communication August 22, 2011.

limitations it would be appropriate to create a surface water treatment system with capacity to treat nitrate contaminated groundwater as well, so the residents have greater supply reliability.

4.2.2 Piped Connection to an Existing System

Costs for a piped connection to an existing water system would include infrastructure, base installed pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings, and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, and connection fees to the existing groundwater system. Most costs will be for distribution and connection.

East Niles Community Services District (ENCSD) charges $5,000 per connection to their system. Installing a 10" PVC pipe and valves was estimated by ENCSD to cost around $85 per foot (Self-Help Enterprises 2011), while EPA estimated $95-$142 per foot (EPA 2007). Rehabilitating a pipeline is slightly less expensive at $73 per foot (EPA 2007). Any obstructions create additional expenses. For example, a railroad track crossing cost ENCSD $75,000 and crossing a canal cost $25,000 (Self-Help Enterprises 2011).

Figure 22 shows the distribution of the minimum distances from a system serving less than 10,000 people (smaller systems) to a system serving more than 10,000 people (larger systems) for the study area (showing distances between sources, not service areas). Within the study area, 306 small systems and 38 large systems are available for interties, disregarding any institutional, political, technical, managerial, or financial barriers and costs. This also assumes clean and safe drinking water quality for the systems with more than 10,000 connections. The connection potential for each basin is discussed further in Section 4.2.4.

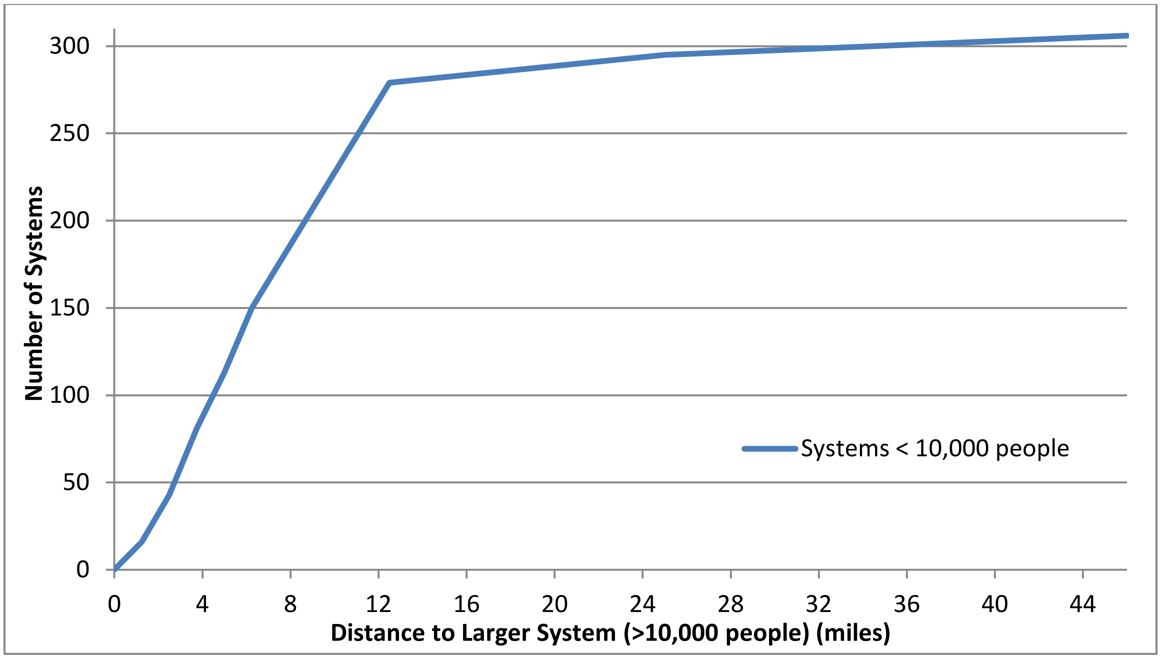

Figure 22. The Cumulative Distribution of the Minimum Distance from a Small System (≤ 10,000 People) to a Larger System (> 10,000 People) for the Entire Study Area [PICME 2010]

4.2.3 Piped Connection to a Larger Newly Developed System

Creating a new public water supply system involves costs for infrastructure, base installed pipe, trenching and excavation, embedment, backfill and compaction, valves, fittings, and hydrants, dewatering, sheeting and shoring, horizontal boring, pavement removal and replacement, utility interference and treatment equipment. For a new groundwater system, a district or community may need to look outside for clean, safe groundwater. If a new groundwater system is constructed within a district's boundaries there must be property available for a structure to house a nitrate treatment system. It is recommended to construct at least two wells since pumping units can fail within a well and it

The San Jerardo Water System spent over $5 million installing two miles of water transmission pipelines, a 285,000 gallon water tank, a potable water well, and pumping station. They also created an intertie with a nearby potable water supply for emergency service (MCWRA, 2011).

Kettleman City CSD identified potential clean, safe water supplies about 8,000 feet away from their property. The CSD's Engineer estimated drilling two new groundwater wells, with an 8,000 foot distribution pipeline, to cost about $6.6 million (Kettleman City CSD, 2011). The CSD also estimated treating two new groundwater wells (treatment for arsenic and odor) drilled on the existing property to cost about $7.7 million (Kettleman City CSD, 2011).

is prudent to have a backup source. Cost estimates would include costs for two wells, distribution, and treatment.

4.2.4 Regionalization and Consolidation

Regionalization and consolidation combines neighboring water systems to improve service and efficiencies, and to lower costs through economies of scale (Eskaf 2009). Regionalization and consolidation should be considered for drinking water systems struggling to meet regulatory compliance, unable to sustain aging infrastructure, unable to operate the system, or worried about future water availability. Regionalization and consolidation is especially attractive for small systems that lack population base and access to financial resources and technical expertise. Systems can achieve economies of scale without being physically connected by sharing capital equipment and management staff, or by participating in joint business and logistic operations. The least to most collaborative regionalization options range from: 1) create a planning document together; 2) initiate communication to discuss water system issues or to call during an emergency; 3) share inventory or equipment; 4) share an operator; 5) join management and delegate bookkeeping or billing to one entity; 6) interconnect systems for emergency purposes only; 7) share water rights or water resources without an intertie; 8) intertie systems, but maintain separate operations; and 9) intertie systems, close current systems, or form a combined system (New Mexico Rural Water Association, 2006).

Regionalization and consolidation in the drinking water sector can take many forms. Inter-tying systems (Option 9) (NMRWA, 2006) combines several small water systems that suffer from diseconomies of scale into one larger water system that serves the desired population and provides treatment to comply with drinking water standards. Regionalization has more formally been defined as “…a creation of an appropriate management or contractual administrative organization or a coordinated physical system plan of two or more community water systems in a geographical area for the purpose of utilizing common resources and facilities to their optimum advantage" (Grigg, 1989). Similarly, consolidation has been defined as "one community water system being absorbed into, combined with, or served by other utilities to gain the resources they lack otherwise" (Raucher et al., 2004). Consolidation often refers to giving up control and independence by one entity (or water system) as it is merged into another single entity. This transfer of control and independence does not always occur with regionalization as multiple smaller systems join together to create a larger system and the management is distributed evenly among all parties.

The optimal economic water system size and least-cost service area are estimated by the cost trade-offs between the acquisition-treatment component and the transmission-distribution component (Clark and Stevie, 1981). Smaller water systems may not have the treatment component, resulting in increased marginal costs for drilling and pumping. Ideally, there is equality between the increasing returns of scale from acquiring the water and the decreasing returns of scale involved in distributing water further. Rural small community water systems are generally farther from large urban systems, resulting in high connection costs that cannot be afforded by low income rural populations (Ottem et al., 2003).

There is significant potential for systems to consolidate in the Tulare Lake Basin. There are 98 large systems for 195 small systems to connect with (Table 17). The Cities of Fresno, Dinuba and Porterville and CSU Fresno water systems are available for 10 or more systems to connect to based solely on their spatial proximity. Of the 195 small systems, about 50% are within five miles of a larger system, and 88% are within 12.5 miles; again the systems with less than 10,000 connections are in black and the systems with more than 10,000 connections are in light grey

(Figure 23). Figure 24 shows the cumulative distribution of the distance between the smaller and larger systems and the quantity of systems available in that range. The total number of smaller systems needing to connect and the total number of larger systems available for connection are displayed above the bars. Considering only piping costs, about 98 smaller systems could consolidate and join a larger system less than five miles away for about $1.6 million[22] per system. Spatial proximity is the only consideration in suggesting these interties; other territorial, institutional or political barriers are ignored.

Within the Salinas Valley, there are 19 large systems for 111 small systems to connect with (Table 18). The California American Water Company in Monterey and the California Water Service Company in Salinas are available for 10 or more systems to connect to disregarding their existing capacity and solely representative of their spatial proximity. Of the 195 small systems, about 15% are within five miles of a larger system, and 97% are within 12.5 miles (Figure 25). Figure 26 shows the cumulative distribution of the distance between the smaller and larger systems and the quantity of systems available in that range. Again, the total number of smaller systems needing to connect and the total number of larger systems available for connection are displayed above the bars. Considering only spatial proximity, about 98 smaller systems in the Salinas Valley could consolidate and join a larger system.

There is much potential for regionalization and consolidation if a system can afford the pipeline and connection costs. The costs for connecting to a new or existing system are primarily for pipeline costs and connection fees. Various cost scenarios for constructing pipeline to a new or existing system are presented in Section 5.1.6.

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[22] This assumes a $61/ft pipe cost (Granite Ridge Regional Water Supply Project Feasibility Study, 2010).

Table 17. Large Systems Available for Smaller System Connections in the Tulare Lake Basin

System Number	System Name (> 10,000 System)	Connection	Population	Potential Number of Connecting Systems (<10,000 ppl)[*]
1010007	City of Fresno	130,176	457,511	10
1010019	City of Kingsburg	3,413	11,300	3
1010024	California Water Service Co. - Selma	6,078	24,307	5
1010025	City of Parlier	2,329	12,058	1
1010027	City of Reedley	5,445	25,584	1
1010029	City of Sanger	5,971	25,404	7
1010339	California State University, Fresno	550	22,000	14
1510001	Arvin Community Services District	3,446	11,847	2
1510005	City of Delano	8,829	53,855	6
1510006	East Niles Community Services District	7,406	25,500	6
1510012	Lamont Public Utility District	3,475	13,296	4
1510015	Oildale Mutual Water Company	7,708	26,000	5
1510019	City of Shafter	4,090	15,609	5
1510022	West Kern CWD	7,443	16,630	2
1510029	Vaughn WC INC F	9,246	28,100	7
1510031	City of Bakersfield	43,086	147,999	4
1610003	City of Hanford	15,509	53,320	4
1610004	City of Corcoran	3,176	25,893	1
1610005	City of Lemoore	6,117	24,500	8
5410002	City of Dinuba	6,025	21,087	10
5410003	City of Exeter	3,012	10,730	5
5410004	City of Farmersville	2,420	10,672	3
5410006	City of Lindsay	2,303	11,450	4
5410010	City of Porterville	14,896	51,467	10
5410015	City of Tulare	15,967	57,375	3
5410016	California Water Service Co. - Visalia	40,530	133,749	9

[*] Within up to 46 miles.

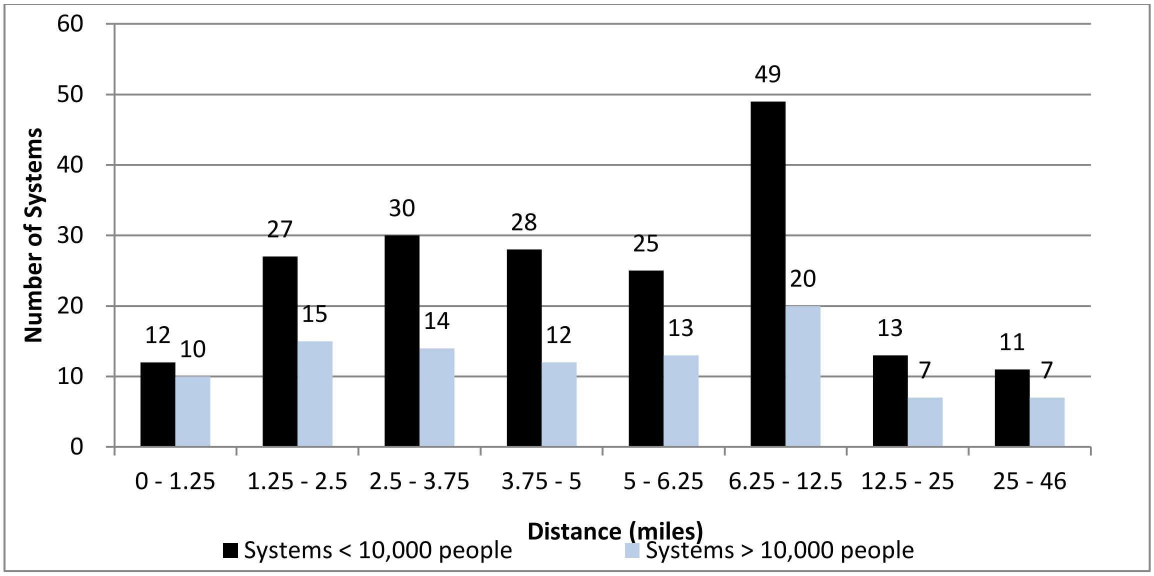

Figure 23. The Minimum Distance from a Small System (≤ 10,000 People) to a Larger System (> 10,000 People) for the Tulare Lake Basin [PICME 2010]

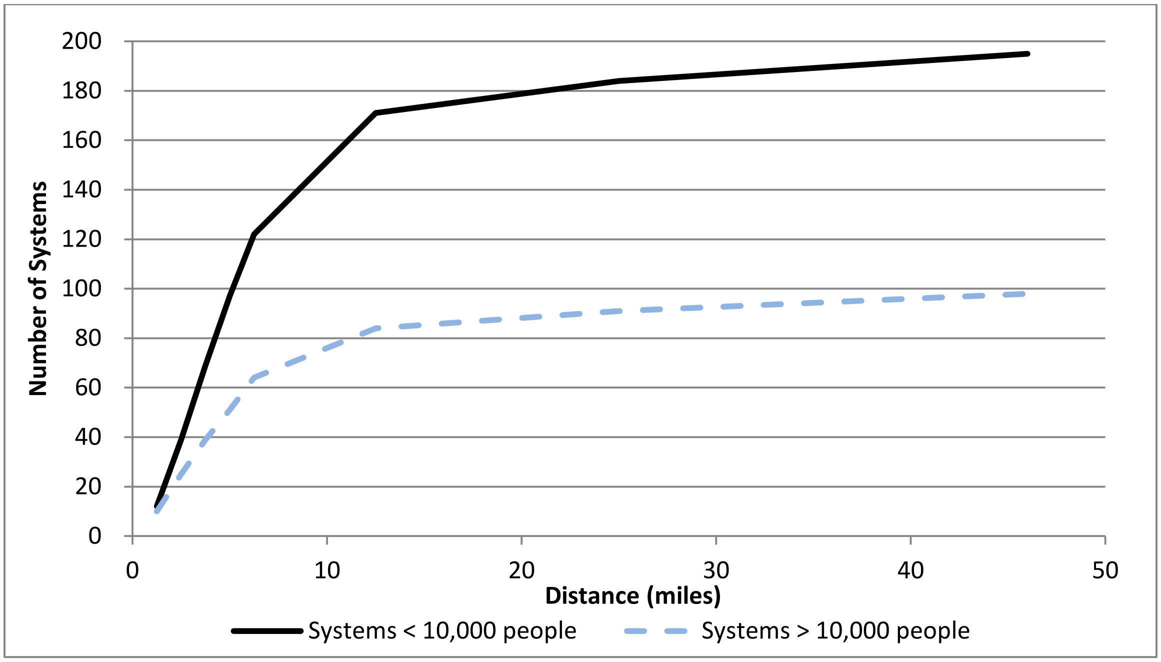

Figure 24. The Cumulative Distribution of the Minimum Distance from a Small System (≤ 10,000 People) to a Larger System (> 10,000 People) for the Tulare Lake Basin [PICME 2010]

Table 18. Large Systems Capable of Allowing Potential Smaller Systems to Connect in the Salinas Valley

System Number	System Name (> 10,000 System)	Connection	Population	Potential Number of Connecting Systems (<10,000 ppl)*
2710004	California American Water Company - Monterey	38,701	122,492	10
2710008	City of Greenfield	3,469	17,547	6
2710010	California Water Service Co. - Salinas	25,451	114,840	40
2710011	City of Soledad	4,082	16,146	4
2710017	Marina Coast Water District	8,357	34,600	2

*Within up to 15 miles.

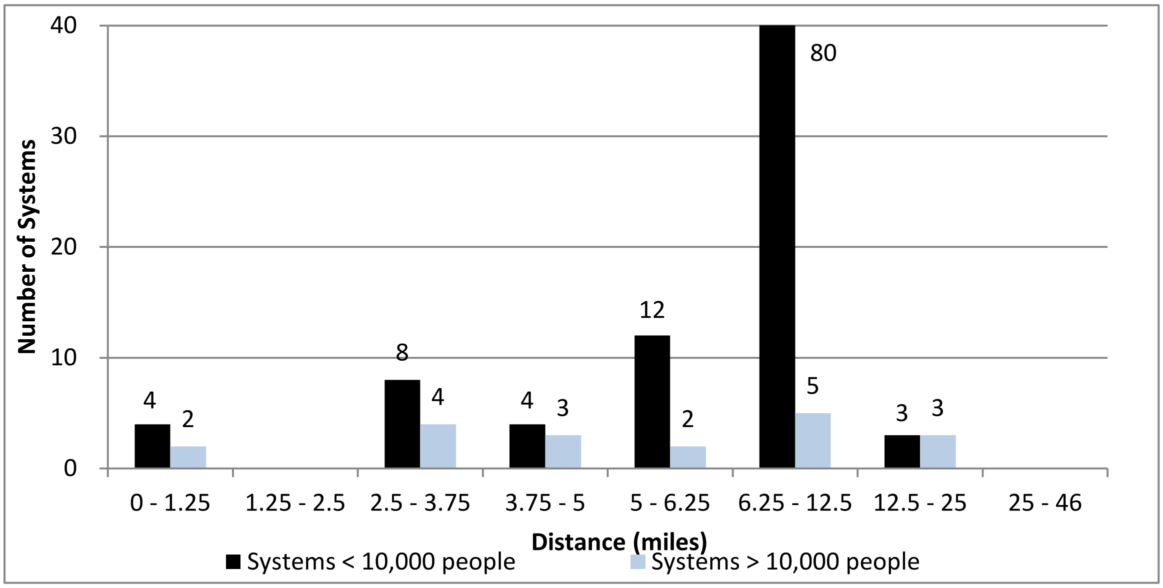

Figure 25. The Minimum Distance from a Small System (≤ 10,000 People) to a Larger System (> 10,000 People) for the Salinas Valley [PICME 2010]

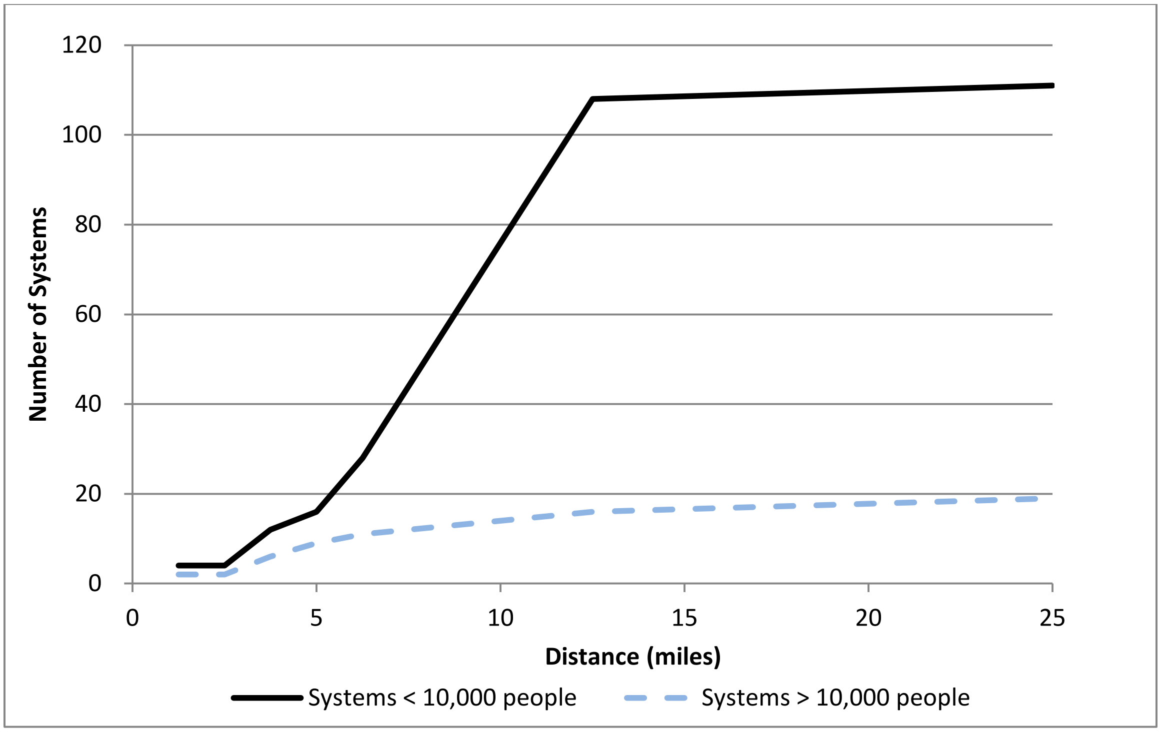

Figure 26. The Cumulative Distribution of the Minimum Distance from a Small System (≤ 10,000 People) to a Larger System (> 10,000 People) for the Salinas Valley [PICME 2010]

4.2.5 Trucked Water

Trucked water is a community or household water supply option that involves hiring a potable drinking water hauler, licensed with the California Department of Public Health, to deliver water to residential and commercial areas. Prior to use, the truck must be cleaned and inspected thoroughly, disinfecting all truck components with chlorine for 24 hours prior to delivery. Trucked water is often used for emergency supplies, but has permitting issues and is not acceptable for new public water systems (CDPH, 2011). CDPH only recommends supplying trucked water for emergency or short-term situations (CDPH, 2011). California water haulers are required to have a Water Hauler License from the Department of Public Health's Food and Drug Branch (FDB) (California Health and Safety Code Section 111120). FDB periodically inspects water hauler trucks to ensure compliance with laws and regulations.

Trucked water also can be used with a dual system, where only potable water for drinking and cooking is trucked in while the contaminated supply is used for other household needs. A trucked water dual system is infeasible as a long-term solution due to costs and CDPH regulations.

The estimated cost for providing a community or household in Tulare County with trucked water is shown in Section 5.1.7.

4.2.6 Bottled Water

Bottled or vended water is often a temporary solution for communities or households with a nitrate problem. While other long-term solutions are being developed, funded, and implemented, bottled water is the quickest solution for low-nitrate drinking water. Bottled water is more expensive than publicly supplied systems or well water, and is regulated less stringently by the FDA than bottled water is by EPA (NRDC, 2010).

Beverly Grand Mutual Water Company (BGMWC) in Porterville serves 108 people and has been in violation of the MCL since 2000, with the most recent violation in April 2010 (65 mg/L as NO3). About 50 people are below or near the poverty level. The Pacific Institute surveyed households served by BGMWC and found that on average households spend $31.63 on non-tap water per month, while still paying $25.00 per month on contaminated tap water (Moore et al., 2011).

Matheny Tract is a 45-acre disadvantaged unincorporated community outside of Tulare City limits that has been purchasing bottled drinking water since 2007. As of 08/10 Tulare LAFCO is requiring the City of Tulare to extend water and sewer service to Matheny Tract (Moore et al., 2011).

As with any dual system, it is conceivable to errantly drink contaminated faucet water (i.e., delivered water exceeding the nitrate MCL) rather than from intended, safely-sourced bottled water. Bottled water must be either delivered or picked up from the store or distributor, so households will occasionally run out of bottled water and use tap water. Households need to ensure that they order the appropriate amount, inventory their usage, and remember to place new orders. The reoccurring monthly cost is particularly unattractive to low income areas. While long-term purchase of bottled water is expensive, the monthly cost is less than a lump sum of capital-intensive solutions like drilling a new well. Households recently informed of their contaminated source purchase bottled water as an immediate solution for potable uses, while still paying for non-potable piped water.

The estimated cost for delivering bottled water to a household in Tulare County is discussed in Section 5.1.8.

4.3 Relocate to Area with Better Water Supply

Relocating residents to a place with safe, reliable water supply is an unpleasant and extreme option. Susceptible populations would face costs of selling property (often at a loss), moving, loss of jobs, increased travel distance to work, and potential social dislocation. Nearby employers would face higher labor costs and landlords reduced rental prospects. The area will likely suffer a decrease in economic activity. Some residents currently living in nitrate-contaminated areas are there because rent is inexpensive and employment is nearby. For small rural communities, residents might be unable to afford to live in areas with clean water supplies. Nevertheless, under some circumstances relocation may be the most attractive option, particularly when a community faces other economic challenges (e.g., chronic unemployment). The estimated costs for relocating households in the study area to a place with a better water supply are discussed in Section 5.1.9.

4.4 Ancillary Activities

Some options can be improved by simultaneously installing a dual water distribution system or well water quality testing program. A dual water system on a self-supplied household level can include a POU RO unit or bottled water. A dual water distribution system for community water system customers will include constructing new plumbing and installing groundwater treatment for the potable supply, and maintaining the existing distribution of contaminated water for the non-potable supply. Well water quality testing improves blending activities and is recommended when drilling a new or deeper well.

4.4.1 Dual Water Distribution System

A dual water distribution system has two separate distribution networks, one for the distribution of potable water and another for the distribution of non-potable water. According to Title 22, Section 60301.250 a dual plumbed potable water system has a separate piping for potable water (CDPH, 2011). A dual water distribution system would rely on water from the current supply for non-potable uses while consuming potable water from a POU treatment system (reverse osmosis), bottled water, trucked water from an outside source, or water for the existing water system that has been separated, treated, and piped through a secondary distribution network to the household. Total costs would be the current monthly cost for the contaminated supply plus the cost for a potable POU treatment system, bottled water, or trucked water. If dually plumbed delivery systems were created for entire water system, the costs would include purchase of contaminated supply, treatment, installation of a new pipeline to existing service connections, and the re-plumbing of households served. A system could continue to distribute the nitrate-contaminated supply for non-potable uses and install a smaller treatment system for the potable supply for deliverance through a secondary distribution network. Any water used for irrigation, or other non-drinking water uses, could be delivered through the existing pipeline, with a new plumbing system installed for the delivery of the treated, potable water. This would greatly reduce the water treatment costs for a system since a smaller volume would need to be treated. Costs for dual water distribution systems also include proper maintenance on existing infrastructure, water quality and water pressure. Costs for dual water distribution options are discussed in Section 5.1.11.

4.4.2 Well Water Quality Testing

Well water quality testing is important for all households on non-public water systems to detect high nitrate levels within their water supply. Well water quality testing is recommended for households or state-small systems that have not yet tested their water supply for harmful contaminants to determine if they are at risk and need an alternative water supply. The National Ground Water Association (NGWA) recommends domestic well owners test the water quality annually for bacteria, nitrates/nitrates, and other constituents of concern. The local health or environmental health department may also provide water quality testing and well cleaning advice. Before blending wells, well water quality testing is needed to discover and manage the appropriate blend of sources to produce water below the MCLs for nitrate and other contaminants. Similarly, when considering drilling a deeper well, the well water quality should be tested for other contaminants such as arsenic or manganese, as those contaminants often exist in deeper wells. When testing the well water quality it is recommended to have a California State-certified drinking water testing laboratory conduct the analyses (a list of drinking water laboratories certified by the CDPH is available at : http://www.cdph.ca.gov/certlic/labs/Documents/ELAPLablist.xls). The costs for residential well water quality testing are discussed in Section 5.1.11.

4.4.3 Rainwater Cisterns

Another option considered is implementing rainwater cisterns. However, cisterns are not commonly feasible for the scale of the problem in this arid area. A short description of this option is included in Appendix Section 11.2.

5 Evaluation of Options

Each option is evaluated on a system scale identifying economic and financial feasibility and addressing any public health concerns. While each water system requires its own engineering analysis to reflect local conditions, here a broad general comparison of the costs of various options for policy purposes is presented. The advantages and disadvantages of each alternative are discussed for public water systems in Table 19 and for household self-supplied and local small water systems in Table 20.

Table 19. Advantages and Disadvantages of Options for Public Water Systems

	ADVANTAGES	**DISADVANTAGES**
Blending	▪ Simple non-treatment alternative ▪ Cost-effective if given 2 or more wells	▪ Capital investment for accessing an alternative source ▪ Relies on availability and consistency of low nitrate source ▪ Monitoring requirements ▪ Rising nitrate levels may increase need for blending water
Drilling a Deeper or New Well	▪ Potentially more reliable water supply ▪ Cheaper than bottled water for households use of less than 8 gpd	▪ Potential decrease in source capacity ▪ Capital and operational costs increase with depth ▪ Temporary “quick-fix”; the nitrate plume follows groundwater movement ▪ Risk of encountering other water quality concerns at greater depths (i.e., arsenic, manganese) ▪ Pipeline costs if source area is far away from original source ▪ Physical limits exist for deeper wells
Community Treatment (IX, RO &EDR)	▪ Multiple contaminant removal ▪ Feasible automation	▪ High volume of hazardous residuals (waste concentrate) ▪ High maintenance and energy demands ▪ Resin/membrane susceptibility
Piped Connection to an Existing System	▪ Safe, reliable water supply	▪ Capital cost of pipe installation ▪ Connection fee ▪ Water rights purchase (surface water)
Piped Connection to a New System	▪ Safe, reliable water supply	▪ Capital cost of pipe installation ▪ High treatment system capital and O&M costs ▪ Water rights purchase (surface water)
Regionalization & Consolidation	▪ Often lower costs	▪ High capital and O&M costs
Trucked Water	▪ Community-wide distribution ▪ No start-up capital cost	▪ Temporary solution; “emergency” ▪ Not approved for new water systems
Relocate Households	▪ Safe, reliable water supply	▪ Unpleasant, extreme option ▪ Loss of property value and jobs ▪ Social, familial dislocation
Well Water Quality Testing (Already in place)	▪ Water quality awareness ▪ Beneficial to blending	
Dual System	▪ Hybrid of options ▪ Treating only potable	▪ Possible consumption of contaminated source ▪ Cost of contaminated supply plus cost for POU system or trucked/bottled water, or capital dual plumbing costs

Table 20. Advantages and Disadvantages of Options for Self-Supplied Households or Local Small Water Systems

	ADVANTAGES	DISADVANTAGES
Drilling a Deeper or New Well	▪ Potentially more reliable water supply ▪ Cheaper than bottled water for households use of less than 8 gpd	▪ Potential decrease in source capacity ▪ Capital and operational costs increase with depth ▪ Temporary "quick-fix"; the nitrate plume follows groundwater movement ▪ Risk of encountering other water quality concerns at greater depths (i.e., arsenic, manganese) ▪ Pipeline costs if source area is far away from original source
Household Treatment (RO)	▪ Multiple contaminant removal ▪ Nitrate-free supply	▪ Unless instructed, risk of improper handling or maintenance of equipment
Regionalization & Consolidation	▪ Cheaper treatment costs on a customer basis	▪ High capital and O&M costs
Trucked Water	▪ Community-wide distribution ▪ No start-up cost	▪ Temporary solution; "emergency" ▪ Extra potable water storage required if a small community
Bottled Water	▪ Nitrate-free supply ▪ No start-up capital cost	▪ Inconvenience, monthly expenditure ▪ Temporary solution
Relocate Households	▪ Safe, reliable water supply	▪ Unpleasant, extreme option ▪ Loss of property value and jobs ▪ Social, familial dislocation
Well Water Quality Testing	▪ Water quality awareness ▪ Beneficial to blending	
Dual System	▪ Hybrid of options ▪ Treating only potable	▪ Possible consumption of contaminated source ▪ Cost of contaminated supply plus cost for community treatment of potable supply and capital dual plumbing costs.

5.1 Economic and Financial Costs

Affordability and sustainability are key issues for deciding if a solution is appropriate for an area. Small water systems with nitrate contamination often will be unable to support new development with limited safe water sources and unable to increase the number of connections (contributing to local economic decline). Consolidation of small water systems can increase economies of scale, and reduce technical and financial burdens by reducing total cost and distributing costs over a larger population. A community must have the technical, managerial and financial capacity to successfully implement a solution.

Moore and others (2011) discuss the cost of avoiding or treating nitrate-contaminated water suggesting that financing “is typically borne by water users and by local government and water providers, and is indirectly incurred by local and state tax payers, through tax revenues that pay for drinking water improvement projects”. Individuals currently connected to an impacted water system must pay for their own bottled water, health care services, or point-of-use treatment device. The same costs may be incurred by individuals connected to systems at risk of future contamination.

Compared to larger cities, small disadvantaged unincorporated communities and self-supplied households often have different economical solutions. The least expensive option for self-supplied households and local small water systems is often to install point-of-use reverse osmosis devices for all potable uses within their households. If a household can afford drilling a new well and if that well can tap an uncontaminated supply, that would be an attractive alternative as there is less potential health concerns from improper handling and accidental consumption of water not treated. The least expensive option for very small community water systems (serving less than 500 people) is often to install ion exchange treatment within the system configuration. For small community water systems (serving 500 to 3,300 people) the least expensive option is often to install reverse osmosis treatment. Another economical option for small water systems (serving less than 3,300 people) is often to connect to another system; however, the costs for connection include pipeline costs and are a rough estimation of connection costs. Constructing a new well also may be economical. For medium community water systems (serving 3,300 to 10,000 people) the least expensive option is often to install groundwater treatment, either ion exchange or reverse osmosis, since the estimated costs overlap. Another economical option for medium systems is to construct a new well or to construct a new well some distance from the existing system location. The economies of scale for pipeline start to prevail for the medium system sizes, and they can pipe their way out of the problem. For larger community water systems, all options are relatively equal and local conditions become more important. A larger community water system also has more opportunity to connect to surface water, with the larger population base the costs of connecting, maintaining, and treating the system can be equitably distributed without imposing too much of a financial burden.

For the final basin-wide cost analysis presented in Section 8, the following alternative water supply options were excluded from community water supply options: bottled water, trucked water, blending, and a dual water distribution system. The EPA does not allow a community water system to distribute bottled water to their consumers as a means of complying with drinking water standards.[23] In addition, new community water systems are not allowed to have trucked water delivered to their consumers and older water systems are only permitted to use this option in an emergency (CDPH, 2011). Lastly, blending was not considered in the basin-wide cost analysis, but is recommended as the first step for a community water system towards complying with the nitrate MCL. If a water system has an additional, nitrate-free or nitrate-low source (at least less than 40 mg/L as nitrate) a blending program should be set-up and permitted by CDPH, as the annual O&M costs are less than a groundwater treatment system. For a small water system (less than 3,300 people), the annualized cost of blending and drilling a new well are almost equivalent, however, they both rely on the future fate of the sources available.

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[23] National Primary Drinking Water Regulations, Title 40 §141.101

The following overall assumptions were made to estimate costs for the alternative water supply options in Table 21:

- Twenty year life of product/equipment/materials (except for household treatment – 10 years and bottled/trucked water – no capital)
- 2.15 gallons per household per day of potable water consumption (NAS, 2004)
- 3.3 persons per household
- 2010 dollars

Table 21. Summary of Approximate Alternative Water Supply Option Costs

OPTION	ESTIMATED ANNUAL COST RANGE ($/year)[1]	
	Self-Supplied Household	**Small CWS (1,000 households)**
IMPROVE EXISTING WATER SOURCE		
Blending[2]	N/A	$200,000 - $365,000
Drill Deeper Well[3]	$860 - $3,300	$80,000 - $100,000
Drill a New Well[4]	$2,100 - $3,100	$40,000 - $290,000
Community Supply Treatment[5]	N/A	$95,000 - $105,000
Household Supply Treatment[6]	$250 - $360	$223,000
ALTERNATIVE SUPPLIES		
Piped Connection to an Existing System[7]	$52,400 - $185,500	$59,700 - $192,800
Trucked Water[8]	$575	$2,850
Bottled Water[9]	$1,339	$1.34 M
RELOCATE HOUSEHOLDS[10]	$15,090	$15.1 M
ANCILLARY ACTIVITIES		
Well Water Quality Testing[11]	$15 - $50	N/A
Dual System[12]	$575 - $1,580	$550,000 - $900,000

[1] The annualized costs are shown for a single self-supplied household and a small community water systems as the system cost per year. All costs are discounted over a 20 year period at a 5% discount rate, except for the RO POU estimate and trucked and bottled water costs.

[2] Self-supplied household: blending is only considered for public water systems with more than one source. Small CWS: assumes a 14” casing well with flow rate ranges of 500-1,200 gpm and well depth of 700 feet (lower bound estimate) and 1,300-1,500 gpm and well depth of 1,000 feet (upper bound estimate). Does not include the cost of obtaining a low-nitrate source. O&M for blending estimated at $250 per acre-foot and indirect costs are estimated to be about 25% of the estimated bid costs. Kennedy Jenks (2004) “bid cost estimates primarily based on nitrate problems.

[3] Self-supplied household: the lower bound estimate for drilling a deeper well is from the EPA Yucca Mountain BID (2001) with estimated drilling costs of $50 per foot. The upper bound estimate is a quote from an experienced hydrogeologist, Chris Johnson; estimated drilling costs of $200 per foot. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh. Small CWS: The lower bound estimate for drilling a deeper well is also from the EPA Yucca Mountain BID (2001) with estimated drilling costs of $100 per foot. The upper bound estimate is also estimated as $1,000 per foot for drilling costs (Chris Johnson, 2011). Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh.

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[4] Self-supplied household: capital costs for drilling a new well were estimated from senior geologist David Abbott. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh. Small CWS: costs estimated from the 2007 EPA Drinking Water Infrastructure Needs Survey and Assessment (O&M assumed to be included in the cost model); projected to 2010 dollars using the 2010 ENR CCI. Upper bound estimates from a multiplication factor of 7 to estimate engineering fees, well demobilization, etc.

[5] Self-supplied household: community supply treatment only refers to community drinking water systems (≥15 connections). Small CWS: cost estimates from Jensen & Darby, 2011. Disposal costs were not included in the EPA costs estimates of ion exchange for arsenic removal (that was used to estimate nitrate removal).

[6] Self-supplied household: uses the 2010 USEPA Cost Estimate Tool for 1 NSF/ANSI Certified Reverse Osmosis Point-of-Use Unit. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated O&M costs. The upper bound estimates includes all lower bound costs plus public education (technical and clerical labor and printed material for all public outreach/education efforts). Assumes a 10 year lifespan for the unit and is discounted for 10 years at a 7% discount rate. Small CWS: Same assumptions as the self-supplied household unit, except for 1,000 units.

[7] Only considers the costs for installing pipeline and connection fees for connecting to an existing system that has a safe drinking water supply. Self-supplied household: the lower bound estimate assumes pipeline costs of $61 per foot for a distance of 2 miles, and $9,000 connection fee. The upper bound estimate assumes the same pipeline costs for a distance of 5 miles, and a $9,000 connection fee, plus engineering and administration costs (43% of the pipeline costs). Small CWS: same assumptions as the self-supplied household, except an estimated connection fee of $100,000 is assumed for 1,000 households.

[8] This is only the cost for a one-time delivery. Self-supplied household: assumes a 500 gallon RMR Water Truck travels from Castaic to Tulare County for a 4 hour round-trip at $100/hour and purchases 500 gallons of a local, clean drinking water supply at $0.35 per gallon. Small CWS: assumes a 7,000 gallon RMR Water Truck with the same assumptions in the self-supplied household case.

[9] Assumes Alhambra in Visalia delivers 5 gallons of water to a location in Visalia with 3 people per household. Each person consumes about 0.7 gallons per day for 365 days.

[10] The median listing prices for houses in each county (City of Salinas was used instead of Monterey County) were examined and the average listing for a house in the study area is estimated to be $188,000 (trulia.com).

[11] Well water quality test for nitrate and bacteria from PurTest sold at Home Depot ($13) and CDPH estimate of $50 for a private well nitrate sample from a State-certified laboratory. All public water systems (≥ 15 connections) are already required to sample and monitor their water.

[12] Self-supplied household: Lower bound estimate is the EPA POU Cost Estimate tool plus the monthly cost of the contaminated supply and the upper bound estimate is the cost for bottled water (Culligan – 5 gallon bottle) plus the monthly cost of the contaminated supply (Visalia Community Water Center is used for the reference, however this is not meant to suggest that Visalia CWC's water is contaminated). Small CWS: Lower bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick et al., 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 5 miles, PEX plumbing through tract type houses with raised wood flooring (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration fee. Upper bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick et al., 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 10 miles, PEX plumbing through slab houses (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration cost.

The capital and operations and maintenance (O&M) costs were researched for each alternative water supply option. The capital costs for household and community treatment include process, construction, engineering and indirect costs, but do not include planning and preliminary alternative analysis costs (EPA, 2000 and 2005). Alternative supply cost estimates were estimated in accordance with EPA cost estimation procedures (EPA, 2000) and from historical project estimates.

Capital costs were converted to annualized capital costs ($/1,000 gallons or 1 kgal) based on the following equation:

Annualized Capital Cost ($/kgal) = $\frac{\{Capital\ Cost\ (\$) * Amortization\ Factor\}}{\{Flow\ (mgd) * \frac{1000\ gal}{Mgal} * \frac{365\ days}{year}\}}$

An amortization value of 0.0802 was used that corresponds with an interest rate (i) of 5% over 20 years (N), represented by the following equation:

Amortization Factor = $\frac{i * (1+i)^N}{((1+i)^N - 1)}$

Annual O&M costs were converted to annualize O&M costs based on the following equation:

Annualized O&M Cost ($/kgal) = $\frac{O\&M Cost\ (\$)}{\{Flow\ (mgd) * \frac{1000\ gal}{Mgal} * \frac{365\ days}{year}\}}$

The total annualized cost of each alternative water supply option equals the sum of the annualized capital and O&M costs.

5.1.1 Blending

To estimate blending costs for nitrate compliance, a report written by Kennedy/Jenks was used that based “bid” cost estimates primarily on nitrate problems (Kennedy/Jenks, 2004).[24] They used two blending design cases for a 14 inch casing well with flow rate ranges of 500-1,200 gpm and 1,300-5,000 gpm, and well depths of 700 and 1,000 feet, respectively. The cost for obtaining a new nitrate-free source is not included in this cost estimate. The original capital and O&M costs are in 2003 dollars and are projected to 2010 dollars using the 2010 ENR CCI. The capital costs incorporate the costs for the basic blending facilities and are estimated to cost about $131,000 and $140,000, respectively. Indirect construction costs such as engineering, contingencies, and permitting were estimated to be about 25 percent of the estimated bid costs (Kennedy/Jenks, 2004). The O&M cost for blending water was estimated at $250 per acre-foot (af), costing approximately $132,000 and $247,000 (2003 dollars) annually for each design case. Table 22 shows the estimated blending costs, with annual costs estimated as $208,000 and $363,000, for each design case, or $1.63 and $2.84 per kilo-gallon. These blending estimates are for a 3,300 person (or 1,000 household) community, as blending is only recommended for public water systems with more than one well and the ability to obtain a nitrate-free source.

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[24] Kennedy/Jenks Consultants, *Cost of Compliance for Three Potential Perchlorate MCLs*, June 2004.

Table 22. Estimated Costs for Blending

Itemized Cost	**Low Estimate**[1]	**High Estimate**[2]
2003 Capital Cost[3]	$131,000	$140,000
Indirect Construction Cost[4]	$32,750	$35,000
2010 Capital Cost[5]	$432,000	$462,000
2010 O&M Cost[6]	$174,000	$326,000
Annualized Cost ($/kgal)[7]	$1.63	$2.84
Annualized Cost ($/year)[8]	**$208,000**	**$363,000**

[1] 14" casing well at 700' deep, 500 to 1,200 gpm. Two sources are assumed per system. A single blending station is assumed for each source. These costs are based on similar projects implemented by Kennedy/Jenks, primarily for nitrate.

[2] 14" casing well at 1,000' deep, 1,300 to 1,500 gpm. Two sources are assumed per system. A single blending station is assumed for each source. These costs are based on similar projects implemented by Kennedy/Jenks, primarily for nitrate.

[3] Capital costs include the construction "bid" costs for constructing the blending facilities.

[4] 25% indirect construction costs.

[5] The 2003 Capital Costs plus 25% Indirect Construction Cost and projected to 2010 costs using the 2010 ENR CCI.

[6] A major O&M cost is the cost of obtaining low-nitrate blending water. These O&M costs assume that there is already an uncontaminated source available for blending. The O&M costs were developed for electrical power, labor, maintenance materials, resin replacement, and monitoring. Labor rates were estimated at an average of $40 per hour, electricity rates were estimate at $0.12/kWh and an annual allowance for maintenance materials was estimated at 1 percent of total capital costs. The average O&M cost within the well range was chosen and projected to 2010 costs using the 2010 ENR CCI.

[7] The cost is annualized over a 20 year period with a 5% annual interest rate and expressed as dollar per kilogallon produced.

[8] The cost is annualized over a 20 year period with a 5% annual interest rate.

5.1.2 Drilling a Deeper Well

The lower bound cost estimates for drilling a deeper well are from a Background Information Document (BID) from EPA[25] that provides well drilling cost estimates (EPA, 2001). For a domestic well (assumed 10 gpm, 8 inch casing well), the drilling costs are about $50 per foot; and for a public supply well (assumed 700 gpm, 14 inch casing well), the drilling costs are about $110 per foot. Chris Johnson, a principal hydrogeologist, advises that drilling a deeper well can cost almost as much as drilling a new well and provided the upper bound cost estimates of $200

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[25] Yucca Mountain BID, EPA, assuming it's June 5, 2001, but not sure; available at: http://www.epa.gov/rpdweb00/docs/yucca/bid/yucca_bid_060501_ch1.pdf

per foot for a domestic well and $1,000 per foot for a public supply well (Johnson, 2011). Table 23 shows the estimated costs for drilling a deeper well based on these two references.

Table 23. Estimated Costs for Drilling a Deeper Well[1]

Itemized Cost	Self-Supplied Household	Public Water System (1,000 hhld)
Drilling Cost ($/foot)	$50 - $200	$110 - $1,000
O&M Cost	$62	$82,000
Annualized Cost ($/kgal)	$6.76 - $25.61	$0.65 - $0.77
Annualized Cost ($/yr)	**$860 - $3,300**	**$84,000 - $98,000**

[1] The lower bound estimates are from the USEPA Yucca Mountain BID Document: *Well Drilling and Pumping Costs* (2001). A domestic well is assumed to be a 10 gpm, 8 inch casing well, originally 300 feet deep and deepened to 500 feet. A public supply well is assumed to be a 7000 gpm, 14 inch casing well, originally 500 feet deep and deepened to 700 feet.

5.1.3 Drilling a New Well

The annualized total cost for drilling a new domestic well is based on cost estimates provided by an experienced senior geologist, and is shown in Table 24. The EPA 2007 Survey and Assessment was used for estimating the costs for drilling a new public supply well, shown in Table 25. New public supply well costs include pump and appurtenances, but do not include well houses. The Survey and Assessment provides the following cost functions for new wells and for rehabilitating existing wells:

$$New\ Well\ Cost = e^{13.6502} * D^{0.56445}$$

$$Well\ Rehabilitation\ Cost = e^{11.72961} * D^{1.59738}$$

D is the design capacity of the well in millions of gallons per day, and *e* represents the exponential function (approximately 2.72).[26]

The annual O&M is assumed to be included in the model. With these functions, rough cost estimates can be made for the lower bound of system categories and a multiplication factor of

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[26] Goldstein, Lay, Schneider, and Asmar, *Brief calculus and its applications,* 11th ed., Prentice-Hall, 2006.

seven is applied to estimate the upper bound cost. Table 25 estimates the low and high cost ranges for a new public supply well and Table 26 estimates the low and high cost ranges for public supply well rehabilitation.

Table 24. Annualized Total Cost Ranges for Drilling a New Domestic Well

Option	**Drill a New Well**[1]
Initial Capital Cost ($/hhld)	$25,000 - $40,000
Annual O&M Cost ($/hhld)	$60
Total Annualized Cost ($/kgal)	$16.17 - $25.59
Total Annualized Cost ($/hhld)	**$2,100 - $3,300**

[1] Initial Capital Cost Estimates from David W. Abbott, Senior Geologist at Todd Engineers (Personal communication, 2010). Annual O&M Estimate: Assumed 300 foot well depth, 0.6 pump efficiency, and $0.15/kWh. Annualized over 20 years.

Table 25. Annualized Total Cost Ranges for Drilling a New Public Supply Well

EPA System Size Classification	**Low Cost Range for a New Well ($/kgal-yr)**[1]	**High Cost Range for a New Well ($/kgal-yr)**[2]
Very Small (25 - 500 people)	$0.44 - $1.60	$3.11 - $11.17
Small (501 - 3,300 people)	$0.20 - $0.44	$1.38 - $3.11
Medium (3,301 - 10,000 people)	$0.12 - $0.20	$0.86 - $1.38
Large (10,001 - 100,000 people)	$0.05 - $0.12	$0.32 - $0.86

[1] EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment.
[2] EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment multiplied by a factor of 7 to estimate engineering fee, well demobilization, etc.

Table 26. Annualized Total Cost Ranges for Public Supply Well Rehabilitation

EPA System Size Classification	**Low Cost Range for Well Rehabilitation ($/kgal-yr)**[1]	**High Cost Range for Well Rehabilitation ($/kgal-yr)**[2]
Very Small (25 - 500 people)	$0.01	$0.01 - $0.07
Small (501 - 3,300 people)	$0.01 - $0.03	$0.07 - $0.22
Medium (3,301 - 10,000 people)	$0.03 - $0.06	$0.22 - $0.42
Large (10,001 - 100,000 people)	$0.06 - $0.22	$0.42 - $1.62

[1] EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment.
[2] EPA 2007 Drinking Water Infrastructure Needs Survey and Assessment multiplied by a factor of 7 to estimate engineering fees and other contingencies.

5.1.4 Community Treatment

The estimated costs for system application of ion exchange and reverse osmosis are shown in Table 27. The economies of scale exist with ion exchange and reverse osmosis treatment systems as the cost per kilo-gallon decreases with increasing capacity. The cost per unit of produced water decreases as system size increases; however, larger treatment systems incur higher total capital and O&M costs. Ion exchange is the cheaper option comparatively (Jensen & Darby, 2011).

Table 27. Annualized Total Cost Ranges for Groundwater Treatment Systems[1]

EPA System Size Classification	**Annualized Total Cost Range for Ion Exchange [$/kgal-yr]**[2]	**Annualized Total Cost Range for Ion Exchange [$/yr]**[2]		**Annualized Total Cost Range for Reverse Osmosis [$/kgal-yr]**	**Annualized Total Cost Range for Reverse Osmosis [$/yr]**[2]
Very Small (25 - 500 people)	$4.60 - $0.62	$2,000 - $285,000		$19.16 - $0.69	$2,300 - $1.2M
Small (501 - 3,300 people)	$2.73 - $0.34	$21,000 - $1.09M		$1.34 - $0.58	$36,000 - $533,000
Medium (3,301 - 10,000 people)	$2.04 - $0.36	$143,000 - $2.4M		$3.39 - $1.35	$537,000 - $4.0M
Large (10,001 - 100,000 people)	$1.81 - $0.22	$258,000 - $20.1M		$3.67 - $0.73	$855,000 - $40.8M

[1] Cost information is an excerpt from Drinking Water Treatment Report: *Treatment Cost Analysis* (Jensen & Darby, 2011).

[2] Disposal costs were not included in the EPA cost estimates of IX for arsenic removal (used to estimate nitrate removal).

EPA’s 2007 Drinking Water Infrastructure Needs Survey and Assessment estimate the cost for a SCADA system by the following equation:

$$Cost\ of\ SCADA = e^{7.7799} * population^{0.48453}$$

The *e* is the exponential function (approximately 2.72).[27] The lower bound annualized cost of SCADA infrastructure was estimated and is shown in Table 28. As the system size increases the cost for SCADA becomes more affordable.

Table 28. Lower Bound Annualized Cost of SCADA Infrastructure[1]

EPA System Size Classification	Annualized Total Cost for SCADA Infrastructure [$/kgal-yr]	Annualized Total Cost for SCADA Infrastructure [$/yr]
Very Small (25 - 500 people)	$4.99	$11,400
Small (501 - 3,300 people)	$1.06	$49,000
Medium (3,301 - 10,000 people)	$0.42	$116,000
Large (10,001 - 100,000 people)	$0.23	$633,000

[1] EPA Drinking Water Infrastructure Needs Survey and Assessment (2007).

5.1.5 Household Treatment

The 2010 USEPA POU/POE cost model was used to estimate the costs for installing a reverse osmosis POU device. The cost model assumes 100 gallons per person per day, 2.6 people per household, a discount rate of 7%, and a discount period of 10 years (the lifetime of the unit) (USEPA, 2010). The cost model includes equipment installation, laboratory analyses, indirect capital costs, equipment maintenance, and public education and outreach. Table 29 shows the estimated cost per household for installing a reverse osmosis POU unit for one household and for 1,000 households. The lower bound estimate does not incorporate public education and outreach that is required for systems using a POU device for emergency purposes to comply with drinking water quality standards (discussed in Section 8). For a self-supplied household it is cost-effective to not incorporate public education and outreach, however, for a 1,000 household (or connection) public water system it would be beneficial to incorporate public outreach to educate the user and ensure proper procedures are followed.

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[27] Goldstein, Lay, Schneider, and Asmar, *Brief calculus and its applications,* 11th ed., Prentice-Hall, 2006.

Table 29. USEPA Reverse Osmosis POU Device Cost Estimates

Options	RO POU Cost Estimate (Single Household)[1]	RO POU Cost Range (1,000 Household System)[1]
Initial Capital Cost ($/hhld)	$406 - 1,981	$493 - $494
Annual O&M Cost ($/hhld)	$197 - $1,781	$144 - $145
Total Annualized Cost ($/kgal/hhld)	$3.01 - $24.85	$2.52 - $2.53
Total Annual Cost ($/hhld)	**$250 - $2,038**	**$214 - $215**

[1] Uses the 2010 USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all listed above and public education (technical and clerical labor and printed material for all public outreach/education efforts). The tool allows for economies of scale.

For comparison, a quote from Culligan estimates a typical nitrate filter to cost about $360 per year including maintenance for one household (Culligan, 2011), cost details are shown in Table 30. The total annualized cost ($/kgal) is greater than the EPA cost model estimates because of the difference in maximum potable water consumption. Culligan also rents RO POU devices for about $26 to $36 per month, plus filter replacement and service fees (Culligan, 2011). An RO POU device is estimated to cost between$250 and $360 annually discounted over 10 years at a rate of 0.07. For households unable to pay the initial capital, the next best option would be to rent a NSF/ANSI certified RO POU device for at least $430 per year (plus filter replacement and service fees).

Table 30. Culligan Reverse Osmosis POU Device Cost Estimates

Options	RO POU Cost Range (1 hhld)[1]
Initial Capital Cost ($/hhld)	$1,200
Annual O&M Cost ($/hhld)	$191
Total Annualized Cost ($/kgal/hhld)	$39.67
Total Annual Cost ($/hhld)	**$362**

[1] Culligan offers a lifetime warranty on the membrane and pre-filters. It costs about $1,100 to $1,200 to purchase the unit and the pre-filter needs to be replaced every 18 months and the main filter needs to be replaced every 3 years (all factored into the costs listed). The maximum potable water consumption of 25 gallons and a discount rate of 0.07 and discount period of 10 years are assumed.

5.1.6 Connect to an Alternative System

Most costs for a system to connect to an alternative system are for installing a pipeline. An estimated pipeline cost of $61 per foot (Granite Ridge Regional Water Supply Project Feasibility Study, 2010) and an estimated connection fee of $100,000 are assumed for estimating the costs of connecting to an alternative system. Table 31 represents the annualized cost range estimates for a system with 1,000 connections to connect to an alternative system. The optimistic estimate (or lower bound) is solely pipeline costs and a connection fee and the pessimistic estimate (or upper bound) includes pipeline costs, a connection fee, and engineering and administration costs as 43% of the capital.[28] These costs are essentially the same if a single household connects to a public water system (estimates shown in Table 31 used a $9,000 connection fee for a self-supplied household); however, the party responsible for the costs would vary by system size and acquisition policies. More involved mergers with a larger system will often require significant additional upgrades to the smaller distribution system.

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[28] Kettleman Community Services District Planning Study Project No. 1610009-005: *Update of Proposed Surface Water Treatment Plant and Commercial Tank Facility* (March, 2011).

Table 31. Estimated Annualized Cost Ranges for a System with 1,000 Connections to Connect to an Alternative System

Pipeline Distance (miles)	Capital Costs[1]	Engineering & Admin. Costs[2]	Total Annualized Cost ($/year)[3]	Annualized Cost ($/kgal)[4]	Annualized Cost ($/hhld)[5]
0.5	$161,040	$69,200	$20,900 - $26,500	$164 - $207	$20.90 - $26.50
2	$644,160	$277,000	$59,700 - $81,900	$467 - $641	$59.70 - $81.90
5	$1,610,400	$692,500	$137,200 - $192,800	$1,074 - $1,509	$137.20 - $192.80
10	$3,220,800	$1,384,900	$266,500 - $377,600	$2,086 - $2,956	$266.50 -$377.60

[1] Pipeline costs at $61 per foot for 1,000 households.
[2] Excerpt from Kettleman City Proposed Surface Water Treatment Plant and Commercial Tank Facility (March, 2011). 43% of the Subtotal: 15% Construction Contingencies; 2% Construction Application, CDPH Information & Labor and Compliance Monitoring; 2% Environmental Documentation & Legal Review; 10% Design & Project Bidding; 7% Project Administration; 5% Project Inspection; and 2% Project Surveying & Geotechnical Testing.
[3] Lower bound includes pipeline and an estimated $100,000 connection fee. Upper bound includes pipeline, an estimated $100,000 connection fee, and engineering and administration costs. Costs are discounted over 20 years at a 5% discount rate.
[4] Assumes a consumption rate of 350 gallon per household per day.
[5] Total annualized cost divided by 1,000 households.

5.1.7 Trucked Water

An estimate from RMR Water Trucks (RMR Trucks, 2011) for providing their water trucks for service is used for estimating the delivered trucked water costs:

($100/hr truck driver)* (x hr travel time) + (truck size (gal))*($0.xx/gal of nearby water supply)

Estimates are provided for a small community public water system serving 1,000 households and for a single household located in Tulare County. Using an RMR 7,000 gallon water truck (traveling for 4 hours round-trip) and purchasing a nearby water supply at $0.35 per gallon, the estimated cost for providing a community with trucked water in Tulare County is about $2,850, or $410/kgal. Assuming one household uses about 2.25 gallons per day[29], 1,000 households (or a small community water system) would receive water for about three days ($2.85/household). To provide one household with water, a 500 gallon RMR truck would cost $575 ($1,150/kgal), and would provide the household with water for 222 days (assuming storage is available).

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[29] NAS Hydration Study Estimate – 3.3 people per household

5.1.8 Bottled Water

To estimate the cost of bottled water, the National Academy of Sciences Hydration Study (2004) was used, assuming 3.3 people per household and predicting about 2.15 gallons per household-day for potable uses. Vended or bottled water can cost $0.25 to $1.30 per gallon, not including transportation costs (Moore et al., 2011). A common low price for water delivered near the city of Visalia by Alhambra Water is a 5 gallon bottle at $1.63 per gallon (Alhambra Water, 2010). The annual cost for a household receiving Alhambra Water is about $1,260. For accuracy and consistency, this cost estimate is used as the cost of bottled water in this report.

5.1.9 Relocate to Area with Better Water Supply

To estimate the costs of relocating a community to an area with better water supply, the true market value of houses in each respective county is evaluated. The range of average listing prices (Trulia, 2011) for houses in each county is in Table 32 and the median value of average ranges is used to estimate the cost of relocating a single household. To better represent Salinas Valley, the City of Salinas' average listing prices will be used, instead of Monterey County. Cost scenarios for relocating households are shown in Table 33, and the average cost for the study area to relocate one household is $188,000. Using this average, it would cost about $5 billion to relocate the susceptible population on self-supplied and local small water systems (about 27,000 households). It is estimated to cost $37.6 million to relocate 200 households per county. The costs for relocating a household will differ slightly between a homeowner and a renter. Renters should be cheaper to move if the County condemns the property and there may also be less attachment or sentimental value to the home. However, the total loss involved in relocation is probably similar for both homeowners and renters.

Table 32. Average Listing Prices for Homes in Study Area Counties

County	Range of Average Listing Prices for Houses ($1,000)[1]
Fresno	$158 - $193
Kern	$137 - $167
Kings	$136 - $166
Tulare	$153 - $188
Monterey (City of Salinas)	$525 - $642 ($261 - $319)

[1]Trulia, Inc. *Range of Average House Listing Prices* (August, 2011)

Table 33. The Estimated Cost for Relocating Households

County	Single Household Relocation ($1,000)[1]	200 Household Relocation ($1,000)[1]
Fresno	$176	$35,100
Kern	$152	$30,400
Kings	$151	$30,200
Tulare	$171	$34,100
City of Salinas	$290	$116,700
Study Area Average	**$188**	**--**

[1] Trulia, Inc. The median of the average range of listing prices (August, 2011).

5.1.10 Dual Water Distribution System

A dual water distribution system would require that a household continue paying for their contaminated water, using it only for non-potable uses, to purchase an alternative supply, and a separate smaller potable plumbing system. Four alternative forms of a dual water distribution system are: 1) purchased bottled or vended water; 2) a POU treatment device; 3) trucked in potable water or; 4) a water system treatment for the potable supply delivered through a separate potable distribution network. Given the nature of trucked water and the need for storage, it is usually not a feasible alternative for a dual water distribution system. To estimate the costs of a dual water distribution system, an average monthly residential water rate of $27 is assumed for the non-potable supply cost.[30] A dual system including the purchase of 5 gallon bottles would cost approximately $1,582 annually per household. A dual system including the

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[30] California Water Company – Visalia, $27 a month for using 6,000 square feet or less per month.

purchase of a POU device would cost about $574 to $686 annually per household, ranging from the lower bound USEPA POU Cost Model value to the Culligan POU quote.

If a dual water distribution system was installed for an existing 1,000 household water system, the total costs would include the cost for the contaminated supply, treating the potable supply, installing a distribution system to each system, and re-plumbing each household for a new supply distribution for the bathroom and kitchen. Table 34 shows rough estimates for the cost of installing a dual water distribution system for a 1,000 household system. The total annualized cost per household is estimated to cost between $550 and $900.

Table 34. Estimated Annualized Cost Ranges for a Dual Water Distribution System

Annualized Costs[1]	**Cost Range for a Dual Water Distribution for 1,000 Household Water System**[2]
Contaminated Supply Costs ($/year)[3]	$324,000
Treatment Costs ($/year)[4]	$645,000
Pipeline Costs ($/year)[5]	$130,000 - $260,000
Re-plumbing Costs ($/year)[6]	$200,000 - $320,000
Engineering & Administration Fees ($/year)[7]	$165,000 - $270,000
Total Annualized Cost ($/year)[8]	$550,000 - $900,000
Household Total Annualized Cost ($/hhld-year)[9]	$550 - $900

[1] Costs are discounted at a 5% discount rate, over a 20 year period.

[2] Assumes a water system serves 1,000 households, with 3.3 people per household, and uses 0.20 million gallons of potable water per day, including showering and toilet flushing (112 gallons per capita per day) (Gleick et al., 2003).

[3] Monthly water supply cost for California Water Company in Visalia.

[4] Costs for treating 0.20 mgd of water using an ion exchange treatment system - includes O&M costs (Jensen & Darby, 2011).

[5] Assumes 6” pipe costs $61 per foot and does not include excavation costs. Lower bound estimate uses 5 miles of pipeline and upper bound estimate uses 10 miles of pipeline. (Granite Ridge Regionalization Feasibility Study, 2010).

[6] Rough cost estimates provided by ZURN and an experienced plumber for PEX piping to be installed in a 1200 sf 3 bed, 2 bath house within the kitchen and both bathrooms. The lower bound estimate is for a tract type house with raised wood floors (ease of “popping” pipes through the floor cabinets), and the upper bound estimate is for a slab house (requiring the sheet rock to be cut, patched and painted after installation). This is a rough estimate and each house will vary based on chosen plumbers site estimate.

[7] Excerpt from Kettleman City Proposed Surface Water Treatment Plant and Commercial Tank Facility (March, 2011). 43% of the Subtotal (treatment, pipeline, and re-plumbing costs): 15% Construction Contingencies; 2% Construction Application, CDPH Information & Labor and Compliance Monitoring; 2% Environmental Documentation & Legal Review; 10% Design & Project Bidding; 7% Project Administration;

5% Project Inspection; and 2% Project Surveying & Geotechnical Testing.

[8] Total annualized cost for all items. Lower bound estimate provides costs for a 1,000 connection system with a service area having a 5 mile distance and consisting of only tract type houses (the economies of scale involved in community tract type housing is ignored here, but could be represented in a true situation where dual plumbing occurs for a whole development). Upper bound estimate provides costs for a 1,000 connection system with a service area having a 10 mile distance and consisting of only slab houses.

[9] Total annualized cost per household.

5.1.11 Well Water Quality Testing

PurTest sells a water test kit for bacteria and nitrate based on EPA methods for $13 with a basic knowledge booklet that could be used for domestic well users.[31] The Environmental Health Investigations Branch of CDPH estimate certified laboratory water quality tests to cost approximately $50 for testing a private well (CDPH, 2000). It is recommended to sample a private well at least once a year, between April and July when nitrate levels are generally the highest (CDPH, 2000).

These two estimates are the lower and upper bound estimates for domestic well water quality testing. County-specific estimates for a State-certified laboratory can be found on the CDPH Environmental Laboratory Accreditation Program (ELAP) website.

5.1.12 Summary of Alternative Water Supply Costs

The economic feasibility of each option will vary based on the effectiveness, benefits, savings, and costs expected from a candidate system. This section only summarizes the expected costs for alternative water supply options, but a true engineering analysis will include economic feasibility studies examined over a project's lifetime.

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[31] Available for purchase at $13 through The Home Depot, available at: http://www.homedepot.com/webapp/wcs/stores/servlet/HomePageView?langId=-1&storeId=10051&catalogId=10053

The alternative water supply options for providing a self-supplied household with low-nitrate water supplies all year ranked from least expensive to most expensive typically are to 1) install a POU RO unit; 2) drill a deeper well; 3) install a dual water system; 4) purchase bottled water; 5) drill a new well; 6) relocate the household; and 7) install pipeline and connect to an existing system. The estimated costs for self-supplied household alternative water supply options are shown in Table 35.

The alternative water supply options for providing a small community water system (serving 1,000 households) with low-nitrate supplies all year ranked from least expensive to most expensive are typically to 1) drill a new well; 2) install a pipeline and connect to an existing system; 3) drill a deeper well; 4) implement a community groundwater treatment system; 5) blend sources; 6) provide households with POU RO units; 7) construct a dual water distribution system; 8) purchase bottled water; and 9) relocated households. The estimated costs for alternative water supply options for a small community water system are shown in Table 36. The analysis performed here is general and includes many necessary assumptions. The costs for each option need to be done on a system specific basis before selecting the most economical option.

The lifetime of each alternative will vary depending on the existing water quality, soil properties, water usage, and existing source supply. An alternative should be evaluated on the least cost and lifetime of the system before choosing the best option for implementation. If a system blends sources for complying with nitrate, the duration of providing nitrate-compliant water will last as long as the low-nitrate source remains low and proper source ratios are maintained. Nitrate contamination and degradation is expected to worsen over the next few decades and it is reasonable to expect that over time a low-nitrate source will approach the MCL. If an existing well is drilled deeper into a different aquifer, the lifetime of the clean supply will depend on the time it takes for the nitrate plume to reach the new depth. If a new well is properly designed, constructed, developed and completed it can last for up to 50 years (Harter, 2003); however, pumping from a new well can quickly draw down an aquifer and draw nitrate to percolate into the existing clean supply. Depending on the type of treatment chosen (IX or RO), a community treatment system can last from 5 to 20 years (membrane and resin lifetime will vary with water quality and pretreatment measures). With proper maintenance and replacement of filters, a household treatment system can last for up to 10 years. Connecting to an alternative system ensures that future problems of nitrate contamination (or other water quality contaminants) can be managed easily from the economies of scale. Switching to surface water shifts the problem of nitrate contamination in groundwater to other surface water contaminations (i.e., *Giardia lamblia* and *Cryptosporidium parvum*). Constructing a dual water distribution system on a community water system scale treats less water, expends less energy and conserves resources.

Table 35. Summary of the Estimated Alternative Water Supply Costs for Self-Supplied Households

Option	**Estimated Annual Cost Range For a Self-Supplied Household**[1]
IMPROVE EXISTING WATER SOURCE	
Blending[2]	N/A
Drill Deeper Well[3]	\$860 - \$3,300
Drill a New Well[4]	\$2,100 - \$3,300
Community Supply Treatment[5]	N/A
Household Supply Treatment [6]	\$250 - \$360
ALTERNATIVE SUPPLIES	
Pipeline and Connection to an Existing System[7]	\$52,400 - \$185,500
Trucked Water [8]	\$575
Bottled Water[9]	\$1,339
RELOCATE HOUSEHOLDS[10]	\$15,090
ANCILLARY ACTIVITIES	
Well Water Quality Testing[11]	\$15 - \$50
Dual Water System[12]	\$574 - \$1,582

[1] All costs are discounted over a 20 year period at a 5% discount rate, except for the RO POU estimate and trucked and bottled water costs.

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[2] Blending is only considered for public water systems with more than one source.

[3] The lower bound estimate is from the EPA Yucca Mountain BID (2001) with estimated drilling costs of $50 per foot. The upper bound estimate is a quote from an experienced hydrogeologist, Chris Johnson; estimated drillings costs of $200 per foot. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh.

[4] Capital costs estimated from senior geologist David Abbott. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh.

[5] Community supply treatment only refers to community drinking water systems (≥15 connections).

[6] Uses the 2010 USEPA Cost Estimate Tool for 1 NSF/ANSI Certified Reverse Osmosis Point-of-Use Unit. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all lower bound costs plus public education (technical and clerical labor and printed material for all public outreach/education efforts). Assumes a 10 year lifespan for the unit and is discounted for 10 years at a 7% discount rate.

[7] Only considers the costs for installing pipeline and the connection fees for connecting to an existing system that has a safe drinking water supply. The lower bound estimate assumes pipeline costs of $61 per foot for a distance of 2 miles, and a $9,000 connection fee per household. The upper bound estimate assumes pipeline costs of $61 per foot for a distance of 5 miles, and a $9,000 connection fee plus engineering and administration costs (43% of the pipeline costs).

[8] Assumes a 500 gallon RMR Water Truck travels from Castaic to Tulare County for a 4 hour round-trip at $100/hour and purchases 500 gallons of a local, clean drinking water supply at $0.35 per gallon. A one-time 500 gallons cost. Does not include the cost for storage.

[9] Assumes Alhambra in Visalia delivers 5 gallons of “Crystal Fresh” water to a location in Visalia with 3 people per household. Each person consumes about 0.7 gallons per day for 365 days.

[10] The median listing prices for houses in each county (City of Salinas was used instead of Monterey County) were examined and the average listing for a house in the study area is estimated to be $188,000 (trulia.com).

[11] Well water quality test for nitrate and bacteria from PurTest sold at Home Depot ($13) and CDPH estimate of $50 for a private well nitrate sample from a State-certified laboratory. All public water systems (≥ 15 connections) are already required to sample and monitor their water.

[12] Lower bound estimate is the EPA POU Cost Estimate tool plus the monthly cost of the contaminated supply and the upper bound estimate is the cost for bottled water (Culligan – 5 gallon bottle) plus the monthly cost of the contaminated supply (Visalia Community Water Center is used for the reference, however this is not meant to suggest that Visalia CWC’s water is contaminated).

Table 36. Summary of the Estimated Alternative Water Supply Costs for a Small Water System (1,000 households)

Option	**Estimated Annual Cost Range For a Small Water System (1,000 hhlds)**[1]
IMPROVE EXISTING WATER SOURCE	
Blending[2]	\$200,000 - \$365,000
Drill Deeper Well[3]	\$80,000 - \$100,000
Drill a New Well[4]	\$40,000 - \$290,000
Community Supply Treatment[5]	\$95,000 - \$105,000
Household Supply Treatment[6]	\$223,000
ALTERNATIVE SUPPLIES	
Pipeline and Connection to an Existing System[7]	\$59,700 - \$192,800
Trucked Water[8]	\$2,850
Bottled Water[9]	\$1.34 M
RELOCATE HOUSEHOLDS[10]	\$15.1 M
ANCILLARY ACTIVITIES	
Dual Water Distribution System[11]	\$550,000 - \$900,000

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[1] All costs are discounted over a 20 year period at a 5% discount rate, except for the RO POU estimate and trucked and bottled water costs.

[2] A 14" casing well with flow rate ranges of 500-1,200 gpm and well depth of 700 feet (lower bound estimate) and 1,300-1,500 gpm and well depth of 1,000 feet (upper bound estimate). Does not include the cost of obtaining a low-nitrate source. O&M for blending estimated at $250 per acre-foot and indirect costs are estimated to be about 25% of the estimated bid costs. Kennedy/Jenks (2004) "bid" cost estimates primarily based on nitrate problems.

[3] The lower bound estimate is from the EPA Yucca Mountain BID (2001) with estimated drilling costs of $110 per foot. The upper bound estimate is a quote from an experienced hydrogeologist, Chris Johnson; estimated drillings costs of $1,000 per foot. Annual O&M costs estimated using a pumping well energy equation and assuming $0.15/kWh.

[4] Costs estimated from the 2007 EPA Drinking Water Infrastructure Needs Survey & Assessment (O&M assumed to be included in the cost model); projected to 2010 dollars using the 2010 ENR CCI. The upper bound estimate is from applying a multiplication factor of 7 to estimate engineering fees, well demobilization, etc.

[5] Cost estimates from Jensen & Darby, 2011. Disposal costs were not included in the EPA cost estimates of ion exchange for arsenic removal (that was used to estimate nitrate removal).

[6] Uses the 2010 USEPA Cost Estimate Tool for 1,000 NSF/ANSI Certified Reverse Osmosis Point-of-Use Unit. The lower bound estimate includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, and contingency) and all associated operations and maintenance costs. The upper bound estimate includes all lower bound costs plus public education (technical and clerical labor and printed material for all public outreach/education efforts). Assumes a 10 year lifespan for the unit and is discounted for 10 years at a 7% discount rate.

[7] Only considers the costs for installing pipeline and connection fees for connecting to an existing system that has a safe drinking water supply. The lower bound estimate assumes pipeline costs of $61 per foot for a distance of 2 miles, and an estimated $100,000 connection fee per household. The upper bound estimate assumes pipeline costs of $61 per foot for a distance of 5 miles, and an estimated $100,000 connection fee plus engineering and administration costs (43% of the pipeline costs).

[8] Assumes a 7,000 gallon RMR Water Truck travels from Castaic to Tulare County for a 4 hour round-trip at $100/hour and purchases 7,000 gallons of a local, clean drinking water supply at $0.35 per gallon.

[9] Assumes Alhambra in Visalia delivers 5 gallons water to a location in Visalia with 3 people per household. Each person consumes about 0.7 gallons per day for 365 days.

[10] The median listing prices for houses in each county (City of Salinas was used instead of Monterey County) were examined and the average listing for a house in the study area is estimated to be $188,000 (trulia.com).

[11] Lower bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick et al., 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 5 miles, PEX plumbing through tract type houses with raised wood flooring (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration fee. Upper bound estimate is the cost of the contaminated supply, the cost for treating 0.20 mgd (Gleick et al., 2003) for 1,000 households assuming 3.3 people per household, a system pipeline distribution distance of 10 miles, PEX plumbing through slab houses (2 bathrooms and 1 kitchen is re-plumbed per house), and a 43% engineering and administration fee.

5.2 Least Cost Management

Most alternative water supply option costs largely depend on the size of the system. Even if a system receives assistance in financing the capital costs for an alternative solution, such as treatment, the solution's sustainability can be threatened by high annual O&M costs. To assess the lasting viability of each alternative, costs estimates shown above are compared broadly, and least cost management alternatives are highlighted. The least cost management discussion is divided into domestic well water systems and public water systems.

5.2.1 Self-Supplied Households or Local Small Water Systems

The estimated costs for alternative solutions for self-supplied households and local small water systems are shown in Table 37 with the total annualized costs displayed per household and per kilo-gallon of water. The primary feasible options available to a household or local small water system are to purchase bottled water, install a POU device, drill a new well, or deepen an existing well. The least cost alternative for households is to install a reverse osmosis POU treatment device, estimated to cost $250 per year (not including any public outreach or education). The second least expensive alternative for households is to install a POE device; however, currently no POE devices are NSF/ANSI certified for removing nitrate from drinking water (the estimate given in Table 37 is for treating Radium). The next least expensive option is to drill a deeper well; however, the user must continually test and monitor the well to make sure the nitrate contamination does not reach the new depth. Figure 27 shows the annualized cost curves of each option and highlights the cost-effective option for expected water use or consumption. If a household only desires to have potable water be nitrate-free, a POU device is the less expensive solution. However, if a household desires to treat more than 60 gallons of water per day a POU device is no longer cost-effective, and drilling a new well is preferred. The cost curves do not represent the actual maximum potable water consumption per day per filter pumping capacity, which varies by manufacturer (i.e., Culligan has a maximum of 25 gallons per day).

Table 37. Estimated Household Costs for Alternative Solutions for Self-Supplied Households or Local Small Systems

Option	Bottled Water[1]	Drill a New Well[2]	Drill a Deeper Well[3]	POE[4]	POU[5]
Initial Capital Cost ($/hhld)	0	$40,000	$25,000	$2,222	$406
Annual O&M Cost ($/hhld)	0	$60	$232	$109	$197
Total Annualized Cost ($/kgal)	$1,630	$25.59	$17.52	$5.12	$3.01
Total Annualized Cost ($/hhld)	**$1,260**	**$3,300**	**$2,238**	**$397**	**$250**

[1] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles. Assumed units of water consumption from NAS Hydration Study.

[2] Initial Capital Cost Estimate: Upper bound estimate of David W. Abbott, Senior Geologist at Todd Engineers (Personal communication, 2010). Annual O&M Estimate: Assumed 300 foot well depth, 0.6 pump efficiency, and $0.15/kWh. Annualized over 20 years.

[3] Initial Capital Cost Estimate: Average estimate of EPA Yucca Mountain BID and Chris Johnson, hydrogeologist (Personal communication, 2011). Annual O&M Estimate: Assumed 500 foot well depth (originally 300 feet, drilled 200 feet deeper), 0.6 pump efficiency, and $0.15/kWh.

[4] Uses the USEPA Cost Estimate Tool for an NSF/ANSI Certified POE Unit for treating Radium. Includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs.**A POE Unit has not been certified for water systems to distribute so the EPA Tool does not have a Unit capable of treating nitrates for estimating the cost. Future research is recommended for evaluating the true cost of a POE device.

[5] Uses the USEPA Cost Estimate Tool for 1 NSF/ANSI Certified ROU Unit for treating Nitrate. Includes unit purchase, installation, scheduling time, indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Does not include public education/outreach costs.

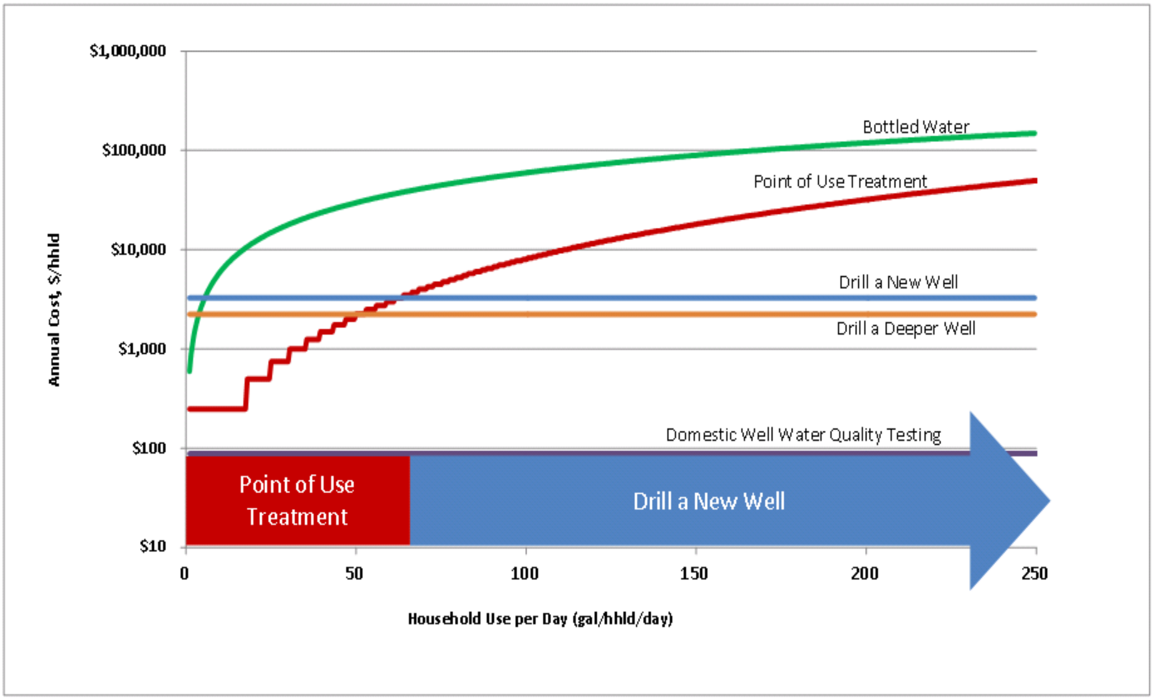

Figure 27. Annualized Total Household Cost for Household Self-Supplied and Local Small Water System Alternatives

5.2.2 Public Water Systems

The minimum and maximum ranges or cost estimates for public water system categories appear in Table 38 and Table 39, and the compiled cost ranges are shown in Table 40. The annualized low and high cost in dollar per kilo-gallon ($/kgal) for each alternative is evaluated by EPA – designated water system size, (Table 39 and Table 39). For the low cost case, a groundwater treatment facility is the cheapest alternative per kilo-gallon for very small and small systems. For medium systems, the cost for installing a pipeline to a nearby system becomes very cost-effective, with groundwater treatment and drilling a new well as the next least cost options. POU RO devices are only cost-effective for systems with less than 3,300 people; this coincides well with the 3-year emergency regulations (discussed in Section 8). Bottled water costs more than all alternatives (per thousand gallons). Table 39 and Table 39 represent connecting to a better water system only as the pipeline costs and the connection costs are not included in the annualized cost.

For the high cost case, drilling a new well, installing a pipeline to a larger system, or installing a POU RO device are the cheaper options for very small systems. For small and medium systems, a pipeline to a larger system is the cheapest option per kilo-gallon, but depends on the distance to a nearby system as only two miles of pipeline are assumed. The next best options for a small system are to implement a groundwater treatment facility or drill a new well. For large systems, the cost-effective solutions are to drill a new well or implement groundwater treatment. Bottled water costs more than all alternatives (per thousand gallons).

Figure 28 and Figure 29 graphically show the annualized cost ($/kgal) of alternative options for public water systems. Similar to the cost table results, Figure 28 shows that for small and medium systems groundwater treatment is the most cost-effective. For medium and large systems an ion exchange treatment facility or a new well are most cost-effective. SCADA costs are shown for treatment and system size comparison. Figure 29 includes the option to construct five miles of pipeline for connecting to another water system or drilling a new well in a nitrate-free location. The economies of scale for pipeline costs can be observed for systems serving more than 3,300 people as pipeline costs decline to less than reverse osmosis costs. A groundwater system with ion exchange remains the cheapest option, however, piping to another system allows a water system to share the treatment experience with a larger entity (i.e., certified operators would already be hired) and the O&M costs would be distributed over a larger population base. Medium and large systems also can search for a low-nitrate source well location near the existing system, instead of installing reverse osmosis treatment.

Figure 30 shows the annualized cost ($/hhld) of alternative options for public water systems, including consolidation (a small system connecting to a larger system). Costs are shown for a system with 2,000 connections (households) and include pipeline costs ($61/foot)[32] and the estimated connection fee ($150,000), and are discounted over 20 years with an annual 0.05 discount rate. For a 2,000 connection system, the best option is to drill a new well if the surrounding groundwater quality is acceptable for drinking water purposes. If drilling a new well is not an available option from poor water quality conditions, the next least expensive option is to connect to a larger system that is less than five miles away. If there are no larger systems less than five miles away for a 2,000 connection system to connect to, then implementing a reverse osmosis system is the cost-effective solution. The maximum distance for connecting to an alternative system will vary with varying system sizes and connection cost estimates. The costs presented and discussed are rough estimates for alternative supply option comparison.

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[32] Granite Ridge Regionalization Feasibility Study, 2010

Table 38. Low Cost Ranges for a Basin-Wide Cost Analysis

<u>**LOW COST RANGES**</u>	**Very Small**	**Small**	**Medium**	**Large**	**[Source]**
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**0.01 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$0.60	$0.30	$0.40	$0.20	[3]
Surface Water Treatment	-	-	-	$0.70 + pipeline	[4]
New Well	$0.44 - $1.60	$0.20 - $0.44	$0.10 - $0.20	$0.05 - $0.10	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] EPA system size classification.

[2] "Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule" (EPA, 2005).

[3] System Surveys and Literature Review.

[4] System Surveys and Literature Review (8.25-10 mgd systems).

[5] "Drinking Water Infrastructure Needs Survey and Assessment: Modeling the Cost of Infrastructure" (EPA, 2007), increased by factor of 7 to account for real system costs (i.e., engineering fee, taxes, etc.).

[6] Granite Ridge regionalization feasibility study.

[7] Uses the USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Assumes 100 gallons of water used per household per day. (USEPA, 2010). Annualized Capital Costs at 7% discount rate over 10 years.

[8] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles.

Table 39. High Cost Ranges for a Basin-Wide Cost Analysis

HIGH COST RANGES	Very Small	Small	Medium	Large	[Source]
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**0.01 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$4.60	$1.30	$2.00	$1.80	[3]
Surface Water Treatment	-	-	-	$1.20 + pipeline	[4]
New Well	$3.10 - $11.20	$1.40 - $3.10	$0.90 - $1.40	$0.30 - $0.90	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] EPA system size classification.

[2] "Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule" (EPA, 2005).

[3] System Surveys and Literature Review.

[4] System Surveys and Literature Review (8.25-10 mgd systems).

[5] "Drinking Water Infrastructure Needs Survey and Assessment: Modeling the Cost of Infrastructure" (EPA, 2007), increased by factor of 7 to account for real system costs (i.e., engineering fee, taxes, etc.).

[6] Granite Ridge regionalization feasibility study ($61 per foot), connection fee not included.

[7] Uses the USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Assumes 100 gallons of water used per household per day. (USEPA, 2010). Annualized Capital Costs at 7% discount rate over 10 years.

[8] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles.

Table 40. Complete Table of System-Wide Alternative Water Supply Options (minimum value of low range and maximum value of high range)

	Very Small	Small	Medium	Large	[Source]
System Population Range:	**(25 - 500 people)**	**(501 - 3,300 people)**	**(3,301 - 10,000 people)**	**(10,001 - 100,000 people)**	[1]
Assumed Design Rate (mgd):	**0.01 - 0.17**	**0.17 - 1.09**	**1.09 - 3.21**	**3.21 - 30.45**	[2]
Annualized Total Cost ($/kgal):					
Groundwater Treatment	$0.60 - $4.60	$0.30 - $1.30	$0.40 - $2.00	$0.20 - $1.80	[3]
Surface Water Treatment	-	-	-	$0.70 - $1.20 + pipeline	[4]
New Well	$0.44 - $10.20	$0.20 - $2.80	$0.10 - $1.30	$0.05 - $0.80	[5]
Pipeline (2 miles)	$0.80 - $15.70	$0.10 - $0.80	$0.04 - $0.10	$0.01 - $0.06	[6]
New Well + 2 Miles of Pipeline	$1.24 - $25.90	$0.30 - $3.70	$0.14 - $1.40	$0.06 - $0.80	[5,6]
Annualized Total Cost for POTABLE USES only ($/kgal):					
POU System for Potable Uses	$2.67 - $3.52	$2.51 - $2.67	$2.51	$2.51	[7]
Bottled Water for Potable Uses	$1,630	$1,630	$1,630	$1,630	[8]

[1] EPA system size classification.

[2] "Economic Analysis for the Final Stage 2 Disinfectants and Disinfection Byproducts Rule" (EPA, 2005).

[3] System Surveys and Literature Review.

[4] System Surveys and Literature Review (8.25-10 mgd systems).

[5] "Drinking Water Infrastructure Needs Survey and Assessment: Modeling the Cost of Infrastructure" (EPA, 2007), increased by factor of 7 to account for real system costs (i.e., engineering fee, taxes, etc.).

[6] Granite Ridge regionalization feasibility study ($61 per foot), does not include connection fee.

[7] Uses the USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Assumes 100 gallons of water used per household per day. (USEPA, 2010).

[8] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles.

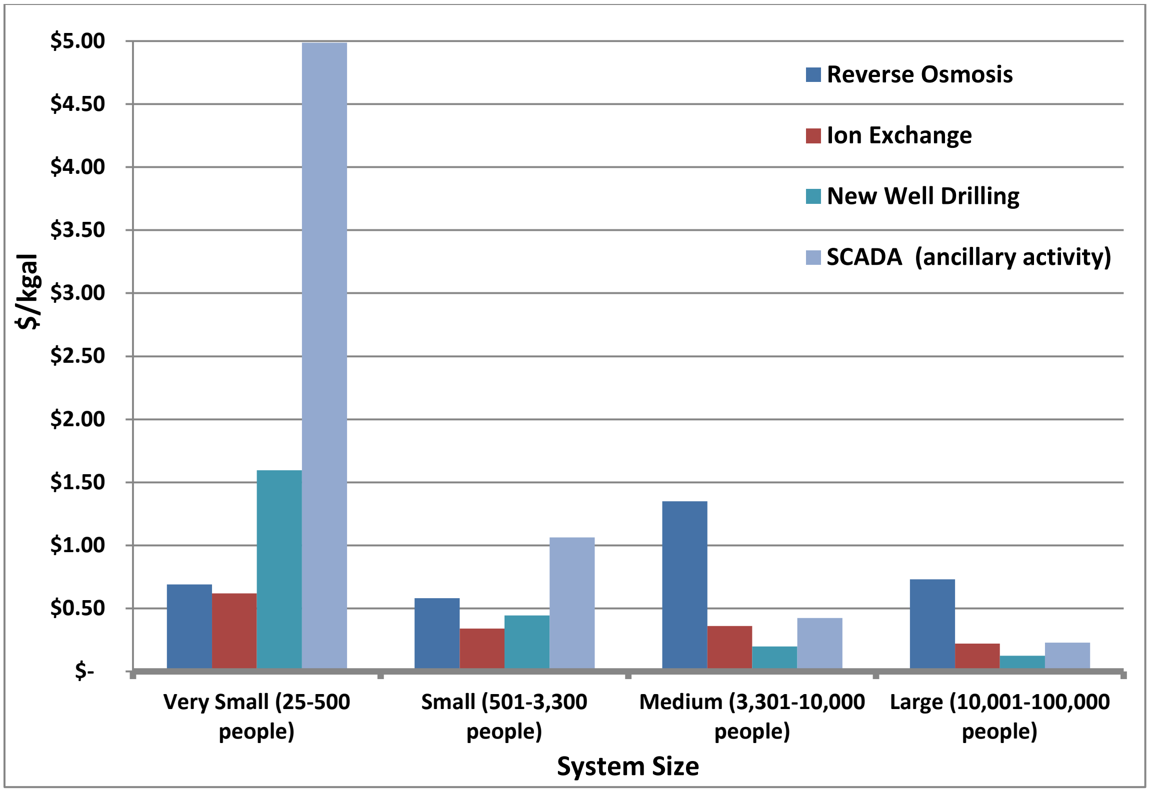

Figure 28. Annualized Cost ($/kgal) for Public Water System Alternatives

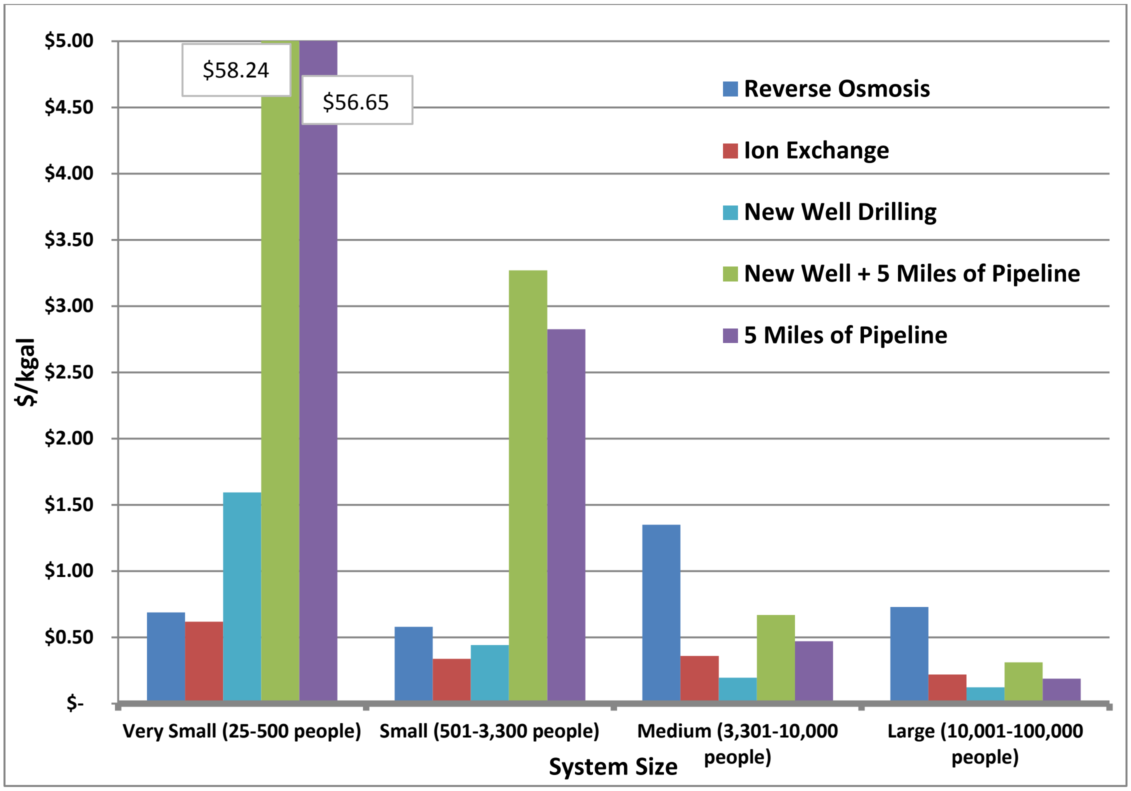

Figure 29. Public Water System Annualized Cost Comparison ($/kgal) for Alternative Water Supply Options

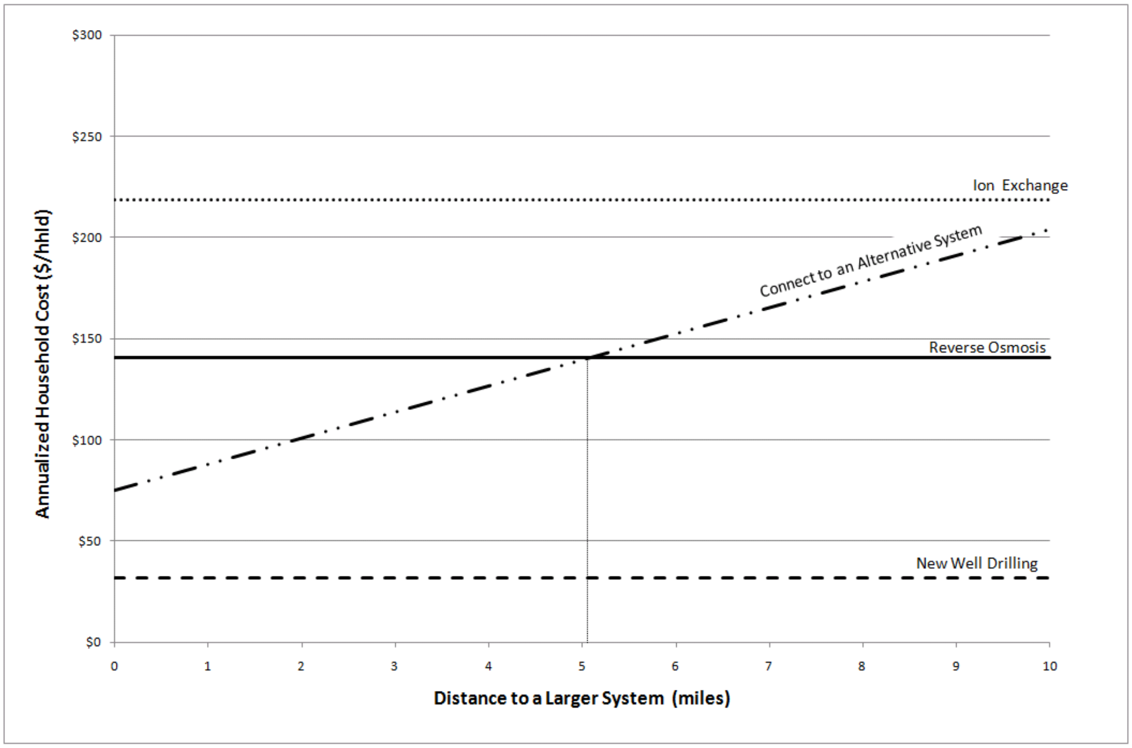

Figure 30. Annualized Cost Comparison ($/hhld) of Alternative Water Supply Options for a 2,000 Connection Public Water System

These cost estimates (Table 37, Table 40, Figure 27-Figure 29) are used to discuss the basin-wide cost estimates for providing alternative solutions to the population susceptible to nitrate contamination in the Salinas Valley and Tulare Lake Basin (in Section 7).

5.3 Public Health and Other Considerations

The most recent twelve year survey of waterborne disease in the United States (1991-2002) documented 183 drinking water-related outbreaks, with 76% from groundwater sources (Reynolds et al., 2008). From 2001 to 2002, 92% of outbreaks related to drinking water were from groundwater, and 39% of the groundwater systems were household self-supplied systems not regulated by the USEPA (Blackburn et al., 2004). Drinking water systems have an enormous effect on public health. Ford (1993, 1996, 1998) suggests that “there is reason to be concerned for the future microbiological safety of drinking water because a) source water continue to receive agricultural, industrial, and municipal waters; b) water treatment and distribution systems age and deteriorate; c) water supplies are overwhelmed by excessive demand; and d) there appears to be an increase in diseases, or at least an increased recognition of disease, caused by pathogens with varying degrees of resistance to treatment and disinfection" (Ford, 1998).

A water system struggling with regulatory compliance must manage and plan for the future and prepare for potential increases in regulations. Reverse osmosis (RO) and ion exchange (IX) are the most cost-effective treatment options to reduce nitrate and to provide the highest quality and reliability of safe water for all households connected to water systems. Furthermore, since nitrate is not the only contaminant of concern within the study area (Jensen & Darby, 2011) RO treatment is recommended because it is effective against many co-occurring contaminants. Until treatment can be afforded or completed, interim solutions include delivery of bottled or trucked water or distribution of point-of-use (POU) treatment devices. Bottled water is regulated by the Food and Drug Administration (FDA) and is not required to follow as rigorous regulations as EPA-regulated tap water; however, bottled water will be better than the current supply of nitrate-contaminated groundwater, albeit at greater expense (particularly since most brands are bottled from EPA regulated municipal drinking water systems). Water delivered by a truck from a low-nitrate source should be of good quality if proper truck cleaning and transfer procedures are followed, however, CDPH does not allow water systems to serve trucked water to their community water supply customers (CDPH, 2011). If POU treatment devices (usually RO) are distributed to households, they must be CDPH approved devices and require for households to be properly educated on their use. RO devices require filter replacement. A plumber often must be employed to install the device and annual maintenance is advisable.

If a self-supplied household has tested their well for nitrate and found a problem, they can employ a POU or POE device and request assistance on installation and maintenance from a nearby vendor or water system. A POE system allows household members to have the convenience of using any sink in the house instead of only the sink with a POU treatment unit. A properly implemented and maintained POE device supplies a household with the highest quality and reliability of water. Drilling a deeper well is promising for households able to access an aquifer with low nitrate water. It would be best to drill to a deeper, lower nitrate level while also testing for arsenic levels.

6 Management Approaches

6.1 Current Management

6.1.1 State and Federal Level

California's drinking water sources are currently managed and protected by the US Environmental Protection Agency (EPA), Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Regional Water Quality Control Boards (RWQCBs), and California Department of Public Health (CDPH) (formerly part of the Department of Health Services (DHS)). Under Section 1443(a) of the Safe Drinking Water Act (SDWA), the EPA annually receives a Congressional appropriation to assist states in carrying out their Public Water System Supervision programs (USEPA, 2010). CDPH has been given primary enforcement responsibility (primacy) for the Public Water System Supervision program and is eligible for receiving grants. The CDPH Drinking Water Program (DWP) is within CDPH's Division of Drinking Water and Environmental Management and is the primary agency that regulates public drinking water systems. The DWP enforces the federal and California SDWAs and oversees about 7,500 public water systems regulating and ensuring the delivery of safe drinking water to consumers (CDPH, 2010). Five regional field operations branches (FOBs) manage these water systems and they are involved in (CDPH, 2010):

- performing field inspections,
- issuing operating permits,
- reviewing plans and specification for new facilities,
- taking enforcement actions for non-compliance with laws and regulations,
- reviewing water quality monitoring results,
- supporting and promoting water system security,

- funding infrastructure improvements,
- conducting source water assessment,
- evaluating projects utilizing recycled treated wastewater, and
- promoting and assisting in drought preparation and water conservation.[33]

Within the study region, CDPH has delegated local primacy to Tulare, Kings and Monterey County Health Departments for regulatory oversight of water systems within their County serving less than 200 connections. Technical assistance and training is provided to the local primacy agencies by the FOBs. A Technical Programs Branch also provides scientific expertise in monitoring and evaluation and administers the Safe Drinking Water State Revolving Fund and the Small Water Systems Program (CDPH, 2010).

The Division of Drinking Water and Environmental Management also developed and implemented California's Drinking Water Source Assessment Protection Program (DWSAP). The program partners the drinking water protection efforts of local, state, and federal agencies. The assessment investigates the area around a drinking water source to determine the probable risk of contamination. Any activities that have the potential, also known as possible contaminating activities (PCAs), to release contaminants within the designated area are recorded to establish the vulnerability of the drinking water source. The assessments also consider the impacts of well construction, depth, and pumping rates. The DWSAP Program addresses both groundwater and surface water sources. Any drinking water system that uses surface water sources may submit their watershed sanitary surveys as a partial fulfillment of the DWSAP Program requirements, still needing to complete the vulnerability ranking. The USEPA requires "that delineation and contaminant inventory elements for ground water sources are to be consistent

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[33] http://www.cdph.ca.gov/programs/pages/dwp.aspx

with wellhead protection program approaches (USEPA, 1997)", and that the DWSAP Program serves as California's wellhead protection program.

The goals of the California DWSAP Program are (CDHS, 1999)

- Protection and benefit of public water systems of the State, gathering information on and paying attention to activities that may affect drinking water quality.
- Improve drinking water quality and support effective management of water resources by using the assessments to develop protection strategies.
- Inform communities and drinking water systems of contaminants and possible contaminating activities that may affect drinking water quality or the ability to permit new drinking water sources.
- Encourage a proactive approach to protecting drinking water sources and enable protection activities by communities and drinking water systems.
- Refine and target monitoring requirements for drinking water sources based on proper identification of PCAs.
- Focus cleanup and pollution prevention efforts on serious threats to surface and ground water sources of drinking water, prioritizing environmental activities.
- Meet federal requirements for establishing wellhead protection and drinking water source assessment programs.
- Assist in meeting other regulatory requirements, such as the Ground Water Rule and the Enhanced Surface Water Treatment Rule.

When groundwater is the sole source of drinking water, the minimum components for a drinking water source assessment protection program are to locate the sources, delineate the source area and protection zones, evaluate the effectives of the drinking water physical barriers, inventory the possible contaminating activities (PCAs), rank the vulnerability of each source, prepare an assessment map, prepare a summary of the assessment for submittal, and notify the public of the assessment specifics. After the drinking water source(s) is located, the source area and protection zones must be delineated using the calculated fixed radius (CFR) method.[34] The CFR equation and outlined requirements will provide the minimum radii of zones. These zones are areas that are differentiated by the vulnerability of contamination to the source and are estimated by drawing a circle around a well to estimate the zone of contribution (ZOC) for a specified time-of-travel[35] criterion (CADWSAP, 1999). Once the zones are estimated a checklist is completed on the drinking water physical barriers effectiveness and the surrounding PCAs are documented. Each source will receive a vulnerability rank based on the PCA risk ranking, the location and the effectiveness of any physical barriers. An assessment map is created to show the location and area of the drinking water source and the zones. After the assessment is complete a summary is prepared and submitted to DHS' Drinking Water Program District office. Finally, the public is notified via the water system's annual consumer confidence report commenting on when the assessment was performed, where it is available for review, and providing a summary of the assessment with the prevalent PCAs. The full assessment is online at the UC Davis Information Center for the Environment (ICE), and has been loaded into the UC Library's Merritt system.

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[34] A fixed radius is calculated using the CFR equation that is based on the theoretical volume of water that will be drawn to a well in the specified time. The input data required by the equation includes the pumping capacity of the well, the screened interval of the well and the effective porosity of the aquifer. The CFR method may be inaccurate because it does not take into account the actual rate and direction of groundwater flow, recharge, and other factors that may influence contaminant transport (http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWSAPGuidance/DWSAP_document.pdf).

[35] Time-of-travel is the time it takes for groundwater to travel from a specified point in an aquifer to a pumping well (http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWSAPGuidance/DWSAP_document.pdf).

6.1.2 Local Level

Drinking water systems that are not currently complying with the nitrate MCL need to identify their current operation and maintenance issues and discover the best methods for compliance. Normally, a competent operator rated at the appropriate treatment and distribution level should be hired and receive updated training throughout employment. Systems treating water by blending or treatment plant are considered water treatment systems. The system is classified as a water distribution system if there is no treatment other than disinfection (CDHS, 2005).

Small systems that are not regulated by CDPH (< 15 connections) should participate in well water quality testing, record keeping, and to conduct drinking water system evaluations and assessments. These systems should also abide by the Safe Drinking Water Act requirements for communicating with the public if there is a water quality concern.

7 Basin-wide Costs of Nitrate Contamination

Rough basin-wide costs for nitrate contamination in the study basins were estimated for community, self-supplied households, and local small water systems, using a range of cost estimates found from literature, surveys, and researching existing proposal estimates and final project costs. The highly susceptible population (shown in Table 12) is estimated to be 766,000 people; 678,000 are connected to community water systems, and approximately 80,000 are connected to self-supplied households or local small water systems. Overall, the cost for providing nitrate-compliant water to the total highly susceptible population in the study area is roughly $25-$30 million per year ($33-$40/susceptible person/year).

7.1 Costs for Community Water System Alternative Solutions

A rough basin-wide cost for solving nitrate contamination of drinking water in the study basins was estimated for community water systems. Only multiple source systems having a recorded level of delivering water above the nitrate MCL, or single source systems that have a raw source water level exceeding the nitrate AL, or lack water quality data within WQM were included in the analysis. As mentioned in Section 5.2.2, the minimum and maximum ranges or cost estimates for community water systems appear in Table 38 and Table 39, with the compiled cost ranges in Table 40. The maps in Figure 31 and Figure 32 show the results of the cost analysis results for these minimum and maximum ranges, respectively. The displayed options are not recommended solutions per system; individual solutions should be engineered locally. This map merely shows promising least cost solutions in an attempt to estimate rough overall costs. The cost for providing nitrate-compliant water to those connected to susceptible community water systems will cost roughly $18-23 million per year (Table 41).

The alternatives examined for community water systems (discussed in Table 39 and Table 39) include drilling a new well, installing a pipeline to a nearby system (within 14 miles) that serves more than 10,000 people, delivering a POU RO device for potable uses, installing groundwater treatment, or installing a pipeline and paying into a nearby new surface water treatment facility. For the final cost estimates, shown in Table 41, the following options were excluded: allowing systems to provide bottled water to their consumers as a means of compliance, allowing medium and large systems to deliver POU RO devices for compliance, and allowing large systems to install a pipeline to a larger system (only systems with less than 10,000 people are connecting to systems with greater than 10,000 people). Also, the cost to connect to an alternative system does not include the estimated connection fee.

The options chosen for the low and high final cost estimates for community and state-small water system solutions are:

1. drilling a new well;
2. delivering POU RO devices for potable uses (only for systems serving up to 200 connections);
3. installing a pipeline to a nearby system (10,000+ system);
4. building a groundwater treatment facility; and
5. installing a pipeline to a nearby surface water treatment facility.

The susceptible systems included in the community and state-small water system cost model are:

1. all CWS and SSWSs with multiple sources delivering water that exceeded the nitrate MCL at least once from 2006 to 2010;

2. all single source CWS and SSWSs with raw source water that exceeded the AL for nitrate at least once from 2006 to 2010; and
3. all CWS and SSWSs with no nitrate water quality data.

There are a total of 103 susceptible community and state-small water systems, serving 678,000 people (Table 41).

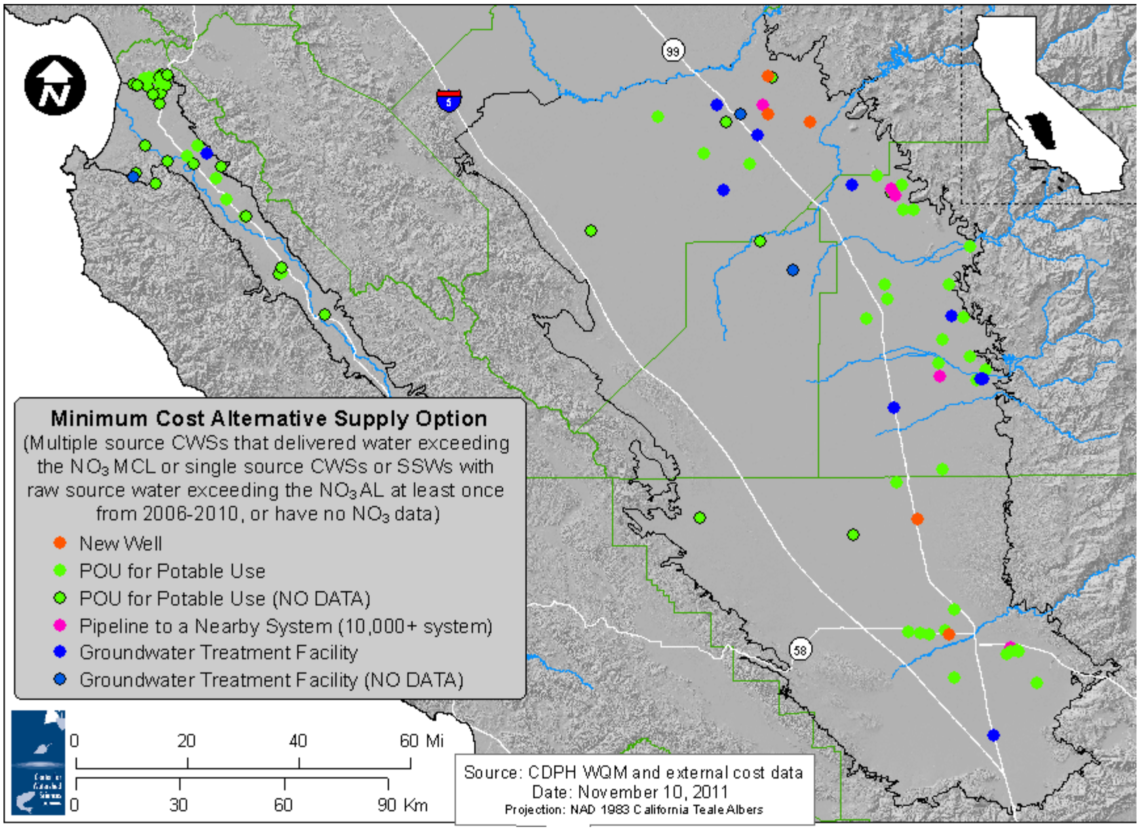

Figure 31. Minimum Cost Alternative Supply Option for Susceptible Community and State-Small Water Systems (Multiple Source CWS or SSWSs Exceeding the Nitrate MCL, or Single Source CWS or SSWSs Exceeding the Nitrate AL at Least Once from 2006-2010, or Having No Data)

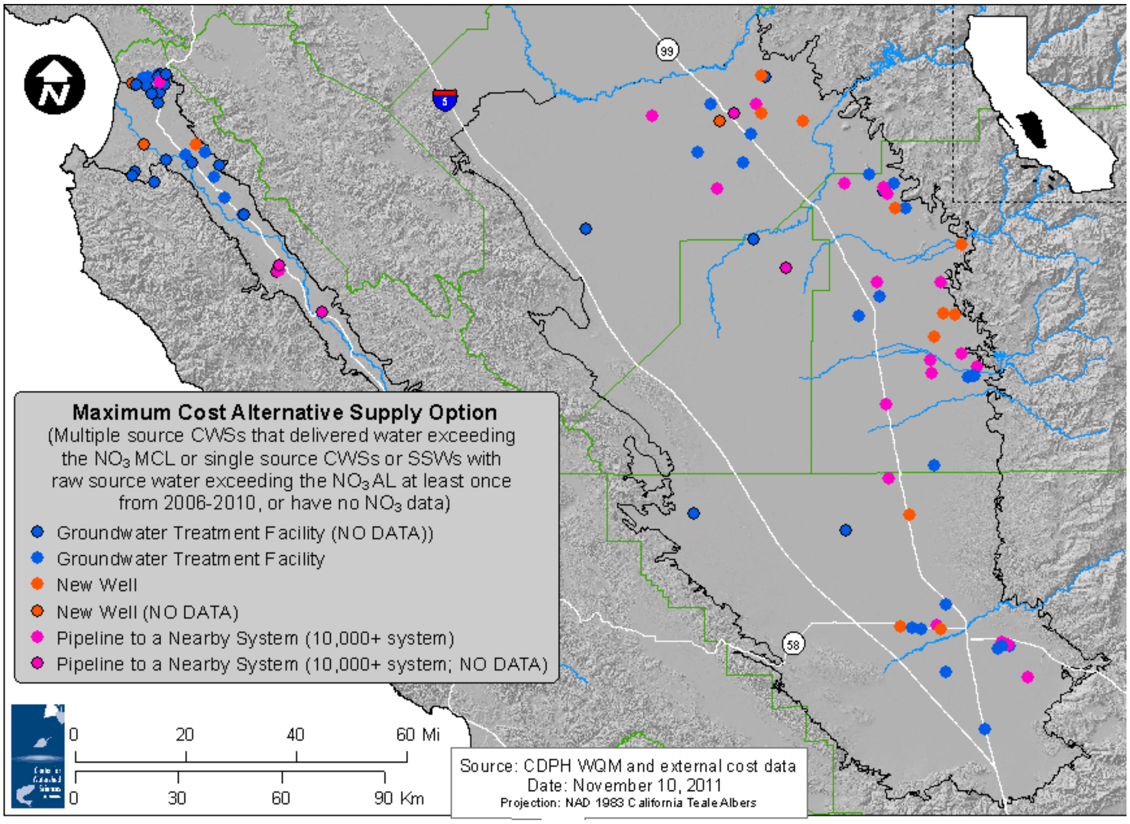

Figure 32. Maximum Cost Alternative Supply Option for Susceptible Community and State-Small Water Systems (Multiple Source CWS or SSWSs Exceeding the Nitrate MCL, or Single Source CWS or SSWSs Exceeding the Nitrate AL at Least Once from 2006-2010, or Having No Data)

Table 41. Estimated Cost Range of Alternative Water Supply Options for Susceptible Community and State-Small Water Systems

	Number of Systems Using LCO		**Population Served by Systems Using LCO**		**Total Cost for LCO ($/year)**	
Least Cost Option (LCO)	**Low**	**High**	**Low**	**High**	**Low Cost**	**High Cost**
Drill New Well	5	17	621,388	635,961	$15,002,322	$17,392,344
POU Device for Potable Use	78	---	10,630	---	$632,236	---
Pipeline to a Nearby System (10,000+ system)	5	27	25,323	35,626	$549,549	$2,570,511
Groundwater Treatment Facility	15	59	21,184	6,938	$1,680,385	$2,609,015
Surface Water Treatment Facility	0	0	0	0	0	0
TOTAL	103	103	**678,525**	**678,525**	**$17,864,492**	**$22,571,870**

The low cost alternative supply case is estimated to cost approximately $18 million per year (annualized), with 15 systems building groundwater treatment facilities, five systems installing a pipeline to a nearby larger system, 78 systems delivering POU RO devices to their customers, and five systems drilling a new well. This is graphically displayed in Figure 31 and numerically shown in Table 41. Installing POU devices for 78 systems (all serving up to 200 connections) provides a solution for about 2% of the susceptible population at a cost of $630,000 per year. Building a groundwater treatment facility for 15 systems provides a solution for about 3% of the susceptible population at a cost of $1.7 million per year. Drilling a new well for five systems provides a solution for 92% of the susceptible population at a cost of $15 million per year; however, there is uncertainty in the amount of time a well can produce safe drinking water before it is contaminated. Building a groundwater treatment facility for these five systems would cost an additional $49 million per year (for RO treatment processes), but would establish a treatment unit more prepared for future co-contaminants. Installing a pipeline to a nearby larger system for five systems provides a solution for 4% of the susceptible population at a cost of $550,000 per year. Connecting to a surface water treatment facility was not a least cost option.

The high cost alternative supply case is estimated to cost approximately $23 million per year (annualized), with 59 systems building a groundwater treatment facility, 27 systems installing a pipeline to a nearby larger system, and 17 systems drilling a new well. This is graphically displayed in Figure 32 and numerically shown in Table 41. Building a groundwater treatment facility for 59 systems provides a solution for less than 1% of the susceptible population at a cost of $2.6 million per year. Drilling a new well for 17 systems provides a solution for 94% of the susceptible population at a cost of $17 million per year. Building a groundwater treatment facility for 17 systems would cost an additional $279 million per year (for RO treatment processes), but would establish a treatment unit more prepared for future co-contaminants. Installing a pipeline to a nearby larger system for 27 systems provides a solution for 5% of the susceptible population at a cost of $2.6 million per year. Connecting to a surface water treatment facility was not a least cost option.

The total estimated range of costs for community water systems is $18 to $23 million per year.

7.2 Costs for Household Self-Supplied and Local Small Water System Alternative Solutions

A rough basin-wide cost for addressing drinking water nitrate contamination in the study basins was estimated for self-supplied households and local small water systems using researched cost estimates (Table 37). Susceptible self-supplied households and local small water systems are those estimated to be within a Thiessen polygon that exceeds the AL for nitrate (as discussed in Section 3.5.1.1); serving approximately 88,000 people. The estimated costs for alternative solutions for self-supplied households and local small water systems are shown in Table 37. The least cost alternative for households is to install a reverse osmosis POU device, estimated to cost $250 per year (not including any public outreach or education). The second least cost alternative for households is to install a POE device; however, currently no POE devices are NSF/ANSI certified for removing nitrate from drinking water (the estimate given in Table 37 is for treating Radium). The primary options available to a household or local small water system are to purchase bottled water, install a POU device, drill a new well, or deepen an existing well. Figure 27 shows the annualized cost curves of each option and highlights the cost-effective option for expected water use or consumption. If a household only desires to have nitrate-free potable water, a POU device is the cheaper solution, however, treating more than 60 gallons of water per day with a POU device is no longer cost-effective and drilling a new well is preferred. Without concurrent reduction in source loading, new wells will run the risk of nitrate contamination; as pumping and time increases, the nitrate will eventually enter the well. The cost curves do not represent the actual maximum potable water consumption per day per filter flow capacity, this will vary by chosen manufacturer (i.e., Culligan has a maximum of 25 gallons per day). The difference in expected total annualized costs for 27,000 households (88,000 people) to install a POU RO device ($6.7 million) or drill a new well ($89 million) is about $82.3 million, however, drilling a new well provides the whole house with low-nitrate water and accidental consumption of nitrate-laden water is not of concern. The lifetime of the alternatives are different as well, as a POU RO device has a ten year expected lifetime while drilling a new well has a fifty year expected lifetime. However, if degradation and contamination of the study area continues, the lifetime of a well will only be as long as it takes for the nitrate plume to spread and reach the well. The POU RO device is annualized over ten years; the cost for drilling a new well is annualized over 20 years.

The range in total cost for self-supplied households is $6.7 to $89 million per year.

7.3 Interim Solutions

The interim solutions discussed here are specific to domestic well users and small water systems serving less than 200 connections. Small water systems (serving less than 200 connections) may use an interim solution for compliance, such as a POU device, for only three years under the emergency regulations established by USEPA (further discussed in Section 8). Providing POU devices to water system customers is only meant for systems that are in the process of creating or implementing a long-term solution. A small water system may not provide bottled water to consumers as an interim compliance option. Domestic well users may use alternative supplies, such as a POU device, for the length of time preferred by the user or lifetime of the device. Table 42 shows the estimated costs for interim water supplies for domestic wells and small water systems. The POU costs include capital, O&M public education, and indirect costs. Cost estimates shown in parentheses are for systems without public outreach. For small public water systems serving 15 to 199 households it is recommended to provide public education to users to increase proper use and handling. The economies of scale are only seen in the added costs of public education, as when there are more users the per capita price for education decreases. For domestic well users the cost for public education is not cost-effective, and self-education (by researching the POU device chosen) is suggested. It is more cost effective for domestic well users to install a POU device versus purchasing bottled water as an interim solution.

Table 42. Estimated Cost Ranges for Interim Water Supplies for Households and Small Water Systems Serving Fewer than 200 Connections

Options	**Bottled Water**[1]	**POU (15 households)**[2]	**POU (199 households)**[3]	**POU (1 household)**[4]
Initial Capital Cost ($/hhld)	0	$443 ($406)	$411 ($406)	$1,981 ($406)
Annual O&M Cost ($/hhld)	0	$272 ($166)	$173 ($165)	$1,781 ($197)
Total Annualized Cost ($/kgal)	$1,630	$5.24 ($3.80)	$3.90 ($3.78)	$24.85 ($3.01)
Total Annualized Cost ($/hhld)	**$1,260**	**$435 ($315)**	**$324 ($314)**	**$2,038 ($250)**

[1] Quote from Alhambra, Visalia for drinking water delivered in 5 gallon bottles. Assumed units of water consumption from NAS Hydration Study.

[2] Uses the 2010 USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. The tool allows for economies of scale representation assuming 15 households will be receiving units and management will be centralized. Costs in parentheses do not include public education.

[3] Uses the 2010 USEPA Cost Estimate Tool for an NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. The tool allows for economies of scale representation assuming 199 households will be receiving units and management will be centralized. Costs in parentheses do not include public education.

[4] Uses the 2010 USEPA Cost Estimate Tool for 1 NSF/ANSI Certified RO Unit for treating nitrate. Includes unit purchase, installation, scheduling time, public education (technical and clerical labor and printed material for all public outreach/education efforts), indirect costs (permitting, pilot testing, legal, engineering, contingency) and all associated operations and maintenance costs. Costs in parentheses do not include public education.

8 Regulatory and Implementation Implications

Each alternative water supply option has its own regulatory and implementation implications. Since domestic well users are excluded from the statewide drinking water protections, and have no regulatory standards for testing their wells (except for a few local county ordinances), the implications of their water supply options will differ slightly from those for community water systems.

8.1 Implications of Household Self-Supplied System Alternatives

The large numbers of self-supplied households pose several regulatory challenges.

Drilling a New or Deeper Well: Some counties have regulations on well drilling for households. In areas with nitrate contamination potential, counties and the state should consider additional monitoring and regulations.

Household Treatment: Since there is no regulatory oversight for domestic well users, there is no requirement for installing POU devices, but purchasing a certified unit is recommended. Households with self-supplied wells that choose to install a POU RO device should consider hiring a certified RO POU distributor to manage and operate the device or should seek proper training in filter replacement. Given the often lesser and declining expense of POU systems, the state should continue to examine its regulations to take advantage of these improving technologies.

Connect to Alternative System: If a household wishes to connect to a nearby safe community water system they must contact the water system or county official and discover if they are within the water system boundary. If a household is outside of water system boundaries they will need to speak with local officials about annexation or an extension of the urban growth boundary or a separate contractual relationship. Households outside of water system boundaries may find it more difficult to be incorporated into an existing water system.

Bottled Water: There are no regulatory implications for households to start purchasing bottled or vended water; however, the quality of bottled water is an under-regulated industrial activity, and can sometimes be of lower quality than other sources.

8.2 Implications of Community Water System Alternatives

Community water systems are larger in size and capacity, and fewer in number, and so have many more options, but higher individual consequences. Community water systems are always in direct contact with the regulators to determine the most effective solution for complying with drinking water standards.

Blending: The CDPH has already established a Blending Program; however, the regulatory implications will differ slightly depending on whether the blending source is groundwater or surface water. If the groundwater source used for blending eventually exceeds the MCL for nitrate an alternative source, such as surface water, may be required. The water system will need to acquire surface water rights from the State Water Resources Control Board or a long-term water contract with an existing surface water right-holder. Once blending is implemented the water system must continually monitor the low-nitrate source to ensure the blending ratio is achieved.

Drilling a New or Deeper Well: California already has a Well Standards Ordinance established for community water systems for drilling a new or deeper well. Local county ordinances also establish rules for each community water system. Also, CPDH regulates the well construction and evaluates the location, source water quality and quantity for drilling a new or deeper well in a community water system supply.

Community Treatment: CDPH has a Division of Drinking Water and Environmental Management (DDWEM) that provides permitting information for community water systems, protects community water system sources, and has established a Drinking Water Treatment and California Operation Certification Program that provides the minimum qualifications for a potable water treatment system operator. Furthermore, the respective regulatory agency for each community water system must verify that the drinking water treatment device employed is consistent with Title 22 California Code of Regulations.[36]

Household Treatment: California regulations currently allow small public water systems to provide POU devices to customers as a means of complying with the nitrate standards under the following restrictions (California Code of Regulations, 2011):

"…a public water system may be permitted to use point-of-use treatment devices (POUs) in lieu of centralized treatment for compliance with one or more maximum contaminant levels… if;

(1) the water system serves fewer than 200 service connections,

(2) the water system meets the requirements of this Article,

(3) the water system has demonstrated to the Department that centralized treatment, for the contaminants of concern, is not economically feasible within three years of the water system's submittal of its application for a permit amendment to use POUs,

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[36] California Code of Regulations: Chapter 4 Water Treatment Devices (2010)

… no longer than three years or until funding for the total cost of constructing a project for centralized treatment or access to an alternative source of water is available, whichever occurs first….”

According to the emergency legislation (Health and Safety Code 11680(a)(1)) for temporary compliance a POE device may also be employed in lieu of centralized treatment, but CDPH is still developing the regulations to incorporate POE into the California Code of Regulations (CCR). The most significant costs of a POU RO device are in the management and monitoring of the unit. Since the law states that POU units must be centrally-managed by the public water system or by a company hired by the public water system, a fair regulatory policy should be developed. For example, a public water system could work with a private company to create a reasonable contract that allows the company to manage, maintain and monitor all devices within a specific public water system service area. To use a POU device for complying with the SDWA amendments there must be 100% participation within a public water system. If any of the connections deny access to their house it automatically prohibits POU as an alternative for compliance. This is a substantial impediment to POU treatment. Other communities have addressed this by passing a local ordinance requiring installation, and employing the authority to disconnect the water supply if installation is refused (USEPA, 2006). A local ordinance was passed in San Ysidro, New Mexico, making water use contingent on POU installation (USEPA, 2006). It is recommended to provide public education to customers before, during and after implementation of a POU device to ensure success.

Connect to Alternative Supplies: All public water systems must submit an amended permit application to the local CDPH drinking water field office prior to changing their source or method(s) of treatment (CDPH, 2011). If a water system switches from groundwater to surface water, the water treatment requirements change as specified in the State and Federal Surface Water Treatment Rule. However, all water served to the public for drinking water purposes is subject to the same nitrate drinking water standard.

<u>Regionalization and Consolidation</u>: Regionalization and consolidation allows systems to increase the levels of service by taking advantage of economy of scale benefits and complying with stringent regulations. Service duplications across management and operational functions can be eliminated, while achieving regulatory compliance and improving financial accountability. Rourke and Smith (1997) estimated that approximately 40-45% of community water systems will experience financial instability from rising operational and future regulatory compliance costs; the larger population base found in regionalization can support increases in operational costs and future regulations. Regulators should consider providing larger systems with financial and ratemaking incentives to encourage the acquisition of smaller systems. Regulatory incentives for regionalization have been considered in many policy areas, and "some states have enacted legislation authorizing the use of mandatory 'takeovers'…but, many water utilities would prefer positive incentives to mandatory takeovers" (Beecher et al., 1996). Furthermore, if there was an incentive for larger systems to acquire smaller systems there would be fewer systems for regulating agencies to monitor, reducing administration costs.

Several studies have examined the advantages and disadvantages of regionalization, but physical implementation depends on the unique needs and barriers in each region. Successful implementation of regionalization and consolidation requires planning to in a regional context, along with strong public and political participation. Comprehensive planning that establishes public policy and resource planning on a regional scale will help meet the objective goals involved in consolidation (Beecher et al., 1996). Some implementation issues must be considered before consolidating systems, including: "(1) system income and expenses, (2) level of contributions in aid of construction, (3) rate base, (4) condition of facilities, (5) reasonableness of price and terms, (6) impact on customers, (7) required additional investments, (8) alternatives to sale and impacts of no sale, (9) ability to operate facilities, and (10) public interest assessment (Cloud, 1994)" (Beecher et al., 1996). Public participation is essential for regionalization, to properly educate the public and assure their involvement in the project and future fate of the system. CDPH supports consolidation efforts through funding programs and low interest loans to construct facilities for the physical consolidation of water systems, but does not have an explicit program to support the planning needed for moving towards regionalization.

To be considered for Safe Drinking Water State Revolving Funds, a water system must prove its technical, managerial and financial (TMF) capability.[37] A water system must also submit an assessment that identifies all public water systems located within a five mile radius and determines the feasibility of consolidation (Darby & Newkirk, 2010).

<u>Trucked Water</u>: Hauled or trucked potable water is often allowed by CDPH and used for public water systems in emergency situations when a water source is interrupted for an extended period of time and if there are no other alternatives. A water system that needs to provide trucked potable water to customers must contact CDPH and ensure that a CDPH Food and Drug Branch licensed water hauler is hired for service delivery. The water must be obtained from another regulated public water system and a "boil water advisory" may be given to each consumer as a precautionary measure to account for possible contamination during the delivery.

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[37] California Health and Safety Code Section 116540

Dual Water Distribution System: The permitting agency for dual water distribution systems or recycled water systems is the local Regional Water Quality Control Board (Central Valley and Central Coast). A water system that wants to install two distribution systems, one for potable and one for non-potable or recycled water, must file a report with the appropriate regional water board (CWC section 13522.5). CDPH reviews and evaluates recycled water proposals to verify the protection of public health and ensures that a system has the correct backflow protection established to prevent non-potable water from entering the drinking water system. CDPH encourages the use of recycled water in urban areas where recycled water or irrigation water is available (CDPH, 2011). To mitigate the concerns of inter-connection of the two sources or improper plumbing, water system personnel must be trained and a cross-connection control program must be implemented (CDPH, 2011). This program must also include annual testing of the backflow prevention devices and periodic shut-down tests (CDPH, 2011).

If a dual water distribution system is implemented on a community water system level there must be full public acceptance among consumers. Along with customer acceptance and approval, there must be a consensus within the City or County about the quantity and quality of water expected for delivery, and communication with the state about existing regulations. If a system desires to install a dual water distribution system there must be consideration of the health effects, treatment, storage and distribution demands (AWWA, 1994).

A wide variety of issues are involved in regulating and monitoring small and self-supplied water systems. Their small size and unique and varying circumstances have meant that these small systems bear a larger-than-proportionate share of financial costs and public health risks.

9 Conclusions

Major Findings

1. **A total of 766,000 people in California's Tulare Lake Basin and Salinas Valley have drinking water supplies susceptible or potentially susceptible to nitrate groundwater contamination.**
   1. Highly susceptible water users are served by a community water system with multiple sources and at least one recorded nitrate MCL (45 mg/L as NO_3) exceedance since 2006, a single source community water system with at least one recorded raw source water nitrate action level (AL; 22.5 mg/L as NO_3) exceedance since 2006, or a household self-supplied or local small water system near a shallow (< 300 feet) nitrate groundwater concentration exceeding the CDPH nitrate action level (AL). Approximately, 670,000 people in 39 multiple-source systems have at least one recorded delivered nitrate MCL exceedance. Approximately, 4,327 people in 51 single-source systems have recorded raw water nitrate AL exceedances or no nitrate water quality data in WQM. In addition, approximately, 27,000 rural households using domestic wells or on local small water systems are near a shallow nitrate groundwater concentration exceeding the nitrate AL.
   2. Other highly susceptible water users include approximately 3,900 people in 13 multiple source water systems in the study area have that no recorded *delivered* nitrate concentration data in the statewide water quality database (WQM). Better data collection will improve knowledge of the extent of nitrate contamination (i.e., for all wells, within water system boundaries and domestic wells, and for these systems with unknown risk).

2. **Nitrate contamination problems will grow.** According to recorded *raw* groundwater data in PICME, **57% of the current population of these basins uses a community water system with recorded raw nitrate levels above the MCL**. Assuming unchanging basin-wide trends in nitrate groundwater levels since 1970, this number is expected to increase to almost 80% by 2050. Nitrate groundwater contamination problems will increase, treatment costs will rise, and there is growing potential for public health impacts.
3. **Each community water system (or state-small water system) with high susceptibility (61 and 42 systems in Tulare Lake Basin and Salinas Valley, respectively) will need individual engineering and financial analyses. No single solution will fit every community affected by nitrate in groundwater.**
4. **There is significant potential for consolidation of systems.** The potential for consolidation is solely based on system size and the distance from a smaller system to a larger system. About 81% and 89% of the Tulare Lake Basin and Salinas Valley water systems are very small or small and serve 89,125 and 23,215 people (4% and 6% of the Tulare Lake Basin and Salinas Valley population), respectively. In the Tulare Lake Basin and Salinas Valley, about 50% and 15% of very small and small systems are within five miles of a larger system, and 88% and 97% are within 12.5 miles of a larger system, respectively. Consolidation permanently addresses nitrate problems, as well as many other small system problems.
5. **Promising options for communities connected to highly susceptible systems** are:
    a. consolidation with a larger system that can provide clean drinking water to more customers;
    b. consolidation of nearby small systems into a single larger system, with a larger rate payer base and economies of scale;
    c. ion exchange community water treatment;

   d. interim bottled water or point-of-use treatment systems until a more long-term and sustainable solution can be implemented;
   e. drilling a new well; and
   f. blending of contaminated wells, at least temporarily.

6. **Promising solutions for self-supplied household or local small water systems considered to be within a highly susceptible area** are reverse osmosis point-of-use treatment systems and drilling a new or deeper well.
7. **The overall estimated capital and operating annualized cost of providing nitrate-compliant drinking water to the Tulare Lake Basin and Salinas Valley is $25-30 million per year for the current level of susceptible population.**

Roughly $18-$23 million per year will be needed to provide safe drinking water for multiple source community water systems exceeding the nitrate MCL, single source community systems (and state-small systems included in CDPH's database) exceeding the nitrate AL, and community water systems (and state-small water systems included in CDPH's database) lacking nitrate records in WQM, that together currently serve an estimated 675,000 people (52 systems).

The annualized cost of providing nitrate-compliant drinking water to the estimated 88,000 people (27,000 rural households) using domestic wells or local small water systems highly susceptible to current or future nitrate contamination ranges from a low estimate of $7 million for point-of-use treatment (POU) for drinking purposes only, to a high $89.1 million for drilling a new domestic well for each household for all water needs. Costs for both could be lower if a manufacturing discount for bulk purchase of POU systems were available or nearby households shared a new well. The lower POU option is included in the total project study area estimated costs.

The cost to fund alternative water supplies for highly susceptible water users amounts to $33-$40 per susceptible person per year, $6-$8 per irrigated acre per year for the four million acres of agriculture in these basins, or $125-$150 per ton of fertilizer (assuming about 200,000 tons of fertilizer is applied in these basins).

Major Recommendations

1. **Construct, populate, and maintain a statewide publicly accessible comprehensive water quality database for groundwater and public water supply systems.** To facilitate accessibility of groundwater quality data throughout the state, one agency should manage a comprehensive database and create a simple graphical user interface for easy extraction.
2. **Regionalize and consolidate.**
   a. **Fund non-structural regionalization/consolidation of drinking water systems.** Programs in California fund physical consolidation activities like the construction of new pipelines, the installation of water meters, or the expansion of treatment systems. Regionalization efforts should be expanded to convene pilot projects that bring together communities of water systems to encourage information, managerial, institutional, and future planning collaboration. This could be done without necessarily having to start with historically, politically sensitive and difficult consolidation, since appropriate regionalization projects can help communities begin to collaborate to address shared nitrate problems, as well as many of the other shared problems encountered by small water systems.
   b. **Provide incentives to large clean water systems to consolidate with or initiate regionalization projects with surrounding smaller systems**. To encourage larger systems to take on the risks of a smaller system, incentives should be offered. For example, it may be beneficial to increase the points given to large systems on State

Revolving Funds' Project Priority Lists who help bring small systems up to the same technical standards as larger systems, often a prerequisite for consolidation.

3. **For any solution, consider lifecycle costs, such as:**
   a. **The need to remove co-contaminants.** Alternative water supplies or treatment options selected should be capable of addressing multiple contaminants.
   b. **The drawdown involved in pumping a new or deeper well.** Over time, as pumping continues, a new well will likely draw down the aquifer and bring nitrate into the well.
   c. **The production of brine waste from treatment systems.** The low brine technologies in groundwater treatment offer a minimal waste approach, and future research and development of brine treatment alternatives seem promising for greatly reducing brine waste from treatment systems.
   d. **Environmental impacts of reliance on bottled water.** Manufacturing and transporting bottles uses a lot of energy and causes negative environmental impacts, and the disposal of these bottles stresses landfills.
4. **Advance household treatment options for community water system compliance.**
   a. Create NSF certifiable POE devices for community water systems to provide to customers.
   b. Allow community water systems to provide POU devices to customers for more than 3 years.
5. **Create a Water and Wastewater System Task Force for integrating water and wastewater treatment projects and efforts.** A Task Force designed to connect water and wastewater issues in a certain watershed or region would improve system management in the long-term, and would require an inventory of existing and future system concerns.

6. **Require domestic well water quality monitoring.** As part of a county program administered by GeoTracker GAMA or the Central Valley Irrigated Lands Regulatory Program, collection of shallow domestic well water quality data is recommended as a management practice for identifying and protecting groundwater quality.

10 References

(NAS), N. A. (2004). *Dietary Intake Levels for Water, Salt and Potassium to Maintain Health and Reduce Chronic Disease Risk.*

Academies, I. o. (2005). *Dietary Reference Instake FOR Water, Potassium, Sodium, Chloride, and Sulfate.* Washington D.C.: The National Academies Press.

Association, N. G. (2009). *Water Testing*. Retrieved September 2011, from Well Owner: Informing consumers about ground water and water wells: http://wellowner2.org/2009/index.php?option=com_content&view=category&layout=blog&id=27&Itemid=27

AWWA. (1994). *Dual Water Systems: AWWA Manual M24 Second Addition.* Denver: Ammerican Water Works Association.

Balazs, C. (2011). *Social Disparaties in Nitrate Contaminated Drinking Water in California's Central Valley.* University of California, Berkeley.

Balazs, C. (2011). *Social Disparities in Nitrate Contaminated Drinking Water in California's Central Valley.* University of California, Berkeley.

Beecher, J. A., Higbee, J., Menzel, A., & Dooley, R. (1996). *The Regionalization of Water Utilities: Perspectives, Literature Review, and Annotated Bibliography.* Ohio State University: The National Regulatory Research Institute (NRRI).

BESST, I. (2008). BESST August 2008 Profiling Services Guide: Edition #1. http://www.besstinc.com/pdf/WSW%20Presentation%20083008.pdf.

Blackburn, R. S., Craun, G. F., Yoder, J. S., Hill, V., Calderon, R. L., Chen, N., et al. (2004). *Surveillance for waterborne-disease outbreaks associated with drinking water - United States, 2001-2002.* MMWR 53(SS-8):23-45.

CaDoF. (2011). Retrieved 2010, from California Department of Finance: http://www.dof.ca.gov/research/demographic/reports/view.php

CaDWR. (2011). *Hydrologic Regions of California: Tulare Lake Hydrologic Region*. Retrieved 2010, from Ca Department of Water Resources: http://www.water.ca.gov/groundwater/bulletin118/tulare_lake.cfm

CaEPA. (1997, December). *Public Health Goals for Nitrate and Nitrite in Drinking Water.* Retrieved from Office of Environmental Health Hazard Assessment: http://oehha.ca.gov/water/phg/pdf/nit2_c.pdf

Cal EPA, C. E. (1997). *Public Health Goals for Nitrate and Nitrate in Drinking Water.* Retrieved 2010, from Office of Environmental Health Hazard Assessment: http://oehha.ca.gov/water/phg/pdf/nit2_c.pdf

Cal EPA, C. E. (1997). *Public Health Goals for Nitrate and Nitrite in Drinking Water.* Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment.

CDHS, C. D. (1999). *Drinking Water Source Assessment and Protection Program.* Retrieved 2010, from Division of Drinking Water and Environmental Management: http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWSAPGuidance/DWSAP_document.pdf

CDHS, C. D. (2005). *Certificates and Licenses.* Retrieved 2011, from California Operator Certification Program - Annual Report: http://www.cdph.ca.gov/certlic/occupations/Documents/Opcert/OpCertAnnualReport2005Update.pdf

CDPH. (2000, February). *Health Concerns Related to Nitrate and Nitrite in Private Well Water.* Retrieved October 2011, from Tulare County Health and Human Services Agency: Environmental Health (Water): http://www.tularehhsa.org/?LinkServID=2D7CA07C-FED0-6A01-19858ADA512AE780&showMeta=0

CDPH. (2009a). Certified Water Treatment Devices.

CDPH. (2009b). List of Certified Water Treatment Devices Certified for the Reduction of Nitrates.

CDPH, C. D. (2000, February). *Health Concerns Related to Nitrate and Nitrite in Private Well Water.* Retrieved October 2011, from Tulare County Health and Human Services Agency: Environmental Health (Water): http://www.tularehhsa.org/?LinkServID=2D7CA07C-FED0-6A01-19858ADA512AE780&showMeta=0

CDPH, C. D. (2009a). Certified Water Treatment Devices.

CDPH, C. D. (2009b). List of Certified Water Treatment Devices Certified for the Reduction of Nitrates.

CDPH, C. D. (2010). Permitting Inspection Compliance Monitoring and Enforcement (PICME) and Water Quality Monitoring (WQM) databases.

CDPH, C. D. (2011). Personal Communication with Marc Commandatore and Paul Collins.

Clark, R., & Stevie, R. (1981). A Water Supply Cost Model Incorporating Spatial Variables. *Land Economics*, 57: 18-32.

Culligan. (2011, July 7). POU Cost Estimate. (K. Honeycutt, Interviewer)

CWC, C. W. (2010). Plainview. http://www.communitywatercenter.org/water-valley.php?content=Plainview.

Darby, J., & Newkirk, D. (2010). CDPH Webcast Series: Evaluation and Design of Small Water Systems. UC Davis, California.

Doan, L. (1995). Town's Thirst For Safe Water. *Visalia Times-Delta*. http://www.lynndoan.com/Towns_Thirst.html.

DWR, C. D. (2011). *Hydrologic Regions of California: Tulare Lake Hydrologic Region*. Retrieved 2010, from Ca Department of Water Resources: http://www.water.ca.gov/groundwater/bulletin118/tulare_lake.cfm

EPA, C. (1997). *Public Health Goals for Nitrate and Nitrite in Drinking Water.* Pesticide and Environmental Toxicology Section, Office of Environmental Health Hazard Assessment.

Ford, T. (1999). Microbiological Safety of Drinking Water: United States and Global Perspectives. *Environmental Health Perspectives*, Vol 107 (Suppl 1), 191-206.

Ford, T. (993). The microbial ecology of water distribution an doutfall systems. *Aquatic Microbiology; an Ecological Approach*, 455-482.

Ford, T. (993). The Microbial Ecology of Water Distribution and Outfall Systems. *Aquatic Microbiology; an Ecological Approach*, 455-482.

Ford, T. E. (1999). Microbiological Safety of Drinking Water: United States and Global Perspectives. *Environmental Health Perspectives*, Vol 107 (Suppl 1), 191-206.

Ford, T. E., & Colwell, R. R. (1996). A Global Decline in Microbiological Safety of Water. *Washington: American Academy of Microbiology*.

Ford, T., & Colwell, R. (1996). A Global Decline in Microbiological Safety of Water. *Washington: American Academy of Microbiology*.

Grigg, N. (1989). Regionalization in Water Supply Industry: Status and Needs. *Journal of Water Resources Planning and Management*, 115 3:367.

Harter, T. (2003). Farm Water Quality Planning Reference: Water Well Design and Construction. *University of California, Division of Agriculture and Natural Resources*, Publication 8086 (6 pages).

Holmes, M. (. (2006). Regionalization of Rural Water Systems in New Mexico. *Southwest Hydrology*, 18-20.

Institute of Medicine of the National Acadamies. (2005). *Dietary Reference Instake FOR Water, Potassium, Sodium, Chloride, and Sulfate.* Washington D.C.: The National Academies Press.

Jensen, V., & Darby, J. (2011). *Drinking Water Treatment Technical Report.* UC Davis.

Johnson, C. (2011, June 8). Principal Hydrogeologist/Owner of Aegis Groundwater Consulting, LLC; Well Drilling Estimate. (K. Honeycutt, Interviewer)

Kulongoski, J., & Belitz, K. (2005). *CA GAMA Program: GW Quality Data in the Monterey Bay and Salinas Valley Basins.* USGS and CA SWRCB.

Mahler, R. L., Colter, A., & Hirnyck, R. (2007). *Quality Water for Idaho - Nitrate and Groundwater.* University of Idaho, College of Agricultural and Life Sciences.

Manning, P., Barefield, A., & Mays, J. (2010). *Consolidation Issues: Pros, Cons, Options and Perceptions.* Department of Agricultural Economics, Mississipppi State University Extension Service.

MCWRA, M. C., Extension, U. C., & ITRC, I. T. (1996). *Irrigation and Nutrient Management Conference and Trade Fair.* CDFA Contract#95-0419.

Moore, E. (2010). *Comments on the Central Valley Regional Water Quality Control Board's Staff-Recommended Long-Term Irrigated Lands Regulatory Program and Draft Technical Memorandum Concerning the Economic Analysis of the Irrigated Lands Regulatory Program.* Pacific Institute.

Moore, E. (2010). *Comments on the Central Valley Regional Water Quality Control Board's Staff-Recommended Long-Term Irrigated Lands Regulatory Program and Draft Technical Memorandum Concerning the Economic Analysis of the Irrigated Lands Regulatory Program.* Pacific Institute.

Morales-Suarez-Varela, M., Llopis-Gonzalez, A., & Tejerizo-Perez, M. L. (1995). Impact of nitrates in drinking water on cancer mortality in Valencia, Spain. *European Journal of Epidemiology*, 11(1): 15-21.

Morales-Suarez-Varela, M., Llopis-Gonzalez, A., Tejerizo-Perez, M. L., & Ferrandiz-Ferragud, J. (1993). Concentration of nitrates in drinking water and its relationship with bladder cancer. *Journal of Environmental Pathology, Toxicology and Oncology*, 12(4): 229-36.

Mueller, D. K., Hamilton, P. A., Helsel, D. R., Hitt, K. J., & Ruddy, B. C. (1995). *Nutrients in Ground Water and Surface Water of the United States—An Analysis of Data through 1992.* U.S. Geological Surveye Water Resources Investigations Report 95-4031.

NAS, N. A. (2004). *Dietary Intake Levels for Water, Salt and Potassium to Maintain Health and Reduce Chronic Disease Risk.*

NHDES. (2008). *Drinking Water/Ground Water Fact Sheets*. Retrieved 2010, from New Hampshire Department of Environmental Services: http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/index.htm

Nolan, B. T., Hitt, K. J., & Ruddy, B. C. (2002). Probability of Nitrate Contamination of Recently Recharged Ground Waters in the Conterminous United States. *Environmental Science and Technology, 36 (10), 2138-2145*.

Nolan, B. T., Ruddy, B. C., Hitt, K. J., & Helsel, D. R. (1997). *Risk of Nitrate Groundwater of the United States - A National Perspective .* Environmental Science and Technology, 31, 2229-2236.

NRC. (1995). *Nitrate and Nitrite in Drinking Water.* National Research Council, Washington D.C.: National Academy Press .

NRDC, N. R. (2011). *Bottled Water: Pure Drink or Pure Hype?* Retrieved November 2011, from Natural Resources Defense Council: The Earth's Best Defense: http://www.nrdc.org/water/drinking/bw/exesum.asp

Raucher, R., Harrod, M., & Hagenstad, M. (2004). *Consolidation for Small Water Systems: What are the Pros and Cons?* National Rural Water Association.

Reynolds, K. A., Mena, K. D., & Gerba, C. P. (2008). Risk of Waterborne Illness Via Drinking Water in the United States. *Reviews of Environmental Contamination and Toxicology*, 192:117-158.

Self-Help_Enterprises. (2010). Estimated Pipeline Cost for Water-Related Projects in Tulare County. (H. Canada, Interviewer)

Singlteon, M. J., Roberts, S. K., Moran, J. E., & Esser, B. K. (2011). *California GAMA Domestic Wells: Nitrate and Water Isotropic Data for Tulare County.* Lawrence Livermore National Laboratory (LLNL).

Spalding, R. F., & Exner, M. E. (1993). Occurrence of nitrate in groundwater- a review. *Journal of Environmental Quality*, Vol. 22, 392-402.

Summers Engineering, Inc. (2011, March 18). Kettleman City Community Services District Update of Proposed Surface Water Treatment Plant and Commercial Tank Facility. Hanford, California.

SWRCB. (2010, August). *Groundwater Information Sheet: Nitrate.* Retrieved 2010, from Division of Water Quality: GAMA Program: http://www.swrcb.ca.gov/gama/docs/coc_nitrate.pdf

Texas Water Development Board. (1997). *Texas Guide to Rainwater Harvesting (Second Edition).* Texas Water Development Board.

Trulia, I. (2011). *Trulia Real Estate Search*. Retrieved September 2011, from Trulia, Inc.: http://www.trulia.com/home_prices/

TWDB. (1997). *Texas Guide to Rainwater Harvesting (Second Edition).* Texas Water Development Board.

US Census, U. S. (1999). *Census Summary File 3.*

USCensusBurea. (2011, July 2011). *Census 2000 Urban and Rural Classification*. Retrieved 2011, from United States Census 2000: http://www.census.gov/geo/www/ua/ua_2k.html

USCensusBureau. (1999). *Census Summary File 3.*

USCensusBureau. (2002). *California: Census 2000 Profile.* U.S. Department of Commerce.

USEPA. (2006). *Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems.* 815-R-06-010 U.S.EPA Office of Groundwater and Drinking Water, Standards and Risk Management Division.

USEPA, U. S. (2006). *Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems.* 815-R-06-010 U.S.EPA Office of Groundwater and Drinking Water, Standards and Risk Management Division.

USEPA, U. S. (2010). Basic Information about Nitrate in Drinking Water. http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm.

USEPA, U. S. (n.d.). Cost Evaluation of Point-of-Use and Point-of-Entry Treatment Units for Small Systems: Cost Estimating Tool and User Guide. Cost Estimating Tool, as revised and updated in 2011.

WA DOH, W. S. (2005). Guidance Document: Nitrate Treatment Alternatives for Small Water Systems. DOH PUB. #331-309.

Ward, M., Mark, S., Cantor, K., Weisenburger, D., Correa-Villasenor, A., & Zahm, S. H. (1996). Drinking water nitrate and the risk of non-hodgkin's lymphoma. *Epidemiology*, 7(5): 465-71.

11 Appendix

11.1 Methods

11.1.1 Susceptibility Charts

Explanations are given below for the population/connections estimates given in the susceptibility breakdown charts (Figure 3, Figure 4, and Figure 5). The number below corresponds to the labeled boxes in the susceptibility breakdown charts.

[1] Total Population: California Department of Finance (CDF) estimates for city-wide populations were combined with US Census population estimates for Census Designated Places (CDP). Average annual county growth rates from the CDF 2007 report were applied to project the CDP population to 2010.

[2] Household Self-Supplied or Local Small Water Systems: All parcels with a parcel use code designated as residential and having one to four residential dwelling units outside of city and water system boundaries and 3.3 people were assumed to be inhabiting each dwelling unit.

[3] Community Water System with Only One Well: Public water system information is from the California Department of Public Health's PICME water system database. Data was pulled for all active community and state-small systems in the study area with only one well.

[4] Community Water System with More than One Well: Public water system information is from the PICME database. Data was pulled for all active community and state-small systems in the study area with more than one well that is delivering water directly to individuals. A system's source was assumed to be a "delivering" source following the method described below. Systems with one well and a treatment plant were also included.

[5] Only Surface Water Sources: Public water system information is from the PICME database. Data was pulled for all active community and state small systems in the study area where all "delivering" sources were surface water. A system's source was assumed to be a "delivering" source following the method described below.

[6] Treating or Blending for Nitrate: A list of systems that treat or blend specifically for nitrate was compiled through personal communication with County Environmental Health departments, individual water systems, and the California Department of Public Health.

[7] Not Treating or Blending for Nitrate: Population and connections from Box #6 was subtracted from Box #4.

[8] High Likelihood of Nitrate in Groundwater: A population range is presented based on the water quality analysis for populations listed in Box #2 and #3. The population estimated to reside in areas where there was exceedance of the nitrate threshold chosen (22.5 mg/L as NO_3). The UC Davis Wells Database (CASTING) was used to examine raw nitrate groundwater levels from 1989 to 2010 in all self-supplied household and local small water systems. The CDPH Water Quality Management (WQM) database was used to examine all raw nitrate groundwater levels from 2006 to 2010 in all community and state-small water systems.

[9] Low Likelihood of Nitrate in Groundwater: A population range is presented based on the water quality analysis for populations listed in Box #2 and #3. The population estimated to reside in areas where there was not exceedance o the nitrate threshold chosen. The UC Davis Wells Database (CASTING) was used to examine raw nitrate groundwater levels from 1989 to 2010 in all self-supplied household and local small water systems. The CDPH WQM database was used to examine all raw nitrate groundwater levels from 2006 to 2010 in all community and state-small water systems.

[10] Nitrate MCL Exceedances: Public water system water quality information is from the CDPH WQM database. A system was assumed to exceed the nitrate MCL (i.e. deliver water to customers that exceeded the nitrate MCL) if the maximum recorded nitrate level from 2006-2010 for any "delivering" source in a system was greater than 45 mg/L as NO3. A system's source was assumed to be a "delivering" source following the method described below.

[11] No Nitrate MCL Exceedances: Public water system water quality information is from the CDPH WQM database. A system was assumed to not exceed the nitrate MCL (i.e. no deliveries of water to customers that exceeded the nitrate MCL) if the maximum recorded nitrate level from 2006-2010 for all "delivering" sources in a system were less than or equal 45 mg/L as NO3. A system's source was assumed to be a "delivering" source following the method described below.

[12] No Nitrate Data: This box contains the community water systems with more than one well (Box #4) that did not contain any water quality data on nitrate levels in PICME's CDPH database from 2006-2010.

11.1.2 Estimating "Delivering" Sources of a System

Often, the "sources" listed in CDPH's PICME database simply refers to a water quality sample point along the treatment/distribution line, and not necessarily a well. Samples can be taken at the beginning, end or middle of the distribution line. A source can even refer to a treatment plant. There are various methods to determine that sources are actually delivering the recorded water quality to customers and that are merely intermediary points along the treatment/distribution line. The method used in this report is by no means infallible, but it uses a column in PICME that is present and consistent for most systems, and can therefore be used as a rough way to understand the bigger picture. CDPH's PICME database contains a column labeled "ENTITY_INFO" that describes the source. All sources (with the exception of inactive sources) that are labeled as "Treated" were considered to be delivering sources because this designation refers to a point along the distribution system after treatment has occurred.

Similarly, all sources (with the exception of inactive sources) that are labeled as “Untreated” were also considered to be delivering because these sources refer to points along the distribution system where treatment has not occurred, but will NOT occur in the future. The sources labeled as “Raw” were not included because these sources will be treated in the future, and are therefore not the final entry point into the distribution line before the water reaches customers. Sources with the following specific codes in the “ENTITY_INFO” column were considered to be delivering sources and their water quality data was assumed to reach customers as listed in PICME:

- AT = Active Treated. Active source after treatment.
- AU = Active Untreated. Active Source that is not treated and will not be treated.
- CM = Combination/Blend Mixed. Blended sources included in this station are both treated and raw or untreated.
- CT = Combination/Blend Treated. Blended sources all treated prior to sample point.
- CU = Combination/Blend Untreated. Blended sources are all untreated and will not be treated using any method prior to delivery.
- DT = Distribution Treated. Sample point within the distribution system, after treatment.
- PT = Purchased Treated. Purchased source water that was treated by the seller
- PU = Purchased Untreated. Purchased source water that has not and will not be treated.
- ST = Standby Treated. Emergency source that is used less than 15 calendar days per year, with periods not to exceed five consecutive days, and that receives treatment when in use.
- SU = Standby Untreated. Emergency source that is used less than 15 calendar days per year, with periods not to exceed five consecutive days, untreated.

(CDPH’s PICME Documentation)

A few active community or state-small water systems in the study area did not have any sources labeled with the above designations. In these cases, all sources were maintained for the system and were considered to be delivering sources, even if they were labeled as “Raw”.

11.2 Rainwater Cisterns

A rainwater cistern is an underground basin or an above ground barrel or tank that collects and stores rainwater from rooftops or other catchments. Rainwater harvesting has been used for centuries to supply water for household, landscape, and agricultural uses and is currently being applied in Hawaii, Africa, Asia and Australia. Rainwater harvesting relies on dependable rainfall and runoff and is suitable for locations where the average rainfall exceeds 400 mm/year (Lye, 2002). A rainwater harvesting system has the following six components: a catchment area or roof, gutters and downspouts, leaf screens and roofwashers, cisterns or storage tanks, conveyance, and water treatment. Within the study area the rainwater will be applied to potable uses that will require proper filtration and disinfection prior to distribution. A rainwater cistern used for potable uses should have durable, watertight exterior and a clean, smooth interior sealed with a non-toxic joint sealant with all materials labeled as FDA-approved. Cisterns may be constructed of plastic, metal, concrete and masonry, or wood. Cistern design depends on the rainfall within the region, the catchment area, and the household's daily water use. The cistern needs to be properly located to avoid sunlight penetration, maintain a minimum distance of 50 feet from septic fields, and have the proper foundation and support.

The average construction costs is estimated to be $1.48 per gallon of collection capacity; a potable water case study of a 5,000 gallon above ground fiberglass cistern with a 5 micron sediment filter, a carbon cartridge filter and UV light costs about $6200 (Texas Water Development Board, 1997).

Air pollution due to crop dusting and agricultural practices would create water quality problems, as the chemicals and debris left on rooftops would wash off into the cistern with the first rainfall. Another concern would be in the reliability, timing, and volume of the rainfall. As previously mentioned, the Salinas Valley annually receives about 20 inches of rain, and the Tulare Lake Basin annually receives between 7 and 13 inches of rain. The Texas Rainwater Harvesting Manual estimates a production of 600 gallons of water for every inch of rain over a 1,000 square foot catchment area, that would yield an annual amount of 12,000 gallons of water per household (32 gallons per day) within the Salinas Valley and an annual amount between 4,200 and 7,800 gallons of water per household (11 to 21 gallons per day) within the Tulare Lake Basin, assuming the average catchment area of 1,000 square feet. The inconsistency and unreliability of the distributional pattern of this source would not be a sufficient supply for a household to depend on for potable water.

Overall, public health and water quality seem likely to be the greatest impediment to use of cisterns as a replacement water supply. Costs can be high, even though water yields are likely to be adequate for drinking and cooking water.

12 Case Studies

CITY OF LINDSAY

Phone Conversation with Public Works Director, Mike Camarena (5/19/11) 559.333.4107

The City of Lindsay's main water supply today is treated surface water from the Friant Kern Canal, they have some groundwater wells, but they prefer to use the surface water due to groundwater quality issues (they contain nitrate, but do not exceed the MCL). The City has a long-term contract with USBR for a set amount of water to be delivered costing $225/af (the contract was signed in 2006). The City is currently helping Paige-Moore Tract by supplying them with water, but the current water treatment plant was built at a specific capacity and the City is starting to have issues with maxing out capacity. They have to chlorinate the raw water from the canal prior to filtration and this initial and final chlorination process is causing disinfection byproducts (DBPs) to contaminate the supply. The facility needs to be expanded to allow the water to sit for a long enough detention time and allow the chlorine to properly disinfect the water. The City of Lindsay is applying for SRF funding for either a new, bigger contact tank or an alternative disinfectant, the total cost is estimated at $300,000 to $400,000. The City will not be funding the distribution or pipeline costs for El Rancho or Tonyville, but they have to apply for SRF funding to connect to the system. The Tonyville application had just been rejected. It is hard for the City to incorporate neighboring communities, even though they want to help because they need to do what is best for their future growth and they must preserve their best interest. Currently within the City of Lindsay it is policy to charge double the cost of water to anyone served outside of the city limits. This double charge allows for the City to help fund their system and prepare for future growth.

**13.04.300 (City Code) – Service Outside City: All water services outside the city limits are subject to council approval, and shall pay twice the applicable monthly rates. (Ord. 329 § 5-5.1974)

Since some of these smaller communities outside of city limits cannot afford double they may have to obtain council approval to try to lower that value. The City is a metered water system and anyone who is connecting must be metered as well. They do not have block water rates. Also, for the City to include Tonyville and El Rancho they must alter their contract with USBR and increase the allotment of Friant Kern Canal water they receive (not sure how this will be charged to the added customers, maybe included in their double charge?). Mike mentioned that the state is starting to learn that irrigation districts are not domestic water suppliers.

LEMON COVE WATER COMPANY

Phone Conversation with Bill Pensar (5/23/11) 559.597.2504

They received Prop 84 Safe Drinking Water funding back in 1991 for a new well at Mateas (sp.) Point, they have been experiencing nitrate fluxes over the past 20 years. The nitrate concentrations have gone up to 100 mg/L as nitrate and then down to below the MCL and then back up to 100 mg/L. Halloween of 2008 they applied for funding for a Feasibility Study to drill a new well. They were accepted for loans, but want grant money. Their application was just recently re-submitted. The feasibility study will cost about $200,000 and drilling a new well will cost about $100,000. They are hoping that the study will also cover expenses for a new tank that can be built up on a hill and can pump at night utilizing the cheap energy costs and gravity driven distribution. The new well will be in a location that is closer to them than the existing well so they will not have to drill pipeline or increase the distribution mains. They believe drilling a new well is the best option since you do not have to worry about brine disposal, purchasing or filing a new license, hiring an operator or participating in a lot of O&M activities. They are under the impression that RO is outrageously expensive and they are worried about disposing the brine back into the TLB. The cost of trucking the brine to a remote location is too expensive as well.

PLAINVIEW MUTUAL WATER COMPANY: Leaky Distribution Lines and Contaminated Back-Up Well

Plainview Mutual Water Company provides drinking water to around 800 people in the unincorporated area of Plainview, Tulare County (CWC, 2010). When one of their wells was shut down because nitrate levels started to exceed the MCL, Plainview was forced to rely on their only other well. This second well had recorded concentrations of DBCP (CWC, 2010). The distribution mains for this area were installed in 1941 and severe rusting and leakage issues caused bacterial contamination of the drinking water being supplied to the homes (Doan, 1995). A flat rate of $25 per month was charged to these households (Doan, 1995) whose median income in 1997 was only $12,000. Funds raised by the water company were not enough to adequately maintain the water system or to protect the water; many households were left to struggle to finance their own in home chlorine treatment for the bacteria (Doan, 1995). Plainview Mutual Water Company was able to secure $2.3 million from federal and state sources to replace their distribution system and build a new well. This tremendous sum could have never been financed by such a small disadvantaged community.

Doan, Lynn (1995). “Towns Thirst For Safe Water”. Visalia Times-Delta <http://www.lynndoan.com/Towns_Thirst.html>

Community Water Center (CWC) (2010). “Plainview”. <http://www.communitywatercenter.org/water-valley.php?content=Plainview>