Chapter 4
Groundwater Quality

Sacramento River Basin—Introduction

Organization and Elements

The discussion of groundwater quality in the Sacramento River Basin is organized by groundwater basin and subbasin. Figure 4-1 shows the Sacramento River Basin. Each subbasin is discussed individually. The subbasin sections include a general physiographic and hydrogeologic description that includes information about groundwater recharge and discharge mechanisms, subsurface lithology, and groundwater bearing zones. We also include information about land use, water agencies, and purveyors; the status of groundwater level changes; and any ordinances that may affect groundwater supply or quality. We present groundwater quality data to the extent available for nutrients, pesticides, salinity, trace elements, and drinking water constituents of concern.

We discuss the available water quality data in the context of agricultural-irrigation related processes affecting the distribution and concentration of individual constituents. This includes description of possible discharge pathways for contaminants. We also include a description of land- and water-management practices that may affect groundwater quality and the adequacy of the available data establishing baseline conditions for the subbasin. Figure 4-2 shows the locations of groundwater basins and subbasins within the Sacramento River Basin. The groundwater quality descriptions are organized as follows. Large subbasins in the Sacramento Valley are discussed first in alphabetical order. Next, we describe small basins peripheral to the Valley in alphabetical order.

General Sources of Information

Sources of information for each subbasin include primarily reports and data from the California Department of Water Resources (DWR), California Department of Pesticide Regulation (DPR) and U.S. Geological Survey (USGS). Specifically, land use data came from the DWR land use surveys conducted periodically throughout California. DWR 2004 Bulletin 118 was the primary source of information for subbasin hydrogeologic and physiographic descriptions. Several USGS reports provided information about concentrations of constituents in several basins. Recent USGS reports from the National Water Quality Assessment Program provided information about probable processes affecting groundwater quality in specific areas of the Sacramento River Basin.

DPR's Ground Water Protection Program determines where and how pesticides are contaminating ground water, identifies areas sensitive to pesticide contamination and develops mitigation measures to prevent that movement. We also adopt regulations and do outreach to carry out those mitigation measures. The measures are designed to prevent continued movement to ground water in contaminated areas and to prevent problems before they occur in other areas.

Other literature was reviewed and cited that provided understanding about agriculturally related processes affecting groundwater quality in general and for specific subbasins. This included peer reviewed journal articles and preliminary data and reports from the Groundwater Ambient Monitoring Assessment (GAMA) Project funded by the State Water Resources Control Board (State Water Board). We were able to obtain reports from the State Water Board website that were helpful in understanding processes and travel times for groundwater to reach well screens for specific areas.

We understand that the USGS has recently completed a comprehensive sampling of groundwater in the Sacramento River Basin. However, repeated phone calls to USGS project leader about the study and sampling results were unreturned. In the following section, we outline general concepts and understanding of processes affecting groundwater quality in the Sacramento River Basin groundwater.

General Concepts and Processes Affecting Groundwater Quality in the Sacramento River Basin

Specific Contaminants

The primary agriculturally related constituents of concern in groundwater in the Sacramento Valley are shown in Table 4-1. Table 4-1 also shows the primary processes affecting the levels and distributions of these constituents.

Table 4-1. Constituents of Concern in Sacramento Groundwater

Constituent of Concern	Agricultural Source
Nutrients—primarily nitrate but may include nitrites and ammonia.	Organic and chemical fertilizers, animal wastes, natural sources
Pesticides (insecticides and herbicides) and degradation products	Crop applications
Salt—primarily as electrical conductivity and total dissolved solids.	Evaporation from shallow water table and evapotranspiration of soil water, fertilizers, irrigation water, natural soil salinity, animal wastes
Trace elements (cadmium, copper, lead, nickel, zinc, selenium, arsenic and boron)	Fertilizers, irrigation water and natural sources
Organic carbon and disinfection byproduct precursors	Mobilization of soil organic matter and plant residues due to cultivation and irrigation
Microorganisms	Animal wastes

Nutrients

The primary nutrient of water-quality concern in Sacramento River Basin groundwater is nitrogen, primarily as nitrate. A certain amount of nitrate exists naturally in Sacramento Valley groundwater. Hull (1984) reported a median nitrate concentration in groundwater in the early 1900s of 0.7 milligrams per liter (mg/L) as nitrate-nitrogen. The highest nitrate-nitrogen concentration was 14 mg/L. Hull (1984) estimated that, under natural conditions, not more than 3 mg/L nitrate-nitrogen would be expected in groundwater. Groundwater nitrate concentrations have generally increased in Sacramento Valley groundwater since the early 1900s (Hull 1984) probably as the result of agricultural fertilization. For example, from 1974 to 1978, Hull (1984) reported the median nitrate-nitrogen concentration as 1.6 mg/L.

Further analysis of nitrate data indicated increasing groundwater concentrations in 3 sub-areas on the Sacramento Valley from 1955 to 1978 (Hull 1984). Specifically, Hull (1984) evaluated the average change in groundwater nitrate-nitrogen concentrations for six sub-areas with different hydrochemical characteristics or facies: Tuscan Volcanic, Victor Plain, Butte Basin, Sutter Basin, North Alluvial Fans, and South Alluvial Fans. Hull (1984) documented statistically significant (at the 90% confidence level) increases in the Butte Basin, South Alluvial Fans, and North Alluvial Fans sub-areas of the Sacramento Valley. Average nitrate-nitrogen concentrations were generally less than 7 mg/L in all the sub-areas.

For the three sub-areas where nitrate-nitrogen concentrations were shown to increase, annual increases ranged from 0.04 to 0.1 mg/L nitrate-nitrogen per year. Association of increasing nitrate concentrations with other indicators of agricultural irrigation such as stable isotopes (Dawson 2001a; Davisson and Criss 1993) and dissolved solids (Hull 1984) indicate irrigated agriculture as the primary source of increasing nitrate concentrations in Sacramento Valley groundwater. Specifically, Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities.

Pesticides

Pesticide detections in Sacramento River Basin groundwater are generally limited to a small number of compounds (DPR 2003). Table 4-2 shows the detected compounds that were the result of legal agricultural use for counties in the Sacramento River Basin from 1985 to 2003. Table 4-2 shows the results of 508 well sampling studies from 1985 to 2003 in which the various agencies throughout California sampled 22,008 wells; 12,289 (55.8%) of the wells were public drinking water wells, 8,500 (39.2%) were private drinking water wells, and 1,027 (5%) were non-drinking or unknown well types. Throughout California, the five compounds with the greatest number of detections were 1,2-dibromo-3-chloropropane (DBCP), ethylene dibromide, simazine, 1,2-D, and diuron (3,573, 612, 421, 372, and 268 detections, respectively).

In the Sacramento River Basin from 1985 to 2003 triazine herbicides and their daughter products (2-amino-4-chloro-6-ethylamino-s-triazine or ACET, Atrazine, Promoton, Simizine, 2,4-diamino-6-chloro-s-triazine or DACT, deethyl-atrazine or DEA, and bentazon comprised 88% of the groundwater pesticide detections. Triazine herbicides and the daughter products comprised 64% of the detections.

Table 4-2. Pesticide Detections in Wells for Counties in the Sacramento River Basin (1985–2003)

County	ACET	Atrazine	Bentazon	Bromocitl	DACT	DEA	Diuron	Norflurazon	Promoton	Simizine
Butte		4	8	2		1	1	2	1	1
Colusa	2		7			1			1	4
Glenn		37	29			4	1		9	21
Placer			1	2						
Sacramento		1	1							
Shasta	1				1					
Solano	6	14			3	11	4	1	1	1
Sutter			7							2
Tehama	1	7				2	1			3
Yolo		3	3							3
Yuba			10							
Total	10	66	66	4	4	19	7	3	12	35

Notes:
ACET = 2-amino-4-chloro-6-ethylamino-s-triazine.
DACT = 2,4-diamino-6-chloro-s-triazine.
DEA = deethyl-atrazine.

Detection of pesticides in groundwater is related to physical and chemical properties of soils and the specific compounds, water management, and spatial and temporal variability of pesticide application and soil-water processes and properties. Factors that generally increase the degradation and soil adsorption of the pesticide reduce the probability of detection in groundwater. Barbash and Resek (1996) discussed the expected trends in pesticide detection in groundwater in relation to pesticide soil dissipation half-life and K_{oc}, the partitioning coefficient for soil organic matter.

Theoretically, groundwater detection is less likely for shorter dissipation half-lives (less than about 100 days) and K_{oc} values greater than about 1,000 milliliters per gram (mL/g). Detection is more likely for soil dissipation half-lives greater than about 100 days and K_{oc} values less than about 1,000 mL/g. However, in a comprehensive evaluation of pesticides in groundwater throughout the United States, Barbash and Resek (1996) did not find strict adherence to these principles. Reasons for the discrepancies include preferential transport of pesticides (including transport in boreholes of poorly constructed or failed wells), disparity and inconsistency in pesticide soil dissipation half-lives, and spatial variability in initial pesticide concentrations in soil water following application.

Water management practices also influence movement of pesticides in irrigated areas. Troiano et al. (1993) investigated difference irrigation methods and found that “leaching of pesticides was less in sprinkler applications because water was applied more frequently in smaller applications than for the basin-flooding method.” For basin-flooding treatments, such as those practiced on rice fields, a large amount of water application was required for each irrigation in order to provide application across the plot. Although irrigations were less frequent, the larger water volume caused greater downward movement of water and atrazine residues.

Triazine herbicides and their degradation products, ACET, DEA, and DACT are consistently detected in groundwater because of their widespread use and chemical characteristics. Atrazine and its degradation compounds represent the most widely detected compounds (44% of the total detections) in the Sacramento River Basin. The K_{oc} for atrazine is 93 mL/g and the soil dissipation half-life is 30 days. Atrazine has a variety of agricultural uses including control of weeds in corn and other forage crops. The major uses for atrazine and bromacil are for weed control in right-of-way areas and for landscape maintenance. Simazine is used for weed control in right-of-way areas and for landscape maintenance and also on many crops grown in the study area, including nut and fruit orchards.

Bentazon (30% of the detections) was widely used in rice prior to 1989 and was officially banned in 1992. Its presence in groundwater in a study completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Dawson (2001a) found that shallower wells had more occurrences of pesticide contamination than deeper wells, indicating the movement of pesticides from the ground surface downward. Concentrations of bentazon showed a statistical relationship to tritium concentrations. Since tritium is used for age-dating groundwater, this relationship suggests that bentazon concentrations are related to recharge age of the groundwater in which it was found.

Dawson (2001a) reported other rice pesticides Molinate, Thiobencarb, and Carbofuran detections in 7, 3, and 4 of the 28 shallow wells sampled in rice growing areas. The presence of rice herbicides in shallow wells indicates movement of these pesticides to groundwater not evidenced by sampling of wells described in the DPR report.

Salinity

Irrigated agriculture can result in increasing groundwater salinity. Irrigation water containing varying levels of dissolved constituents or salts is partially evaporated as the result of crop transpiration and evaporation from the soil. These processes concentrate salts in the remaining water that percolates to groundwater. The extent of the effect on groundwater salinity depends on rainfall, volume of water applied, groundwater pumping and hydraulics, the salinity of the irrigation water, and chemical reactions in soils and aquifer materials. However, mixing of naturally occurring saline groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a) can also affect groundwater salinity.

Hull (1984) documented significant increases in total dissolved solids (TDS) in 5 out of 6 areas in Sacramento Valley groundwater between 1955 and 1977. Specifically, Hull (1984) evaluated the average change in groundwater TDS for six sub-areas with different hydrochemical characteristics or facies: Tuscan Volcanics, Victor Plain, Butte Basin, Sutter Basin, North Alluvial Fans, and South Alluvial Fans. For all these areas except the Sutter Basin, dissolved solids concentrations increased significantly with time. Increases in time explained 31 to 76% of the variance in dissolved solids concentrations for these five areas. In other words, the r^2 ranged from 0.36 to 0.76. Also, the regression relations for these five areas were statistically significant at the 90% confidence interval. Increases ranged from 0.95 mg/L per year in the Tuscan volcanic sub-area to 4.75 mg/L per year in the South Alluvial Fans. All of the remaining annual increases were less than 2 mg/L. Concomitant increases in nitrate concentrations in 3 of the sub-areas indicate a probable association of increasing groundwater dissolved solids and nitrate concentrations.

Using stable isotope data, Davisson and Criss (1993) further elucidated the probably processes influencing increasing groundwater salinity in the Davis area. Specifically, their data supported the hypothesis of higher salinity groundwater within about 240 feet of land surface could be attributed to infiltration of irrigation water. The increased isotopic enrichment of this groundwater indicated soil evaporation associated with irrigated agriculture. This isotopic enrichment was also associated with high nitrate concentrations indicating fertilization influence. In general, dissolved solids concentrations in Sacramento Valley groundwater are less than 1,000 mg/L and are generally not substantially affected by geochemical reactions in groundwater.

Drinking Water Constituents of Concern

There is some evidence of increased dissolved organic concentrations in groundwater in rice growing areas. We were unable to identify evidence for increases disinfection byproduct precursor concentrations.

Microorganisms

We did not identify any data for microorganism contamination related to irrigated agriculture in the Sacramento River Basin.

Groundwater Movement and Solute Transport

We did not encounter recent studies of groundwater solute movement for much of the Sacramento River Basin. Recent studies as part of the GAMA Program funded by the State Water Board provide some insight about the physical processes affecting contaminant movement in Sacramento River Basin groundwater. The primary objective of the GAMA Program is to assess the water quality and to predict the relative susceptibility to contamination of groundwater resources throughout the state of California.

The goal of the study is to provide a probabilistic assessment of the relative vulnerability of groundwater used for the public water supply to contamination from surface sources. This assessment of relative contamination vulnerability is based on the results of two types of analyses that are not routinely carried out at public water supply wells: ultra low-level measurement of volatile organic compounds (VOCs), and groundwater age dating (using the tritium-helium-3 method). In addition, stable oxygen and hydrogen isotope measurements help determine the recharge water source. Interpreted together, and in the context of existing water quality and hydrogeologic data, these observable parameters help define the flow field of a groundwater basin, and indicate the degree of vertical communication between near-surface sources (or potential sources) of contamination, and deeper groundwater pumped at high capacity production wells.

A study of groundwater age and movement in the Chico area provides some insight to processes affecting potential future contamination due to irrigated agriculture. A major result of the study with isotopes shows the influence of stream recharge in groundwater, relatively lower influence with increasing distance from the streams, and infiltration of irrigation water in other locations. Groundwater age-dating results indicate that a large volume of the water produced from drinking wells is derived from pre-1955 recharge. A few wells produced water that was less than 10 years old, but they were located close to major rivers and show evidence of river recharge to the wells. The large volume of old groundwater observed in these wells is not likely to have carried advectively transported modern-day contaminants.

In addition to public supply wells, this report included results from 39 monitoring wells that are widely spaced across the Sacramento Valley. Eleven sets of nested monitoring wells with relatively narrow well screens provide a more detailed picture of the vertical patterns in isotope tracers, and reveal the presence of paleowater in deep monitoring wells, especially to the west of the Sacramento River. These wells produce groundwater consistent with residence times of 20,000 years or more. Shallow monitoring wells on the east side of the valley show evidence for recent recharge of evaporated water from irrigation.

The large variation in groundwater ages and the presence of paleowater in deep wells indicate as yet little potential movement of contaminants to deep groundwater (below about 300 feet in the Chico area study). Similar information is required in other areas and further analysis to evaluate direction and timing of long-term flows paths to water-supply wells and future contamination potential.

Groundwater Quality Summary

The results of our investigation reported here are consistent with this theme of relatively localized evidence of groundwater contamination due to irrigated agriculture in the Basin. Table 4-3 summarizes the results of our review of the available information. Twenty-five percent of the basins or subbasins have insufficient data or available data indicate no groundwater quality problems. Table 4-3 indicates in a large number of the basins or a subbasin (30%), irrigated agriculture occupies 5% or less of the area.

The key groundwater quality problems are in the areas of most intensive agriculture in the Sacramento Valley Basin, specifically subbasins in which rice cultivation occupies a significant percentage of the land use indicate potential groundwater quality issues related to movement of pesticides and nitrates. These include Colusa (24% of the land is used for rice cultivation), East Butte (41%), North American (22%), North Yuba (40%), South Yuba (16%), Sutter (23%) and West Butte (29%).

Table 4-3. Summary of Groundwater Quality Issues for the Groundwater Basins

Basin/Subbasin Number*	Basin Name Subbasin Name	Water Quality Issues That Are Probably Related to Irrigated Agriculture	Percent Irrigated Agriculture
5-21	**Sacramento Valley**		
5-21.54	Antelope	Nitrate concentrations of 20–45 mg/L observed in the west-central part of the subbasin.	44
5-21.53	Bend	No apparent problems.	3
5-21.52	Colusa	Elevated groundwater salinity and concentrations of nutrients and rice pesticides.	66
5-21.51	Corning	Possibly salinity.	35
5-21.55	Dye Creek	Possibly salinity.	20
5-21.59	East Butte	Pesticides and nitrates are the primary constituents of concern. There are also localized areas of high salinity.	60
5-21.56	Los Molinos	Possibly salinity. Insufficient data to determine effects of irrigated agriculture.	18
5-21.64	North American	Nitrates, pesticides, dissolved solids and volatile organic compounds are the result of agricultural and urban land uses.	38
5-21.60	North Yuba	Nutrients (nitrogen, phosphorus), salinity, pesticides, and trace elements are the primary constituents of concern. Pesticides are persistent in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring but some are elevated to levels above the national limits. There is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the North Yuba subbasin.	71
5-21.50	Red Bluff	Salinity.	10
5-21.66	Solano	High levels of pesticides, nitrates and salinity are probably related to irrigated agriculture.	65
5-21.65	South American	High levels of pesticides, nitrates and salinity are probably related partially to irrigated agriculture and partially to urban land uses.	25
5-21.61	South Yuba	Pesticides and increasing salinity are the primary constituents of concern related to irrigated agricultural practices.	48
5-21.62	Sutter	Pesticides and increasing salinity are the primary constituents of concern related to irrigated agriculture. Localized high nitrogen concentrations may be caused by agricultural practices.	79

Basin/Subbasin Number*	Basin Name Subbasin Name	Water Quality Issues That Are Probably Related to Irrigated Agriculture	Percent Irrigated Agriculture
5-21.57	Vina	Groundwater quality problems include localized high calcium and high nitrate, TDS and VOCs primarily in the Chico area. It is uncertain whether these contaminants originate from agricultural practices. High nitrates are likely from septic systems. Dissolved Solids may originate from irrigation practices, but it is uncertain.	36
5-21.58	West Butte	Dissolved solids are elevated in localized areas throughout the subbasin and pesticides have been detected in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring, as well as nitrates in some locations. However, there is evidence of elevated groundwater salinity and concentrations of nutrients and pesticides as the result of irrigated agriculture.	70
5-21.67	Yolo	High dissolved solids and nitrate are related to irrigated agriculture.	66
5-2	**Alturas Area**		
5-2.01	South Fork Pitt River	Salinity in localized areas	31
5-2.02	Warm Springs Valley	Salinity in localized areas	23
5-91	**Antelope Creek**	No groundwater quality data available.	5
5-54	**Ash Valley**	No water quality data available. All agricultural land is pasture.	37
5-64	**Bear Valley**	Insufficient water quality data.	5
5-20	**Berryessa Valley**	No irrigated agriculture in this basin.	0
5-15	**Big Valley**	Increasing levels of nitrate in individual wells may be the result of irrigated agriculture. TDS ranges from 270 to 790 mg/L, averaging 535 mg/L, which is above the EPA SMCL, may also be the result of irrigated agriculture. Elevated levels of iron and boron caused by thermal waters.	37
5-4	**Big Valley**	Localized high levels of nitrates, manganese, fluoride, iron, sulfate, conductivity, calcium, adjusted sodium absorption ratio, ammonia, phosphorus and total dissolved solids. Pasture land comprises 28% of the basin and may be the cause for nitrates, phosphorus, ammonia, and dissolved solids.	37
5-92	**Blanchard Valley**	No groundwater quality data available.	10
5-48	**Burney Creek Valley**	Insufficient water quality data available to determine effects of irrigated agriculture. All agricultural land is pasture.	41
5-17	**Burns Valley**	No indication that groundwater quality problems are due to agricultural irrigation.	19
5-51	**Butte Creek Valley**	No irrigated agriculture in this basin.	0

Basin/Subbasin Number*	Basin Name Subbasin Name	Water Quality Issues That Are Probably Related to Irrigated Agriculture	Percent Irrigated Agriculture
5-21.68	**Capay Valley**	Dissolved solids from 6 wells range from 300 to 500 mg/L, the EPA MCL is 500 mg/L. Naturally occurring boron and other minerals exist in the groundwater. Mercury seepage from mining waste could be an issue in this subbasin. There is insufficient data to determine the effects of irrigated agriculture.	31
5-45	**Cayton Valley**	No groundwater quality data available. All agricultural land is pasture.	69
5-61	**Chrome Town Area**	No irrigated agriculture in this basin.	0
5-66	**Clear Lake Cache Formation**	Insufficient water quality data.	1
5-58	**Clover Valley**	No irrigated agriculture in this basin.	0
5-19	**Collayomi Valley**	High boron. Locally high iron and manganese. All are naturally occurring.	10
5-18	**Coyote Valley**	No apparent agriculturally related groundwater quality problems.	28
5-53	**Dixie Valley**	No groundwater quality data available. All agricultural land is pasture.	51
5-49	**Dry Burney Creek Valley**	No irrigated agriculture in this basin.	0
5-41	**Egg Lake Valley**	No irrigated agriculture in this basin.	0
5-62	**Elk Creek Area**	No groundwater quality data available	6
5-5	**Fall River Valley**	Localized high concentrations of nitrate, manganese, ammonia, and phosphorus. Pasture land comprised 31% of the land use.	43
5-90	**Funks Creek**	Insufficient groundwater quality data.	17
5-47	**Goose Valley**	No groundwater quality data available.	92
5-1	**Goose Lake Valley**		
5-1.02	Fandango Valley	Insufficient data.	25
5-1.01	Lower Goose Lake Valley	Insufficient data.	26
5-52	**Grays Valley**	No irrigated agriculture in this basin.	0
5-59	**Grizzly Valley**	No irrigated agriculture in this basin.	0
5-16	**High Valley**	TDS ranges from 480 to 745 mg/L, averaging 598 mg/L, which is above the EPA SMCL. Locally high ammonia, boron, phosphorus, chloride, iron, and manganese.	8
5-40	**Hot Springs Valley**	No groundwater quality data available. All agricultural land is pasture.	10
5-60	**Humbug Valley**	Insufficient groundwater quality data.	4
5-3	**Jess Valley**	Insufficient data.	53
5-86	**Joseph Creek**	No groundwater quality data available.	20
5-46	**Lake Britton Area**	No irrigated agriculture in this basin.	0
5-57	**Last Chance Creek Valley**	No irrigated agriculture in this basin.	0
5-65	**Little Indian Valley**	Insufficient data.	24
5-31	**Long Valley**	Insufficient data	24
5-44	**Long Valley**	No irrigated agriculture in this basin.	0

Basin/Subbasin Number*	Basin Name Subbasin Name	Water Quality Issues That Are Probably Related to Irrigated Agriculture	Percent Irrigated Agriculture
5-30	**Lower Lake Valley**	High boron. Localized high iron, manganese, calcium, sodium, sulfate, and TDS. Insufficient data to determine effect of irrigated agriculture	6
5-35	**McCloud Area**	No irrigated agriculture.	0
5-95	**Meadow**	Insufficient groundwater quality data.	5
5-94	**Middle Creek**	No groundwater quality data available.	5
5-87	**Middle Fork Feather River**	Insufficient groundwater quality data.	4
5-50	**North Fork Battle Creek**	No groundwater quality data available.	6
5-93	**North Fork Cache Creek**	No irrigated agriculture.	0
5-38	**Pondosa Town Area**	No information available about the basin.	–
5-68	**Pope Valley**	No groundwater quality data available. Almost all agricultural land is vineyards.	28
5-6	**Redding Area**		
5-10	American Valley	Insufficient groundwater quality data.	42
5-6.03	Anderson	Localized high nitrate may be due to irrigated agriculture.	13
5-6.01	Bowman	No known groundwater quality problems due to agricultural land use.	3
5-6.04	Enterprise	High total dissolved salts and chlorides in the lower Tehama and Tuscan Formations. Sodium and boron at shallow depth where wells draw from the Chico Formation. Locally high iron and manganese. No known groundwater quality problems due to agricultural land use.	9
5-9	Indian Valley	Insufficient groundwater quality data.	39
5-7	Lake Almanor Valley	Locally high copper, iron, lead, manganese, calcium and boron. No apparent groundwater quality problems due irrigated agriculture.	19
5-6.05	Millville	High concentrations of total dissolved salts and chlorides in underlying marine deposits. Sodium and boron occur where wells draw from the Chico Formation. Locally high iron and manganese concentrations. No known groundwater quality problems due to agricultural land use.	4
5-11	Mohawk Valley	Locally high iron, manganese, ammonia, phosphorus, ASAR and boron levels, most likely from natural sources.	7
5-8	Mountain Meadows Valley	Insufficient groundwater quality data.	46
5-6.02	Rosewood	No known groundwater quality problems.	4
5-6.06	South Battle Creek	No known groundwater quality problems.	6
5-43	**Rock Prairie Valley**	No irrigated agriculture.	0
5-36	**Round Valley**	TDS ranges from 141 to 633 mg/L, averaging 260 mg/L. Most agricultural land is pasture land. Insufficient information to determine effects of irrigated agriculture.	34

Basin/Subbasin Number*	Basin Name Subbasin Name	Water Quality Issues That Are Probably Related to Irrigated Agriculture	Percent Irrigated Agriculture
5-14	**Scotts Valley**	Nitrate, iron, manganese, and boron concentrations exceed EPA maximum acceptable concentrations agricultural irrigation for selected wells. Insufficient information to determine effects of irrigated agriculture.	22
5-12	**Sierra Valley**		
5-12.02	Chilcoot	Localized high dissolved solids.	25
5-12.01	Sierra Valley	Localized high dissolved solids, boron, fluoride, iron, sodium, arsenic, manganese. Thermal groundwater intrusion is the most likely source for these constituents.	31
5-89	**Squaw Flat**	No irrigated agriculture in this basin.	0
5-88	**Stony Gorge Reservoir**	No groundwater quality data available.	4
5-63	**Stonyford Town Area**	Insufficient groundwater quality data.	12
5-37	**Toad Well Area**	No irrigated agriculture in this basin.	0
5-13	**Upper Lake Valley**	Localized high salinity likely due to irrigated agriculture.	42
5-56	**Yellow Creek Valley**	No water quality data available. All agricultural land is pasture.	61

Notes:
EPA = U.S. Environmental Protection Agency.
MCL = Maximum Contaminant Level. (EPA 2005.)
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Limit. (EPA 2005.)
TDS = total dissolved solids.
VOCs = volatile organic carbons.
* Basin/Subbasin Number from California Department of Water Resources Bulletin 118.

Sacramento River Basin—Subbasins

Antelope Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Antelope subbasin is bounded on the west by the Sacramento River, on the north by the Red Bluff Arch, on the northeast by the Cascade Range, and the southeast by Antelope Creek. The Antelope subbasin is contiguous with the Dye Creek Subbasin to the south. The subbasin is 18,710 acres (29 square miles [mi^2]) in size and is located in Tehama County.

The following description of the hydrogeology in the Antelope subbasin is taken from DWR Bulletin 118 (DWR 2004). The aquifer system in this subbasin is comprised of continental deposits of Tertiary to late Quaternary age. The Quaternary deposits include Pleistocene Modesto and Riverbank Formations. The Tertiary deposits include the Pliocene Tehama Formation and the Tuscan Formation. The Tuscan Formation is the primary water-producing zone in the basin.

The Pleistocene Modesto Formation consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tehama, Tuscan, and Riverbank Formations. Well logs for wells drilled on the floodplain east of Red Bluff indicate that coarse-grained clean sand and gravel extend to a depth of approximately 50 feet below the surface. Below this depth, cemented gravel, sandstone, and hard clay of the Tehama and Tuscan Formations are encountered. The Modesto Formation yields limited groundwater due to its limited thickness.

The Pleistocene Riverbank Formation is observed in the far northern extents of the subbasin. The Riverbank Formation yields limited groundwater due to its limited thickness and areal extents.

The Pliocene Tuscan Formation is composed of volcanic breccia, tuff, tuff breccia, volcanic sandstone and conglomerate, basalt flows, and tuffaceous silt and clay. The formation is mostly consolidated tuff in the area of exposure east of the valley in the Cascade Range foothills. From there tuff breccias grade westerly into volcanic sands, gravels, and clay (DWR 1978). The Tuscan Formation is the major water-bearing aquifer in the northeastern portion of the Sacramento Valley. Thickness of the formation within the subbasin is approximately 1,500 feet.

The Pliocene Tehama Formation interfingers with the Tuscan Formation along the Sacramento River and is exposed in Westside Sacramento River banks. The formation consists of fluvial deposits of predominantly silt and clay with gravel and sand interbeds. The formation is identified within the subbasin at depths ranging from 100 to 150 feet.

Long-term groundwater levels indicate a decline of 5–10 feet associated with the 1976–1977 and 1987–1994 droughts, followed by a recovery to pre-drought conditions of the early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation of approximately 2–15 feet for normal and dry years. Overall, there does not appear to be any increasing or decreasing trends in groundwater levels.

Groundwater storage capacity was estimated to be 269,200 acre-feet. This estimate was based on an average specific yield of 7.2% and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (23–27 inches/year), irrigation infiltration, stream infiltration, and infiltration from on-site domestic waste disposal systems.

Stream infiltration comes from the Sacramento River, Salt Creek, and Antelope Creek. In an investigation conducted by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), the upper and intermediate aquifer zones (located between the local groundwater elevation and 150 feet in depth) were found to intercept the Sacramento River. Diurnal fluctuations in river stage produce diurnal water level fluctuations in the deeper aquifer zone.

A 1987 study of the Antelope Groundwater Subbasin by DWR stated that seepage from Lake Red Bluff raised groundwater levels 5–10 feet in the southern part of the subbasin since 1966, when then diversion dam gates were first closed.

Municipal and industrial use is approximately 2,100 acre-feet. Deep percolation of applied water is estimated to be 3,800 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 49% of the subbasin, urban land use accounts for about 10% of the subbasin, and native land accounts for about 41% of the subbasin. The primary crop types in the region are orchards and pasture. Table 4-4 provides details of the land uses within the subbasin.

Table 4-4. Land Use in the Antelope Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	20	0.10
Deciduous Fruits and Nuts	5,730	30.60
Field Crops	180	1.00
Grain and Hay	490	2.60
Pasture	1,730	9.30
Truck, Nursery, and Berry Crops	20	0.10
Idle	880	4.70
Semiagricultural and Incidental	150	0.80
Subtotal	9,200	49.20
Urban		
Urban—unclassified	100	0.50
Urban Landscape	60	0.30
Urban Residential	1,190	6.40
Commercial	190	1.00
Industrial	80	0.40
Vacant	300	1.60
Subtotal	1,920	10.30
Native		
Native Vegetation	6,000	32.10
Barren and Wasteland	120	0.60
Riparian	990	5.30
Water	470	2.50
Subtotal	7,580	40.50
Total	**18,700**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Antelope groundwater subbasin is within the Shasta Tehama Subwatershed. The public agencies within the Antelope subbasin are the Tehama County Flood Control and Conservation District and the City of Red Bluff. Tehama County adopted a groundwater ordinance in 1994 and a countywide Assembly Bill 3030 (AB3030) groundwater management plan in 1996. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance include off-parcel groundwater use, and influence of well pumping restrictions. The city of Red Bluff is located partly within the subbasin. This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Groundwater in the subbasin is characterized as calcium-magnesium bicarbonate and magnesium-calcium bicarbonate. TDS ranges from 119 to 558 mg/L, averaging 280 mg/L. High concentrations of boron, chloride, and TDS are found in groundwater in the vicinity of Salt Creek and Little Salt Creek. Nitrate concentrations of 20–45 mg/L have been observed within the west-central portion of the basin (DWR 2004).

A 1987 study by DWR stated that the quality of the groundwater in the subbasin is generally good. At that time it had a median concentration of dissolved solids of 296 mg/L. The current (2005) national secondary drinking water standard for dissolved solids is 500 mg/L. The median alkalinity, or hardness[1], of the water was 134 mg/L as $CaCO_3$.

According to Tehama County (2003), a recent groundwater quality issue is related to increased levels of fecal coliform and nitrates in the Antelope area, which is just east of the city of Red Bluff. Fifty-two percent of the wells tested for nitrates in 2002 showed concentrations greater than 22.5 mg/L, including 20% that had concentrations greater than 45 mg/L. Forty-eight percent of the wells tested for coliform in 2002 showed a presence of the organism. Because the majority of wells with detections of nitrates and coliform were located in a developed area (previously agricultural land) with septic systems, DWR concluded that the most likely sources are the individual septic systems.

Discharge Pathways and Sources of Contaminants

Estimate of groundwater extraction for agricultural use is estimated to be 17,000 acre-feet. The Antelope aquifer system appears to be leaky, allowing water from shallow aquifers percolate into deeper water (DWR 1987).

Dissolved Solids

The 1987 study by DWR found the concentration of dissolved solids in 75 groundwater wells to range from 140 to 558 mg/L with a median concentration of 296 mg/L. Electrical conductivity[2] from 72 wells ranged from 205 to 980 µohms/cm at 25 degrees C, with a median of 450 µohms/cm. These median values are within acceptable range for domestic and irrigation use.

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[1] Water hardness is primarily the amount of calcium and magnesium in the water. Water hardness is measured by adding up the concentrations of calcium, magnesium and converting this value to an equivalent concentration of calcium carbonate ($CaCO_3$).

[2] Electrical conductivity (EC) is a measure of how well the water accommodates the transport of electric charge. EC estimates the amount of total dissolved salts, or the total amount of dissolved ions in the water.

Nitrate

High nitrate concentrations (20–45 mg/L) were found throughout the west-central (north and west of State Highway 36 between Kaer and Trinity Avenues) portion of the subbasin. Concentrations above 3 mg/L are indicative of human induced contamination. The most probable sources of nitrogen in the subbasin are domestic wastes from septic systems and fertilizers. Another factor that may contribute to the movement of nitrate downward into the aquifer is the poor quality surface seals on some wells in the area. (DWR 1987.)

Boron

High boron concentrations were found in groundwater underlying Salt Creek and Little Salt Creek. This groundwater also contained high chloride and dissolved solids and a high adjusted sodium adsorption ratio (ASAR)[3], which indicates salt build-up in the sediments. Water is this area may harm sensitive crops. The boron in the groundwater in naturally occurring and is derived from marine rocks like those in the recharge areas for Salt Creek and Little Salt Creek. (DWR 1987.)

Pesticides

Antelope Valley subbasin contains 49% agricultural land uses. The DPR tests groundwater wells for pesticides on a regular basis. In Tehama County, in which Antelope Valley subbasin is located, DPR verified the detection of 5 different pesticides in the groundwater: ACET, bentazon, DEA, diuron, and simizine. These pesticides were detected 1, 7, 2, 1, and 3 times respectively.

Management Practices

We were unable to document any specific practices affecting groundwater quality degradation. Integrated pest management (IPM) is being promoted in the Central Valley of California. IPM is an approach to crop production that minimizes pest-related losses with as little cost to the grower and as little disruption of the environment as possible. It accomplishes these goals by emphasizing biological controls, cultural practices, monitoring programs and other techniques that result in fewer pesticide applications or none at all.

A Reduced Risk Pest Management Program for walnuts was funded by DPR in 1998, 1999 and 2000. The Walnut Alliance was established in 1998 to evaluate and demonstrate commercial walnut production using reduced-risk pest management practices. Codling moth and blight disease are the key pests in walnuts. Alternative practices are being demonstrated with good results. They

[3] Adjusted sodium adsorption ratio (ASAR) is calculated from the ratio of soluble sodium to calcium and magnesium, adjusted for the precipitation or dissolution of Ca^{2+} in waters containing significant amounts of bicarbonate.

include mating disruption, release of natural enemies particularly Trichogramma, use of low-risk biological pesticides, and disease forecasting allowing growers to better time disease treatments. The continuing focus of the Alliance is to increase grower adoption of economical reduced-risk alternatives. The group has identified a 75% reduction of organophosphate use on 12,000 acres as a realistic goal.

Assessment of Data Adequacy and Need for Added Data

Data from DWR provide somewhat limited picture of groundwater quality in the Antelope subbasin in that there is not extensive areal coverage for groundwater quality. However, the available data indicate key issues related to human influence on groundwater are nitrates; fertilizers and on-site domestic waste disposal system contribute to this problem. The leaky aquifer and lack of sufficient well seals may contribute to contaminant transport to the deep aquifer.

Bend Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Sacramento River serves as the subbasin boundary to the west and the Cascade Range to the east. The subbasin is bounded on the north by the hydrologic divide between the Redding and Sacramento groundwater basins along the north side of Paynes Creek. The anticlinal structure above the projected trace of the Red Bluff fault serves as the subbasin boundary to the south. The subbasin is about 21,760 acres (34 mi^2) in size and is located in Tehama County.

The following description of the hydrogeology in the Bend subbasin is taken from DWR Bulletin 118 (DWR 2004).

The Bend subbasin aquifer system is comprised of continental deposits of late Tertiary to Quaternary age. The Quaternary deposits include stream channel deposits, Holocene alluvium, and Pleistocene deposits of Modesto and Riverbank Formations. The Tertiary deposits include the Tuscan Formation.

Holocene Alluvial deposits in the subbasin consist of unconsolidated gravel, sand, silt and clay from stream channel and floodplain deposits. These deposits are found along stream and river channels. The thickness ranges up to 30 feet. This unit represents the perched water table and the upper part of the unconfined zone of the aquifer. Although the alluvium is moderately permeable, it is not a significant contributor to groundwater usage.

The Pleistocene Modesto and Riverbank Formations consist of poorly consolidated gravel with some sand and silt deposited during the Pleistocene. They are usually found as terrace deposits near the surface along the Sacramento River and its tributaries. The thickness ranges up to 50 feet. The deposits are highly permeable and yield limited domestic water supplies.

The Pliocene Tuscan Formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone and volcanic ash layers and is the principal water-bearing formation in the subbasin. The formation is described as four separate but lithologically similar units, Units A through D (with Unit A being the oldest), which in some areas are separated by layers of thin tuff or ash units.

Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of a fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Coarse cobble to boulder conglomerate predominates in the eastern and northern parts of mapped unit. The formation is approximately 430 feet thick.

Unit C is the primary surficial deposit and consists of several massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. The thickness of Unit C exposed in the vicinity of Tuscan Springs and Tuscan Buttes ranges from 165 to 265 feet. Unit D consists of fragmental deposits characterized by large monolithologic masses of andesite, pumice, and fragments of black obsidian in a mudstone matrix. The deposit varies in thickness from 30 to 160 feet.

Bulletin 118 did not report any information on groundwater levels or storage for the subbasin.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (23–31 inches/year), infiltration of applied water, and stream infiltration.

Estimate of groundwater extraction for agricultural use is estimated to be 220 acre-feet. Municipal and industrial use is approximately 120 acre-feet. Deep percolation of applied water is estimated to be 340 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 3% of the subbasin, urban land use accounts for about 2% of the subbasin, and native land accounts for about 95% of the subbasin. The primary crop types in the region are pasture, orchards, and grains. Table 4-5 provides details of the land uses within the subbasin.

Table 4-5. Land Use in the Bend Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Deciduous Fruits and Nuts	50	0.20
Field Crops	20	0.10
Grain and Hay	150	0.70
Pasture	360	1.70
Truck, Nursery, and Berry Crops	20	0.10
Idle	40	0.20
Semiagricultural and Incidental	10	0.05
Subtotal	650	3.00
Urban		
Urban Landscape	10	0.05
Urban Residential	220	1.00
Commercial	10	0.05
Industrial	10	0.05
Vacant	80	0.40
Subtotal	330	1.50
Native		
Native Vegetation	20,200	93.00
Barren and Wasteland	50	0.20
Riparian	150	0.70
Water	340	1.60
Subtotal	20,740	95.50
Total	**21,720**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Bend groundwater subbasin is within the Shasta Tehama Subwatershed. The public agency operating within the subbasin is the Tehama County Flood Control and Water Conservation District. Tehama County adopted a groundwater ordinance in 1994 and a countywide AB3030 groundwater management plan in 1996. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance include off-parcel groundwater use, and influence of well pumping restrictions. No urban areas are located within the sub-area. This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Groundwater in the subbasin is characterized as magnesium-calcium bicarbonate. TDS ranges from 334 to 360 mg/L. Localized high calcium concentrations occur in the basin.

Discharge Pathways and Sources of Contaminants

We were unable to identify specific discharge pathways or sources of contaminants.

Management Practices

We were unable to identify specific management practices affecting groundwater quality.

Assessment of Data Adequacy and Need for Added Data

The available data is generally inadequate to identify groundwater quality problems. However, the small amount of land use in the basin indicates small likelihood for groundwater quality problems.

Capay Valley Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Capay Valley subbasin is 25,000 acres (39 mi^2) in size and located within the Coast Ranges in the western portion of Yolo County. It is defined by depositional sediments within the northwest-southeast trending Capay Valley. The subbasin extends from the Yolo County boundary on the north end to the confluence of Salt Creek and Cache Creek on the south end. Structurally, the Capay Valley is a broad, elongated synclinal depression between the Blue Hills of the Vaca Mountains and the Rumsey Hills in the Coast Range Geomorphic Province (DWR 1961).

The following description of the hydrogeology in the Antelope subbasin is taken from DWR Bulletin 118 (DWR 2004).

Primary water bearing deposits within the Capay Valley subbasin include Recent stream channel deposits and the Tehama Formation, which is underlain by older non-freshwater bearing Cretaceous Marine Rocks (DWR 1978; Wagner and E.J. Bortugno 1982).

Recent stream channel deposits consist of unconsolidated silt, fine- to medium-grained sand, gravel and occasionally cobbles deposited in and adjacent to Cache Creek and its tributaries. These deposits are moderately to highly permeable and range in thickness from approximately 0 to 150 feet (DWR 1978).

The Tehama Formation consists of moderately compacted silt, clay, and silty fine sand enclosing lenses of sand and gravel, silt and gravel, and cemented conglomerate. This formation can be seen outcropping along the edges of the Capay Valley, and in other places within the western Yolo, Colusa, and Solano Counties. The Tehama Formation within the Capay Valley is generally less than a few hundred feet thick, however is found in much greater thickness to the east in the Sacramento Valley. The permeability of the Tehama Formation is variable, but generally less than the overlying recent stream channel deposits units.

Cretaceous Marine Rocks make up the basement rock beneath the fresh water bearing deposits of the Capay Valley Subbasin. Consisting of consolidated sandstone and shale of marine origin, these basement rocks generally contain saline connate water and are not considered useable water bearing formations.

Recharge for the Capay Valley Subbasin comes primarily from Cache Creek. Additional recharge comes from surrounding minor tributaries, including Bear Creek. Bear Creek is the source of waters high in boron, and has an influence on water quality within Cache Creek and on groundwater extracted from Cache Creek deposits within the Capay and Sacramento Valleys (DWR 1961).

Groundwater levels within most the Capay Valley Subbasin vary from approximately 10 to 40 feet below ground surface and remain relatively stable, even through dry years. Wells located in the higher elevations along the edge of the valley show a greater variability, and appear to be more impacted by dry years.

Groundwater Storage for the Capay Valley region was calculated in DWR Bulletin 90 (1961) based on estimated specific yield values for three discrete intervals between the depths of 20 and 200 feet. It was estimated that the Groundwater Storage Capacity of the Capay Valley is approximately 99,800 acre-feet. It can be assumed that the Groundwater in Storage for the Capay Valley is roughly equal to the groundwater storage capacity, since water levels tend to remain at relatively shallow depths.

Major Sources of Recharge

Recharge to the subbasin is from precipitation, irrigation infiltration, and stream infiltration. Stream infiltration comes from the Cache Creek and its tributaries. Bear Creek is a tributary that is high in boron that influences the water quality in the Capay Valley groundwater subbasin. Annual precipitation is about 25 inches at ridge tops.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1997. Agricultural land use accounts for about 38% of the subbasin, urban land use accounts for about 1% of the subbasin, and native land accounts for about 61% of the subbasin. Table 4-6 provides details of the land uses within the subbasin.

Table 4-6. Land Use in the Capay Valley Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	10	0.04
Deciduous Fruits and Nuts	3,920	15.66
Field Crops	220	0.88
Grain and Hay	2,550	10.19
Idle	1,670	6.67
Pasture	570	2.28
Semiagricultural and Incidental	130	0.52
Truck, Nursery, and Berry Crops	480	1.92
Vineyards	0	0.00
Subtotal	9,550	38.00
Urban		
Urban—unclassified	20	0.08
Commercial	0	0.00
Industrial	10	0.04
Urban Landscape	0	0.00
Urban Residential	120	0.48
Vacant	10	0.04
Subtotal	160	1.00
Native		
Native Vegetation	15,000	59.93
Water	320	1.28
Subtotal	15,320	61.00
Total	**25,030**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Yolo County Flood Control and Water Conservation District is the only water agency in the basin. The towns of Rumsey, Guinda and Brooks are located within the subbasin. This subbasin falls with the area included in the Solano-Yolo Coalition.

Water Quality

Groundwater quality within the Capay Valley Subbasin is primarily the result of infiltration of Cache Creek and its tributaries and is generally of good quality. It is calcium-sodium bicarbonate-type with moderate to very high hardness. Highly mineralized water from Bear Creek and North Fork Cache Creek is a primary source of mineral constituents, especially boron, in groundwater in the Capay Valley Subbasin (DWR 1961). TDS measured in water taken from 6 wells in the Capay Valley ranged from approximately 300 to 500 mg/L, and was comparable to that found in water samples taken from Cache Creek (EPA 2001; DWR 1961).

Discharge Pathways and Sources of Contaminants

Groundwater is pumped from the Capay Valley subbasin for domestic, municipal and irrigation purposes and discharges to Cache Creek in lower reaches of the Valley. We could not identify specific agricultural sources of groundwater contamination.

Management Practices

Yolo County Flood Control and Water Conservation District monitors groundwater levels through an extensive network of 11 wells in the subbasin. The District assesses the condition of the groundwater annually by the employment of a consulting engineer. (YCFCWCD 2005.) DHS monitors 3 wells semi-annually for water quality (Title 22) constituents. We could not identify specific management agricultural practices affecting groundwater quality.

Assessment of Data Adequacy and Need for Added Data

Data from DWR provide somewhat limited picture of groundwater quality in the Capay Valley subbasin in that there is not extensive areal coverage for groundwater quality. The available data show that naturally occurring boron and mercury from mining waste are the primary surface water quality issues in this subbasin. There are no apparent groundwater quality problems.

Colusa Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Colusa subbasin aquifer is bound by Stony Creek in the north, Cache Creek in the south, the Coast Ranges on the west and the Sacramento River on the east. The aquifer system is 1,434 mi^2 in size and is located in parts of Colusa, Glenn, Yolo and Tehama Counties.

The following description of the hydrogeology in the Colusa subbasin is taken from DWR Bulletin 118 (2004). The Colusa Subbasin aquifer system is composed of continental deposits of late Tertiary to Quaternary age. Quaternary deposits include Holocene stream channel and basin deposits and Pleistocene Modesto and Riverbank formations. The Tertiary deposits consist of the Pliocene Tehama Formation and the Tuscan Formation. All Formations consist of varying amounts of gravel, sand, silt, and clay. The Holocene Stream Channel deposits are the upper part of the unconfined zone and are moderately-to-highly permeable. The Holocene basin deposits are interbedded with the Stream Channel deposits, have low permeability and yield low quality and quantity of water.

The Modesto deposits consist of moderately to highly permeable gravels, sands, and silts. Thickness of the formation ranges from less than 10 feet to nearly 200 feet across the valley floor. The Riverbank deposits are the older terrace deposits that consist of poorly to highly pervious pebble and small cobble gravels interlensed with reddish clay, sand, and silt. Thickness of the formation ranges from less than 1 foot to over 200 feet depending on location. The formation yields moderate quantities of water to domestic and shallow irrigation wells and also provides water to deeper irrigation wells that have multiple zones of perforation. Generally, the thickness of the formation limits the water-bearing capabilities.

The Tehama Formation is the predominant water-bearing unit within the Colusa Subbasin and reaches a thickness of 2,000 feet. The formation occurs at depths ranging from a few feet to several hundred feet from the surface. The formation consists of moderately compacted silt, clay, and fine silty sand enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate. Occasional deep sands and thin gravels constitute a poorly to moderately productive, deep, water-bearing zone.

The Tuscan Formation occurs in the northern portion of the subbasin at an approximate depth of 400 feet from the surface and may extend to the west to the Greenwood Anticline east of Interstate Highway 5. The formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash layers. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subbasin. Unit A is the oldest water-bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. Unit B is composed of a fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B.

Groundwater levels in the Colusa subbasin tend to fluctuate by 5 feet in normal and dry years. There is no consistent decreasing trend in the aquifer levels. DWR (2004) estimated the specific yield to by 7.1% and the storage capacity (to a depth of 200 feet) to be 13 million acre-feet (maf).

Major Sources of Recharge

Irrigation is the primary source of groundwater recharge to the subbasin. Regionally, stream infiltration and to a lesser extent precipitation are also sources of recharge. The Sacramento River, Stony Creek, Cache Creek, and the Glenn-Colusa Canal recharge the aquifer. Annual precipitation ranges from 17 to 27 inches with higher precipitation occurring to the west. Twenty-four percent of the Colusa subbasin is used for rice cultivation where the fields are typically flooded for six months each year. Groundwater discharge occurs as evapotranspiration, loss to streams, and pumpage.

Land Uses

The Colusa subbasin is primarily utilized for irrigated farming, rice farming being the most prevalent. The second most prevalent land use in the subbasin is native vegetation. Both Glenn and Colusa Counties contain a wildlife refuge. Land use surveys were conducted within the basin by DWR from 1997 to 1999. Agricultural land use accounts for about 69% of the basin, urban land use accounts for less than 3% of the basin, and native land accounts for about 29% of the basin. Table 4-7 provides details on the distribution of land use throughout the Colusa subbasin.

Table 4-7. Land Use in the Colusa Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	5,057	0.55
Deciduous Fruits and Nuts	79,827	8.69
Field Crops	90,527	9.86
Grain and Hay	82,831	9.02
Vineyards	6,936	0.76
Pasture	47,494	5.17
Rice	217,573	23.69
Semiagricultural and Incidental	6,432	0.70
Truck, Nursery, and Berry Crops	76,603	8.34
Idle	17,863	1.94
Subtotal	631,143	68.72
Urban		
Urban—unclassified	2,699	0.29
Commercial	822	0.09
Industrial	4,135	0.45
Urban Landscape	528	0.06
Urban Residential	4,437	0.48
Vacant	12,036	1.31
Subtotal	24,657	2.68
Native		
Riparian	37,096	4.04
Native Vegetation	206,826	22.52
Water	15,755	1.72
Barren and Wasteland	2,950	0.32
Subtotal	262,627	28.60
Total	**918,427**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The public entities within the Colusa subbasin aquifer system are: Knights Landing WUA, Orland Unit WUA. Cortina Creek FC&WCD, Colusa County FC&WCD, and Yolo County FC&WCD Artois CSD, Butte City CSD, Hamilton City CSD, NE Willows CSD, Ord CSD, City of Colusa, City of Orland, City of Williams, 4-M WD, Chrome WD, Colusa County WD, Cortina WD, Davis WD, Dunnigan WD, Glenn Valley WD, Glide WD, Holthouse WD, Kanawha WD, La Grande WD, Orland-Artois WD, Princeton WD, Westside WD, and Yolo-Zamora WD, Glenn-Colusa ID, Maxwell ID, Princeton-Cordora-Glenn ID, Provident ID, Maxwell ID, Reclamation Districts (RDs) 108, 478, 730, 787, 1004, 2047, Arbuckle PUD, Maxwell PUD. (DWR 2004.)

The private entities within the Colusa subbasin aquifer system are: California Water Service Co., Colusa Drain Mutual Water Co., California Water Service Co., Roberts Ditch & Irr. Co. Inc, Willow Creek Mutual Water Co. (DWR 2004.)

Tehama County adopted a groundwater management ordinance in 1994. Glenn County adopted a groundwater management ordinance in 2000. Colusa County adopted a groundwater management ordinance in 1998. Yolo County adopted a groundwater management ordinance in 1996 (DWR 2004). These ordinances affect primarily the volume of groundwater that can be pumped and/or exported from the subbasin. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county.

This subbasin falls with the area included in the Solano-Yolo and Colusa Coalitions.

Water Quality

Groundwater quality issues in the Colusa subbasin include excess nutrients, dissolved solids, trace elements, and pesticides. Dissolved solids are elevated in localized areas throughout the subbasin and pesticides are persistent in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring, as well as nitrates in some locations. However, there is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the Colusa subbasin. Tables 4-8 and 4-9 summarize the available data.

Table 4-8. Water Quality in the Colusa Subbasin

Constituent of Concern	Available Information about Groundwater Concentrations for Colusa Subbasin
Nutrients	Median NO_3 concentration under rice fields was 2mg/L (Domagalski et al. 2000). High concentrations of nitrates found in groundwater near the Colusa, Arbuckle, Knights Landing, and Willows. Localized areas throughout the subbasin have high ammonia, and phosphorus concentrations. (DWR 2004.) Nitrate, ammonia, phosphorus measured in shallow groundwater in rice growing areas (Dawson 2001a).
Pesticides (insecticides and herbicides) and degradation products	Dawson (2001a) reported pesticides detections in 89% of the 28 wells sampled, 82% of which were pesticides used on rice fields: bentazon, carbofuran, molinate, and thiobencarb. Bentazon was found in 71% of the wells.
Salt—primarily as electrical conductivity and total dissolved solids.	High EC, TDS, adjusted sodium absorption ratio (ASAR) in groundwater near the City of Colusa and Knight's Landing. Localized areas throughout the subbasin have high TDS. High TDS concentrations measured in shallow groundwater in rice growing areas (Dawson 2001a). In the western half of the Sacramento Valley south of Willows, groundwater contains TDS frequently in excess of 500 mg/L. (DWR 1978.)
Trace elements	High boron concentrations found near Knights Landing. Localized areas throughout the subbasin have high manganese, fluoride and iron. Dawson (2001a) found concentrations of inorganic constituents that exceeded primary state and federal drinking water standards at least once in 25% of the wells. The inorganic constituents detected above the primary limits were boron, barium, cadmium, molybdenum or sulfate. Secondary drinking water standards were exceeded at least once in 79% of the wells. The constituents detected above secondary limits were chloride, iron, manganese, specific conductance (EC), or dissolved solids. Mercury from mining—Cache Creek/Putah Creek
Organic carbon and disinfection byproduct precursors	Dissolved organic carbon elevated relative to expected background in some areas (Dawson 2001a).
Microorganisms	No available data

Notes:
EC = electrical conductivity.
mg/L = milligrams per liter
TDS = total dissolved solids.

Table 4-9. Concentrations of Constituents of Concern Detected in the Colusa Subbasin

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standard
Nutrients	Nitrate	Median 2mg/L (Domagalski et al. 2000)	Nitrate was reported to exceed the MCL in two public supply wells in the Colusa subbasin (Moran et al. 2004).
	Ammonia as N	0.02–0.46 mg/L	30 (HAL)
	Ammonia + organic N as N	0.3–0.7 mg/L	30 (HAL)
	Nitrate+Nitrite, as N	0.08–6.2 mg/L	10 (MCL)
	Nitrate as N	0.08–6.2 mg/L	10 (MCL)
	Nitrite as N	0.01–0.01 mg/L	1 (MCL)
	Orthophosphate, as P	0.01–0.36 mg/L	
	Phosphorus, as P	0.03–0.362 mg/L	
	Dissolved organic carbon, as C	0.3–6.8 mg/L	
Pesticides (insecticides and herbicides) and degradation products*	Atrazine	*0.002*–0.026 µg/L	3 (MCL)
	Bentazon	0.06–*7.8* µg/L	18 (MCL)
	Bromacil	0.19 µg/L (one detection)	90 (HAL)
	Carbofuran	0.016–0.8 µg/L	18 (MCL)
	Desethly atrazine	*0.001–0.005* µg/L	
	Dichlorprop	*0.1* µg/L (one detection)	
	Diuron	0.04–0.09 µg/L	10 (HAL)
	Azinphos-methyl	*0.014* µg/L (one detection)	
	Molinate	*0.002*–0.056 µg/L	20 (MCL)
	Simazine	*0.002*–0.027 µg/L	4 (MCL)
	Tebuthiuron	*0.006* µg/L (one detection)	500 (HAL)
	Thiobencarb	0.006–0.025 µg/L	70 (MCL)
Salt—primarily as electrical conductivity and total dissolved solids.		120–1,220 mg/L, mean 391 mg/L (DWR 2004)	
		168–8,730 mg/L, median 532 (Dawson 2001a)	
Trace elements	Aluminum	0.002–0.010 mg/L	1 (MCL)
	Arsenic	0.001–0.015 mg/L	
	Barium	0.01–5.05 mg/L	1(MCL)
	Boron	0.02–1.8 mg/L	0.6 (HAL)
	Bromide	0.03–12 mg/L	
	Cadmium	0.006–0.007 mg/L	0.005 (MCL)
	Chromium	0.002–0.016 mg/L	0.05 (MCL)
	Cobalt	0.001–0.004 mg/L	
	Copper	0.001–0.003 mg/L	1.3 (MCL)
	Ferrous Iron Fe2+	Detected in 19/28 wells	
	Fluoride	0.1–1.8 mg/L	4 (MCL)

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standard
	Iron Fe	0.003–5.3 mg/L	0.3 (SMCL)
	Manganese	0.1–0.05 mg/L	0.05 (SMCL)
	Molybdenum	0.001–0.051 mg/L	0.04 (HAL)
	Nickel	0.001–0.009 mg/L	0.1 (HAL)
	Selenium	0.003–0.022 mg/L	0.05 (MCL)
	Sulfide	Detected in 14/28 wells	
	Uranium	0.001–0.023 mg/L	2000 (MCL)
	Zinc	0.001–0.017 mg/L	2 (HAL)

Notes:
* Numbers in *italics* are estimates.
MCL = Maximum Contaminant Level set by EPA (2005).
µg/L = micrograms per liter.
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).
HAL = Health Advisory Level set by EPA (2005).

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the Colusa basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology and soils influence the groundwater major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the Colusa subbasin is anoxic and chemically reducing. This results in high concentrations of manganese and iron and the presence of ammonia and phosphorus. In some areas of the subbasin, naturally occurring highly saline groundwater is present at varying depths and can influence the water quality of production wells. Agricultural processes affecting groundwater quality include use of fertilizers and pesticides and the evaporation of irrigation water. Groundwater from the Colusa subbasin discharges to wells and streams. Most of the irrigation water used in Colusa subbasin is pumped from groundwater. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. There are naturally occurring nitrates in some formations of the Sacramento Valley. However, most nitrogen species that occur at levels above contaminant levels are introduced into the groundwater via human activates such as agriculture and urbanized development. At this time, the data available for the Colusa subbasin indicates two public supply wells impacted by high nitrate concentrations.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The predominant geochemical facies of the groundwater in the Colusa subbasin are calcium-magnesium bicarbonate and magnesium-calcium bicarbonate. Two processes appear to primarily affect groundwater salinity in the Colusa subbasin: evaporation of irrigation water and shallow groundwater and mixing of naturally occurring saline groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a). Using isotope data, Dawson (2001a) presented evidence that partial evaporation as indicated by the isotope data accounted for some of the measured increase in salinity among shallow groundwater samples.

Pesticides

Rice pesticides Molinate, Thiobencarb and Carbofuran were detected in 7, 3, and 4 of the 28 wells sampled during the 1997 study by the USGS (Dawson 2001a). The most prevalent pesticide detected in groundwater was bentazon. This chemical was used in rice fields until it was suspended in 1989 and officially banned in 1992. Its presence in groundwater in studied completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Although present in most wells in the rice growing areas of the Colusa subbasin, pesticide concentrations were below state and federal 2000 drinking water standards in all occurrences.

Dawson (2001a) investigated the relationship between groundwater quality and rice cultivation land use practices in data collected during 1998. Dawson (2001a) found that shallower wells had more occurrences of pesticide contamination than deeper wells, indicating the movement of pesticides from the ground surface downward. Concentrations of bentazon showed a statistical relationship to tritium concentrations. Since tritium is used for age-dating groundwater, this relationship suggests that bentazon concentrations may be related to recharge age of the groundwater in which it was found. Tritium concentrations in all wells except one indicate that groundwater in the rice growing areas of the Colusa subbasin were recharges after 1950. To further identify the date at which the pesticides entered groundwater, the first application dates of the pesticides in the Sacramento Valley were studied. This resulted groundwater recharge dating in the late 1970s.

Irrigation practices can have an affect on the amount of pesticides that reach groundwater. Troiano et al. (1993) investigated difference irrigation methods and found that “leaching of pesticides was less in sprinkler applications because water was applied more frequently in smaller applications than for the basin-flooding method. For basin-flooding treatments, as those practiced on rice fields, a large amount of water application was required for each irrigation in order to provide application across the plot. Although irrigations were less frequent, the larger water volume caused greater downward movement of water and atrazine residues."

Trace Elements

The chemistry of geology formations in the Colusa subbasin influences the concentrations of trace elements. Dawson (2001a) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of potassium were significantly lower in the western alluvial fans, which contain the Colusa subbasin. Concentrations of boron, chloride, fluoride, molybdenum, sulfate, and zinc were significantly higher in the western alluvial fans. Concentrations of arsenic were significantly higher in the central flood basins, which are also part of the Colusa subbasin. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Organic Carbon and DPBs

There is some evidence that recent changes in management practices in rice may result in higher dissolved organic carbon concentrations in deep percolation water. High dissolved organic carbon content was confirmed in 43% of the wells studied by Dawson (2001a). The median concentration of which was 2.7 mg/L, much higher than the national median of 0.7 mg/L (Leenheer et al. 1974).

Management Practices

Rice field management practices began in 1983, to protect surface waters quality. Rice field irrigation water began to be held in the fields after the application of pesticides to allow more time for degradation (Dawson 2001a; Holden 1986). More irrigation water recycling was also encouraged at this time. These practices may have caused more contamination to percolate downward to groundwater. Rice growing in general provides opportunity for mobile pesticides to move to groundwater due to large volumes of groundwater recharge. Irrigation practices affect the rate at which pesticides reach groundwater. Troiano et al. (1993) investigated difference irrigation methods and found basin-flooding treatments, as those practiced on rice fields, cause a greater volume of downward percolation of irrigation water and the pesticides contained in that water.

Assessment of Data Adequacy and Need for Added Data

Data from USGS, DPR, and DWR provide substantial information about groundwater quality in the Colusa subbasin. However, there is not extensive areal coverage for groundwater quality, especially for crops besides rice. However, the available data indicate key issues related to rice pesticides, nutrients and salinity. Additional data is needed for the areal distribution of constituents and specific processes and management practices that result in the spatial distribution of contamination.

Corning Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Corning Subbasin is bounded on the west by the Coast Ranges, on the north by Thomes Creek, on the east by the Sacramento River, and on the south by Stony Creek. Stony Creek is believed to be a hydrologic boundary throughout the year. The Corning Subbasin is likely contiguous with the Red Bluff Subbasin at depth. The subbasin is 205,600 acres (321 mi^2) in size and is located in parts of Tehama and Glenn Counties.

The following description of the hydrogeology in the Corning subbasin is taken from DWR Bulletin 118 (DWR 2004).

The Corning Subbasin aquifer system is comprised of deposits of late Tertiary to Quaternary age. The Quaternary deposits include Holocene alluvium and the Pleistocene terrace deposits of the Modesto and Riverbank Formations. The Tertiary deposits consist of the Pliocene Tehama and Tuscan Formations.

Holocene Stream Channel deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Tehama Formation and Quaternary stream terrace deposits. The thickness varies from 1 to 80 feet. The unit represents the upper part of the unconfined zone of the aquifer and is moderately-to-highly permeable; however, the thickness and areal extent of the deposits limit the water-bearing capability.

The Pleistocene Modesto Formation consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tehama and the Riverbank Formations. The deposit ranges from less than 10 feet to nearly 200 feet across the valley floor. These terrace deposits are observed along Thomes Creek, Burch Creek, and Stony Creek.

The Pleistocene Riverbank Formation consists of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. The formation ranges from less than one foot to over 200 feet thick depending on location. Surficial deposits are observed over the eastern third of the subbasin and along Burch Creek and its tributaries.

The Pliocene Tehama Formation consists of sediments originating from the coastal mountains and is the primary source of groundwater for the subbasin. The formation ranges in thickness up to 2,000 feet, increasing in thickness from west to east, dipping 4 degrees to the east. The majority of the formation consists of fine-grained sediments indicative of deposition under floodplain conditions. The majority of both coarse and fine-grained sediments are unconsolidated or moderately consolidated.

The Pliocene Tuscan Formation is located within the eastern third of the subbasin. The formation occurs at a depth of approximately 200 feet from the surface and is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash layers. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are believed to extend as far west as the Corning Canal.

Unit A is the oldest water-bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B.

Sub-areas of the Corning Subbasin

Sacramento Valley Floodplain. Pleistocene and Holocene silt, sand, and gravel deposits in the vicinity of the City of Corning extend to depths of 50–185 feet. The Tehama Formation near the City of Corning consists of yellow clay, poorly consolidated sandstone, and conglomerate.

Dissected Uplands. The surface of the upland area within the central third of the subbasin between Thomes Creek and Stony Creek includes a coarse-grained gravelly conglomerate locally capping the Tehama Formation. Wells drilled in this area encounter up to 60 feet of coarse deposits before reaching fine-grained Tehama deposits. The deposits are believed to be formed as a response to a fixed base level by impeded or enclosed drainages and have been referred to as the Red Bluff Formation. The shallow gravel is not a significant contributor to groundwater storage due to its position above the saturated zone.

Thomes Creek Floodplain. Bounding the northern extents of the subbasin, the Thomes Creek floodplain includes Holocene alluvium underlain by deposits of both the Modesto and Riverbank Formations. The floodplain averages about 1 mile in width and extends from the Coast Ranges to the Sacramento River floodplain.

Stony Creek Floodplain. The southern part of the subbasin, including the Capay plain, is alluviated by older floodplain deposits and channel deposits of Stony Creek. This area includes a moderately well-defined, highly productive, shallow water-bearing zone reaching a thickness of 150 feet along Stony Creek and 110 feet along the Sacramento River. Domestic and shallow irrigation wells along the west side of the Capay plain and south of the Tehama County line provide moderate-to-high yields from confined groundwater in 10–50-foot thicknesses of highly pervious pebble and cobble gravels. In the northwest part of Capay plain, older alluvium of the Riverbank Formation extends from the surface to 150 feet. Wells in this zone have low-to-moderate yields. This zone is underlain by a highly productive confined gravel averaging 40 feet in thickness.

Groundwater level data show seasonal fluctuations of approximately 3–15 feet for unconfined wells (5 feet near the Sacramento River), up to 30 feet for semi-confined wells away from the river, 5–20 feet for composite wells, and 10–30 feet for confined wells. Overall, there does not appear to be any increasing or decreasing trends in the groundwater levels. During the 1976–1977 and 1987–1994 droughts, there was a decline in groundwater levels of 5–12 feet, followed by a recovery to pre-drought conditions of the early 1970s and 1980s.

Groundwater storage capacity was estimated to be 2,753,000 acre-feet. This estimate was based on an average specific yield of 6.7% and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (19-25 inches/year), irrigation infiltration, and stream infiltration. The Tehama-Colusa Canal and Corning Canals intersect the basin. These canals, which are part of the Central Valley Project, serve to provide irrigation water to the member water user associations, including the Corning WD, which has jurisdiction in the Colusa Basin.

Estimate of groundwater extraction for agricultural use is estimated to be 152,000 acre-feet. Municipal and industrial use is approximately 6,600 acre-feet. Deep percolation of applied water is estimated to be 54,000 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 37% of the subbasin, urban land use accounts for about 4% of the subbasin, and native land accounts for about 59% of the subbasin. The primary crop types in the region are eucalyptus, olives, orchards, and pasture (Tehama County 2003). Table 4-10 provides details of the land uses within the subbasin.

Table 4-10. Land Use in the Corning Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	19,000	9.20
Deciduous Fruits and Nuts	19,500	9.50
Field Crops	2,900	1.40
Grain and Hay	10,500	5.10
Pasture	18,100	8.80
Rice	1,170	0.60
Truck, Nursery, and Berry Crops	750	0.40
Idle	1,950	0.90
Semiagricultural and Incidental	1,910	0.90
Subtotal	75,780	36.90
Urban		
Urban Landscape	40	0.02
Urban Residential	5,720	2.80
Commercial	390	0.20
Industrial	730	0.40
Vacant	1,970	1.00
Subtotal	8,850	4.30
Native		
Native Vegetation	108,900	53.00
Barren and Wasteland	2,580	2.60
Riparian	4,200	2.00
Water	5,250	2.60
Subtotal	120,930	58.80
Total	**205,560**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Corning groundwater subbasin is within parts of the Shasta Tehama and Colusa Subwatersheds. The public agencies within the Corning subbasin are: Tehama County Flood Control and Water Conservation District, Orland Unit Water Users' Association, Capay Rancho WD, City of Corning, Corning WD, Kirkwood WD, Richfield WD, Tehama WD, O'Connell MWD. City of Orland, Glenn Colusa ID, Thomes Creek WD. Tehama County adopted a groundwater management ordinance in 1994 and a countywide AB3030 plan in 1996. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance are off-parcel groundwater use, and influence of well pumping restrictions. The city of Corning is located within the subbasin. This subbasin falls with the area included in the Solano-Yolo and Colusa Coalitions.

Water Quality

Calcium-magnesium bicarbonate and magnesium-calcium bicarbonate are the predominant groundwater types in the subbasin. The subbasin has localized areas of calcium bicarbonate waters near Stony Creek. TDS concentrations range from 130-to 490-mg/L, averaging 286 mg/L. The Corning Subbasin has locally high calcium. We were unable to identify groundwater quality problems in the Corning Subbasin due to irrigated agriculture.

Two groundwater supply wells have been shut down and are being monitored by the City of Corning because of methyl tertiary butyl ether (MTBE) and perchloroethylene (PCE) concerns. Monitoring for water quality also occurs twice weekly at seven locations for bacterial and fecal coliform.

Discharge Pathways and Sources of Contaminants

Groundwater appears to flow toward a groundwater depression adjacent to the Sacramento River on the east side of the basin (DWR 1978; Tehama County 2003).

Management Practices

The Tehama County Flood Control and Water Conservation District has identified the need for installation and monitoring of additional wells in the subbasin area due to the indication of a groundwater depression to the east-southeast of the City of Corning, which is an area with little extraction (Tehama County 2003).

The City of Corning monitors 2 groundwater supply wells monthly for standing water level and drawdown and daily for chlorine. Monitoring for water quality also occurs twice weekly at seven locations for bacterial and fecal coliform.

We were unable to identify information about management practices that specifically affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

There is insufficient data to discern whether there are groundwater quality problems in the Corning Subbasin.

Dye Creek Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Dye Creek Subbasin is bounded on the southwest by the Sacramento River, on the northwest by Antelope Creek, on the east by the Chico Monocline, and on the south by Mill Creek. The subbasin is contiguous with the Antelope and Los Molinos subbasins at depth. The subbasin is 27,700 acres (43 mi^2) in size and is located in Tehama County.

The following description of the hydrogeology in the South American subbasin is taken from DWR Bulletin 118 (DWR 2004).

The aquifer system is comprised of continental deposits of Tertiary to late Quaternary age. The Quaternary deposits include Holocene basin deposits and Pleistocene deposits of the Modesto and Riverbank Formations and Pleistocene fanglomerate. The Tertiary deposits include Pliocene Tehama and Tuscan formations.

Holocene basin deposits are exposed east of Highway 99, north and south of Dairyville, within the central portion of the subbasin. Basin deposits are the result of sediment-laden floodwaters rising above the natural levees of streams and rivers and spreading across low-lying areas. Thickness of the deposits has not been determined. The deposits generally have low permeability and yield low quantities of poor quality water to wells.

The Pleistocene Modesto Formation is observed along the western extents of the subbasin. The formation consists of undifferentiated terrace deposits of unconsolidated weathered and un-weathered gravel, sand, silt and clay. Thickness of the unit can range from 0 to 150 feet.

The Pleistocene Riverbank Formation is exposed east of the Sacramento River north of Mill Creek. The formation is not a significant water-bearing formation due to its limited depth and areal extents.

Pleistocene Fanglomerate is observed along the eastern foothills and within the southern third of the subbasin. The formation is an alluvial fan deposit derived from erosion and deposition of volcanic mudflows of the Tuscan Formation and consists of polylithic volcanic clasts set in weathered tuffaceous matix. The fan deposits are poorly sorted and somewhat indurated to well cemented. Thickness of the fan deposits is up to 150 feet. The fanglomerate is not sufficiently thick to produce large quantities of groundwater.

The Pliocene Tuscan Formation is composed of a series of volcanic breccia, tuff, tuff breccia, volcanic sandstone and conglomerate, basalt flows, and tuffaceous silt and clay layers. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subbasin and extend in the subsurface west to the Sacramento River. Surface exposures of Unit D appear along the east side of the subbasin and east of the subbasin boundary. The subsurface extent of Unit D is unknown.

Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B. The Tuscan Formation reaches a thickness of 1,500 feet over older sedimentary deposits. The slope of the formation averages approximately 2.5 degrees, east of the valley, and steepens sharply to 10 to 20 degrees southwestward towards the valley at the Chico Monocline (Olmsted and Davis 1961). The formation flattens beneath valley sediments.

The Pliocene Tehama Formation consists of fluvial deposits of predominantly silt and clay with gravel and sand interbeds and occurs in the subsurface along the western boundary of the subbasin.

Long-term comparison of groundwater levels indicate a decline of 2 to 5 feet associated with the 1976–1977 and 1987–1994 droughts, followed by a recovery to pre-drought conditions of early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation ranging from 2 to 10 feet for normal and dry years. Overall, there does not appear to be any increasing or decreasing trends in the groundwater levels.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (17 inches/year), irrigation infiltration, stream infiltration, and subsurface flow. The main water source for irrigation is a mix of groundwater and surface water (Tehama County 2003). The Chico Monocline serves as a geographical boundary with some areas of recharge located east of the boundary.

Estimate of groundwater extraction for agricultural use is estimated to be 9,300 acre-feet. Municipal and industrial use is approximately 680 acre-feet. Deep percolation of applied water is estimated to be 3,200 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 23% of the subbasin, urban land use accounts for about 3% of the subbasin, and native land accounts for about 74% of the subbasin. The primary crop types in the region are orchards and pasture

(Tehama County 2003). Table 4-11 provides details of the land uses within the subbasin.

Table 4-11. Land Use in the Dye Creek Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Deciduous Fruits and Nuts	2,400	8.70
Field Crops	30	0.10
Grain and Hay	10	0.04
Pasture	3,160	11.40
Idle	530	1.90
Semiagricultural and Incidental	240	0.90
Subtotal	6,370	23.00
Urban		
Urban Landscape	20	0.04
Urban Residential	580	2.10
Commercial	10	0.04
Industrial	120	0.40
Vacant	180	0.70
Subtotal	910	3.30
Native		
Native Vegetation	18,900	68.30
Barren and Wasteland	80	0.30
Riparian	1,060	3.80
Water	360	1.30
Subtotal	20,400	73.70
Total	**27,680**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Dye Creek groundwater subbasin is within the Shasta Tehama Subwatershed. The only public agencies within the subbasin are the Tehama County Flood Control and Water Conservation District. Tehama County adopted an AB3030 groundwater management plan in 1996. There are no major urban areas within the subbasin. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance include off-parcel groundwater use and influence of well pumping restrictions. This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Groundwater in the Dye Creek subbasin is characterized as calcium-magnesium bicarbonate and magnesium-calcium bicarbonate. TDS ranges from 119 to 558 mg/L, averaging 280 mg/L. The DPR verified detections of five compounds in Tehama County between 1985 and 2003. There were 14 detections total: 1 detection of ACET, 7 detections of atrazine, 2 detections of DEA, 1 detection of diuron, and 3 detections of simizine. Verified detections are those that are found at more than one sampling date. These groundwater contaminants are the result of legal, agricultural uses.

Discharge Pathways and Sources of Contaminants

Groundwater discharges primarily to wells and the Sacramento River. Pesticide contamination appears to be the result of legal, agricultural uses but we were unable to find sufficient information about specific land-use sources for the pesticide contamination.

Management Practices

Tehama County has an AB3030 groundwater management plan in place. The DWR monitors groundwater levels in 8 wells semiannually and water quality in one well biennially. The California Department of Health Services (DHS) monitors 3 wells for water quality constituents. We were unable to find documentation for management practices for prevention of groundwater contamination.

Assessment of Data Adequacy and Need for Added Data

There is limited data and analysis for the spatial distribution of groundwater pesticide contamination and sources of contamination. Additional data is needed to develop management practices that may reduce movement of pesticide to the subsurface.

East Butte Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The East Butte Subbasin is bounded on the west and northwest by Butte Creek, on the northeast by the Cascade Ranges, on the southeast by the Feather River and the south by the Sutter Buttes. The subbasin is 265,400 acres (415 mi^2) in size and is located in parts of Butte and Sutter Counties.

The following description of the hydrogeology in the East Butte subbasin is taken from DWR Bulletin 118 (DWR 2004).

The East Butte aquifer system is comprised of deposits of late Tertiary to Quaternary age. The Quaternary deposits include Holocene stream channel deposits and basin deposits, Pleistocene deposits of the Modesto and Riverbank Formations, and Sutter Buttes Alluvium. The Tertiary deposits include the Tuscan and Laguna Formations.

Holocene Stream Channel deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Quaternary stream terrace alluvial deposits. The thickness varies from 1 to 80 feet. These deposits represent the upper part of the unconfined zone of the aquifer and are moderately-to-highly permeable; however, the thickness and areal extent of the deposits limit the water-bearing capability.

Holocene Basin deposits are the result of sediment-laden floodwaters that rose above the natural levees of streams and rivers to spread across low-lying areas. They consist primarily of silts and clays and may be locally interbedded with stream channel deposits. These deposits result from deposition from erosion from portions of the Cascade Ranges to the Sutter Buttes. Thicknesses of the deposits range to 150 feet (DWR 2000). These deposits have low permeability and generally yield low quantities of poor quality water to wells.

The Pleistocene Modesto Formation in this subbasin consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tuscan Formation, Laguna Formation, and the Riverbank Formation. Surface exposure of the formation is west of the Feather River extending from south of the Thermalito Afterbay to the southern subbasin boundary. The formation may extend across the entire subbasin, underlying basin deposits, with thicknesses ranging from 50 to 150 feet.

The Pleistocene Riverbank Formation is older terrace deposits that consist of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. Surface exposure of the Riverbank Formation is primarily south and west of the Thermalito Afterbay. The formation may extend across the entire subbasin, underlying basin and Modesto deposits, with thicknesses ranging from 50 to 200 feet.

In the southern portion of the subbasin, alluvium of the Sutter Buttes is observed in the subsurface and may range in thickness up to 600 feet. The fan deposits forming the apron around the buttes consist largely of gravel, sand, silt and clay and may extend up to 15 miles north of the Sutter Buttes and westerly beyond the Sacramento River. Utility pump test records show the average well yield for that formation to be approximately 2,300 gallons per minute (gpm) with an average specific capacity of 64.

The Pliocene Tuscan Formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone and volcanic ash layers. Thickness of the formation is estimated to be 800 feet. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subsurface in the northern part of the subbasin and Units A and B are found in the southern part of the subbasin. Surface exposures of Units B and C are located in the foothills at the far eastern extents of the subbasin.

Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B.

The Pliocene Laguna Formation consists of interbedded alluvial sand, gravel, and silt deposits that are moderately consolidated and poorly-to-well cemented. The Laguna Formation is compacted and generally has a low-to-moderate permeability, except in scattered gravels in the upper portion. The formation yields moderate quantities of water to wells along the eastern margin of the valley. Wells of higher capacity generally tap underlying Tuscan deposits.

Surface exposures of the Laguna appear along the eastern margin of the subbasin in the vicinity of the Thermalito Afterbay and extend westerly in the subsurface. The lateral extent of the formation is unknown. The thickness of the formation is difficult to determine because the base of the unit is rarely exposed. Estimates of maximum thickness range from 180 to 1,000 feet. Geologic cross sections developed by DWR estimate the thickness to be approximately 500 feet. Wells completed in the formation yield only moderate quantities of water.

Wide seasonal fluctuations in groundwater levels exist in the northern part of the subbasin. Composite well fluctuations average about 15 feet during normal years and 30–40 feet during drought years. Annual groundwater fluctuations in the confined and semi-confined aquifer system range from 15 to 30 feet during normal years. In the part of the subbasin located within the southern part of Butte County, groundwater level fluctuations for composite wells average about 4 feet during normal years and up to 10 feet during drought years. The groundwater fluctuations for wells constructed in the confined and semiconfined aquifer system average 4 feet during normal years and up to 5 feet during drought years.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (18–27 inches/year), subsurface flow, irrigation infiltration, and stream infiltration. The northeast boundary along the Cascade Ranges is primarily a geographic boundary with some groundwater recharge occurring beyond that boundary. Localized fluctuations in groundwater levels observed just south of the Thermalito Afterbay are due to the recharging of groundwater from this surface water system.

Estimates of groundwater extraction for agricultural; municipal and industrial; and environmental wetland uses are 104,000, 75,500 and 1,300 acre-feet respectively. Deep percolation of applied water is estimated to be 126,000 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1995 (Yuba County and 1999 (Butte County). Agricultural land use accounts for about 62% of the subbasin, urban land use accounts for about 4% of the subbasin, and native land accounts for about 35% of the subbasin. Table 4-12 provides details of the land uses within the subbasin.

Table 4-12. Land Use in the East Butte Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	2,470	0.90
Deciduous Fruits and Nuts	35,400	13.30
Field Crops	3,130	1.20
Grain and Hay	1,660	0.60
Pasture	6,810	2.60
Rice	110,000	41.40
Truck, Nursery, and Berry Crops	480	0.20
Vineyards	97	0.04
Idle	3,000	1.10
Semiagricultural and Incidental	1,480	0.60
Subtotal	164,500	61.90
Urban		
Urban—unclassified	4,260	1.60
Urban Landscape	560	0.20
Urban Residential	1,690	0.60
Industrial	1,290	0.50
Vacant	1,400	0.50
Subtotal	9,520	3.60
Native		
Native Vegetation	59,500	22.40
Barren and Wasteland	3,130	1.20
Riparian	22,900	8.60
Water	6,350	2.40
Subtotal	91,880	34.60
Total	**265,900**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The East Butte groundwater subbasin is within the Butte Sutter Yuba Subwatershed. The public agencies within the East Butte subbasin are: Butte Basin Water Users Association, Biggs-West Gridley WD, Butte WD, Durham ID, City of Biggs, City of Gridley, Oroville-Wyandotte ID, Richvale ID, Thermalito ID, and Western Canal WD. The North Burbank Public Utility District is a private water agency in the East Butte subbasin. Butte County adopted a groundwater management ordinance in 1996. The Butte County ordinance requires export permits for groundwater extraction and substitute pumping, establishes the Water Commission and Technical Advisory Committee, and provides countywide groundwater monitoring programs. The city of Oroville is the largest urban area within the subbasin. This subbasin falls with the area included in the Butte Sutter Yuba Coalition.

Water Quality

Calcium-magnesium bicarbonate and magnesium-calcium bicarbonate waters are the predominant groundwater water types in the subbasin. Magnesium bicarbonate waters occur locally near Biggs-Gridley, south and east to the Feather River. TDS ranges from 122 to 570 mg/L, averaging 235 mg/L. Localized high concentrations of manganese, iron, magnesium, TDS, conductivity, ASAR, and calcium occur within the subbasin. There is evidence of groundwater pesticide contamination in Butte County (DPR 2003); triazine herbicides and degradation productions, diuron, bromocil, norflurazon and bentazon were detected in wells in Butte County. We were unable to obtain data for the locations of detections.

Discharge Pathways and Sources of Contaminants

Groundwater flows primarily to the southwest towards the West Butte subbasin and the Sacramento River. Sources of pesticide contamination include irrigated agriculture.

Management Practices

We were unable locate documentation of management practices for limiting groundwater quality impacts of irrigated agriculture. There is evidence that rice cultivation results in movement of pesticides to the subsurface.

Assessment of Data Adequacy and Need for Added Data

There is limited data and analysis for the spatial distribution of groundwater pesticide contamination and sources of contamination. Additional data is needed to develop management practices that may reduce movement of pesticide to the subsurface.

Los Molinos Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Los Molinos Subbasin is bounded on the west by the Sacramento River, on the north by Mill Creek, on the east by the Chico Monocline, and on the south by Deer Creek. Mill Creek and Deer Creek serve as hydrologic boundaries in the near surface. The subbasin is hydrologically contiguous with Dye Creek and Vina subbasins at depth. The subbasin is 33,200 acres (52 mi^2) in size and is located in Tehama County.

The following description of the hydrogeology in the Los Molinos subbasin is taken from DWR Bulletin 118 (DWR 2004).

The aquifer system of the subbasin is comprised of continental deposits of late Quaternary to Tertiary age. The Quaternary deposits include Holocene stream channel deposits, Pleistocene Modesto Formation terrace deposits located along most stream and river channels, and Pleistocene fanglomerate deposits from the Cascade Range. The Tertiary deposits include the Tuscan Formation.

The western edge of the subbasin is bounded by Holocene stream channel deposits of the Sacramento River. These deposits consist of moderately to highly permeable unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of the adjacent Tuscan and Tehama Formations. The thickness varies from 1 to 80 feet. The unit represents the upper part of the unconfined zone of the aquifer and is moderately-to-highly permeable; however, the thickness and areal extent of the deposits limit the water-bearing capability.

Pleistocene Modesto Formation deposits extend from Mill Creek to Deer Creek on the west side of the subbasin and along the courses of Mill Creek, Deer Creek, and Thomes Creek. The formation consists of undifferentiated terrace deposits of unconsolidated weathered and un-weathered gravel, sand, silt and clay. Thickness of the unit can range from 0 to 150 feet.

Along with the Modesto Formation, the Pleistocene Fanglomerate is a primary surficial deposit in the subbasin. The formation is an alluvial fan deposit derived from erosion and deposition of volcanic material from mudflows of the Tuscan

Formation and consists of polylithic volcanic clasts set in a weathered tuffaceous matix. The fan deposits are poorly sorted and somewhat indurated to well cemented. The fanglomerate is being dissected by Mill Creek and Deer Creek. Thickness of the deposit is up to 150 feet. The fanglomerate is not sufficiently thick to produce large quantities of groundwater.

The Pliocene Tuscan Formation is the primary source of groundwater in the subbasin. The formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone and volcanic ash layers. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subbasin and extend in the subsurface west of the Sacramento River.

Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick confining layers for groundwater contained in the more permeable sediments of Unit B.

The Tuscan Formation reaches a thickness of 1,500 feet over older sedimentary deposits. The dip of the formation averages approximately 2.5 degrees, east of the valley, and steepens sharply to 10–20 degrees southwestward towards the valley at the Chico Monocline. The formation flattens beneath valley sediments.

Long-term comparison of groundwater levels indicates a slight decline associated with the 1976–1977 and 1987–1994 droughts, followed by a recovery to pre-drought conditions of the early 1970s and 1980s. Generally, groundwater level data show an average seasonal fluctuation of approximate 2 feet for normal and dry years. Overall, there does not appear to be any increasing or decreasing trends in groundwater levels.

Groundwater storage capacity was estimated to be 397,700 acre-feet. This estimate was based on an average specific yield of 6.0% and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (18 inches/year), irrigation infiltration, stream infiltration, and subsurface flow. The major source for irrigation water is a mix of groundwater and surface water (Tehama County 2003). The Chico Monocline serves as a geographical boundary with some areas of recharge located east of the boundary.

Estimate of groundwater extraction for agricultural use is estimated to be 5,900 acre-feet. Municipal and industrial use is approximately 1,000 acre-feet. Deep percolation of applied water is estimated to be 3,000 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 62% of the subbasin, urban land use accounts for about 4% of the subbasin, and native land accounts for about 35% of the subbasin. The primary crop types are orchards and pasture (Tehama County 2003). Table 4-13 provides details of the land uses within the subbasin.

Table 4-13. Land Use in the Los Molinos Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Deciduous Fruits and Nuts	3,380	10.20
Field Crops	110	0.30
Grain and Hay	190	0.60
Pasture	2,180	6.60
Idle	180	0.50
Semiagricultural and Incidental	110	0.30
Subtotal	6,150	18.50
Urban		
Urban Landscape	40	0.10
Urban Residential	510	1.50
Commercial	60	0.20
Industrial	140	0.40
Vacant	140	0.40
Subtotal	890	2.70
Native		
Native Vegetation	23,400	70.50
Barren and Wasteland	460	1.40
Riparian	1,700	5.10
Water	600	1.80
Subtotal	26,160	78.80
Total	**33,200**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Los Molinos groundwater subbasin is within the Shasta Tehama Subwatershed. The public agencies within the subbasin are: Tehama County

Flood Control and Water Conservation District, Stanford Vina Ranch ID, Los Molinos Mutual Water Co., Los Molinos Water Works. Tehama County Flood Control and Water Conservation District adopted an AB3030 groundwater management plan in 1996. There are no major urban areas within the subbasin. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance include off-parcel groundwater use and influence of well pumping restrictions. This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Groundwater in the Los Molinos subbasin is characterized as calcium-magnesium bicarbonate and magnesium-calcium bicarbonate. TDS ranges from 119 to 558 mg/L, averaging 280 mg/L.

Los Molinos Community Service District (CSD) provides water to the town of Los Molinos. The primary water supply well (650 feet deep, open from 550 to 650 feet) produces water with about 10 parts per million (ppm) of arsenic (County of Tehama 2003). The current U.S. Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) for arsenic is 50 mg/L; however, lower MCL for arsenic (0.005 mg/L or 0.010 mg/L) have been proposed (Dawson 2001a; EPA 2005).

Discharge Pathways and Sources of Contaminants

We were unable to locate information for discharge pathways and sources of contaminants.

Management Practices

A small portion of the groundwater basin is irrigated agriculture. We were unable to identify management practices that affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

There is no readily available information about the effects of irrigated agriculture on groundwater quality in the Los Molinos Subbasin.

North American Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The North American groundwater subbasin is bounded by the Sierra Nevada foothills on the east, the Feather and Sacramento Rivers on the west, the Sacramento and American Rivers on the south, and the Bear River on the north. The subbasin is about 548 mi^2 in size and is located in parts of Sutter, Placer, and Sacramento Counties.

The following description of the hydrogeology in the South American subbasin is taken from DWR Bulletin 118 (DWR 2004).

The eastern boundary represents the approximate edge of the alluvial basin, where little or no groundwater flows into or out of the groundwater basin from the rock of the Sierra Nevada. The eastern portion of the study area is characterized by low rolling dissected uplands. The western portion is nearly a flat flood basin for the Bear, Feather, Sacramento and American rivers, and several small east side tributaries.

The water-bearing materials of the North American subbasin are dominated by unconsolidated continental deposits of Late Tertiary and Quaternary age. Deposits include Miocene/Pliocene volcanics, older alluvium, and younger alluvium. The alluvium can be characterized as comprising the upper aquifer system, occupying the upper 200–300 feet below ground surface. The Mehrten and older geologic units can be characterized as comprising the lower aquifer system, occurring generally deeper than 300 feet towards the west side of the subbasin. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 2,000 feet along the western margin of the subbasin. Most of the groundwater is produced in the northern portion of the subbasin. The aquifer zones in the upper 200–300 feet of this portion of the subbasin appear to be unconfined and behave similarly to stresses imposed on them. Conversely, deeper zones show a delayed response to stresses in the upper zone, indicating possibly limited interconnection with the shallower zones.

The younger alluvium deposits include flood basin deposits and recent stream channel deposits. The flood basin deposits occur along the western margin of the subbasin adjacent to the Sacramento River. The flood basin deposits consist primarily of silts and clays, although they may be locally interbedded with stream channel deposits of the Sacramento River. Thickness of the unit ranges from 0 to 100 feet. These fine-grained flood basin deposits have low permeability and generally yield low quantities of water to wells. Brackish water is often encountered in these deposits. The stream channel deposits include sediments deposited in the channels of active streams as well as overbank deposits of those streams, terraces, and local dredge tailings. These deposits occur predominantly along the Sacramento and American Rivers and their major tributaries, and consist primarily of unconsolidated silt, fine- to medium-grained sand, and gravel. Thickness of the unit ranges from 0 to about 100 feet. Sand and gravel zones in the younger alluvium are highly permeable and yield significant quantities of water to wells.

The older alluvium deposits consist of loosely to moderately compacted sand, silt, and gravel deposited in alluvial fans during the Pliocene and Pleistocene. A number of formational names have been assigned to the older alluvium, including the Modesto, Riverbank, Turlock Lake, Victor, Laguna and Fair Oaks Formations, and the Arroyo Seco and South Fork Gravels. The older alluvial units are widely exposed between the Sierra Nevada foothills and overlying younger alluvial units near the axis of the Sacramento Valley. Thickness of the older alluvium ranges between 100 and 650 feet. It is moderately permeable.

The Miocene/Pliocene Volcanics deposits consist of the Mehrten Formation, a sequence of fragmented volcanic rocks. The Mehrten Formation is exposed along the eastern margin of the subbasin between the towns of Lincoln and Folsom. It is composed of intervals of “black sands,” stream gravels, silt, and clay interbedded with intervals of dense tuff breccia. The sand and gravel intervals are highly permeable and wells completed in them have reported yields of over 1,000 gpm. The tuff breccia intervals act as confining layers. Thickness of the unit is between 200 and 1,200 feet.

Groundwater levels in southwestern Placer County and northern Sacramento County have generally decreased for the last 40 years or more. Groundwater levels in Sutter and northern Placer Counties generally have remained stable, although some wells in southern Sutter County have experienced declines.

DWR (2004) used and estimated specific yield of 7% and depth of 200 feet to calculate a storage capacity of 4.9 maf.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (18-20 inches/yr in the west, 20-24 inches/yr in the east), irrigation infiltration, and stream infiltration. Groundwater discharge likely occurs as evapotranspiration, subsurface flow, stream discharge, and pumpage. DWR estimated the groundwater budget components for a 1990 level of development. Estimated inflows include natural recharge at 83,800 acre-feet and applied water recharge at 29,800 acre-feet. Estimated outflows include urban pumpage at 109,900 acre-feet and agricultural pumpage at 289,100 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1994 (Placer County), 1998 (Sutter County), and 2000 (Sacramento County). Agricultural land use accounts for about 42% of the subbasin, urban land use accounts for about

29% of the subbasin, and native land accounts for about 29% of the subbasin. Table 4-14 provides details of the land uses within the subbasin.

Table 4-14. Land Use in the North American Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	200	0.10
Deciduous Fruits and Nuts	9,680	2.80
Field Crops	12,400	3.60
Grain and Hay	15,200	4.50
Pasture	15,300	4.50
Rice	74,100	21.80
Truck, Nursery, and Berry Crops	1,230	0.40
Vineyards	50	0.01
Idle	11,900	3.50
Semiagricultural and Incidental	2,070	0.60
Subtotal	142,130	41.80
Urban		
Urban—unclassified	76,300	22.40
Urban Landscape	3,710	0.20
Urban Residential	5,210	1.50
Industrial	3,810	1.10
Commercial	660	0.20
Vacant	10,800	3.20
Subtotal	100,490	28.70
Native		
Native Vegetation	90,200	26.50
Barren and Wasteland	290	0.10
Riparian	4,360	1.30
Water	2,860	0.80
Subtotal	97,710	29.50
Total	**340,330**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The North American groundwater subbasin is within the Placer North Sacramento Subwatershed.

The public agencies within the North American subbasin are: South Sutter WD, Camp Far West ID, Rio Linda/Elverta CWD, Citrus Heights WD, San Juan Suburban WD, Fair Oaks WD, Carmichael WD, Sacramento Suburban WD, Western Placer ID, Placer County WA, Del Paso Manor WD, City of Sacramento WSA, City of Roseville, Sacramento County Water Agency (DWR 2004).

The public agencies within the North American subbasin are Pleasant Grove—Verona MWC, Natomas Central MWC, California-American WC, Orangevale WC, Southern California WC.

The Sacramento Groundwater Authority (SGA) is a joint powers authority formed to manage the North Area Groundwater Basin, which is in the southern part of the North American subbasin. The Regional Water Authority (RWA) is a joint powers authority that serves and represents the interests of 21 water providers in the greater Sacramento, Placer and El Dorado County region.

The Sacramento Groundwater Authority adopted a groundwater management plan on December 11, 2003. South Sutter WD adopted an AB3030 plan in 1995. Placer County Water Agency adopted an AB3030 plan in 1998. City of Lincoln adopted a groundwater management plan on November 12, 2003.

The Sacramento Metropolitan urban is partly located within the subbasin including the cities of Sacramento, Roseville, Citrus Heights, and Lincoln.

This subbasin falls with the area included in the Placer-North Sacramento Coalition.

Water Quality

Many areas of good quality groundwater exist in the North American subbasin. However, in some parts of the basin groundwater quality is marginal. The three major groundwater types are: magnesium calcium bicarbonate or calcium magnesium bicarbonate; magnesium sodium bicarbonate or sodium magnesium bicarbonate; and sodium calcium bicarbonate or calcium sodium bicarbonate.

Comparison of groundwater quality data with applicable water quality standards and guidelines for drinking and irrigation indicate elevated levels of TDS, chloride, sodium, bicarbonate, boron, fluoride, nitrate, iron, manganese, and arsenic may be of concern in some locations within the subbasin.

High TDS levels exist in an area along the Sacramento River extending from Sacramento International Airport northward to the Bear River. The highest levels of TDS are found in an area extending just south of Nicholas to Verona, between RD 1001 and the Sutter Bypass. Some wells in this area have reported TDS exceeding 1,000 mg/L.

This same area along the Sacramento River extending from Sacramento International Airport northward to the Bear River also contains high levels of chloride, sodium, bicarbonate, manganese, and arsenic. The groundwater in the southern part of the basin is generally characterized as good quality, low in disinfection by-product precursor materials and moderate in mineral content, although some localized contamination issues do exist.

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the North American basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology, and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the North American subbasin is chemically oxidizing. This results in lower concentrations of manganese and iron and the presence of nitrate and sulfate. Agricultural processes include use of fertilizers and pesticides and the evaporation of irrigation water. Groundwater from the North American subbasin discharges to wells and streams. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. There are naturally occurring nitrates in some formations of the Sacramento Valley. However, most nitrogen species that occur above 3 mg/L signify contamination introduced into the groundwater via human activates such as agriculture and urbanized development. At this time, the data available for the Southeastern Sacramento Valley, an area that includes the North American subbasin, show that 8 of the 31 wells studied by Dawson (2001b) were impacted by nitrate concentrations above 3 mg/L. The median concentration for nitrate in this study was 1.4 mg/L, which is higher than the national median (1.0 mg/L) for drinking water aquifers.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The groundwater in the North American subbasin was classified as multiple geochemical facies: magnesium calcium bicarbonate or calcium magnesium bicarbonate; magnesium sodium bicarbonate or sodium magnesium bicarbonate; and sodium calcium bicarbonate or calcium sodium bicarbonate.

Two processes appear to primarily affect groundwater salinity in the North American subbasin. The first is evaporation of irrigation water and shallow groundwater. The second is mixing of naturally occurring groundwater (Hull

1984; Olmsted and Davis 1961; Dawson 2001a). Using isotope data, Dawson (2001a) presented evidence that partial evaporation accounted for some of the measured increase in salinity among shallow groundwater samples.

Pesticides

Pesticides were detected in four wells that affect the North American subbasin (Dawson 2001b). Three wells are located in the subbasin and one well is located in the South American subbasin but contamination is known to be moving across the American river to the North American subbasin. All concentrations were below the drinking water limits.

The most common pesticides detected in Dawson’s (2001b) 1996 study of the Southeastern Sacramento Valley were bentazon, simazine, atrazine, bromacil, and tebuthiuron were detected. The major uses for atrazine, bromacil, and tebuthiuron are for weed control in right-of-way areas and for landscape maintenance. Simazine is used for weed control in right-of-way areas and for landscape maintenance, and also on many crops grown in the study area, including nut and fruit orchards.

Trace Elements

The chemistry of geology formations in the North American subbasin influences the concentrations of trace elements. Dawson (2001a) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of silica were significantly higher in the eastern alluvial plain, which contains the North American subbasin. The eastern alluvial plains showed higher concentration of arsenic than in the western alluvial plain. However she also presented evidence (Dawson 2001b) that, within the Southeastern Sacramento Valley, the concentration of arsenic is related to the dissolved oxygen concentration (or redox condition) of the groundwater. She found that as the concentration of dissolved oxygen increases, the arsenic concentrations decrease. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Organic Carbon and DPBs

Twenty-two percent of the North American subbasin is utilized as rice fields. There is evidence that recent changes in management practices in rice cultivation may result in higher dissolved organic carbon concentrations in water that reaches the groundwater via deep percolation or irrigation water. High dissolved organic carbon content was confirmed in 43% of the wells in rice growing areas studied by Dawson (2001a). The median concentration of which was 2.7 mg/L, much higher than the national median of 0.7 mg/L (Leenheer et al. 1974).

Volatile Organic Compounds

VOCs have many different uses including pesticides gasoline, degreasers, solvents, and refrigerants. Some VOCs are byproducts of the chlorination of drinking water. VOCs were detected in four of the ten wells in the North American subbasin in the 1996 study of the Southeastern Sacramento Valley by Dawson (2001b). The VOCs found in the wells are consistent with the land use surrounding each well. Those detected in agricultural areas were VOCs found in pesticides or gasoline while those detected in urban areas were VOCs associated with landscape maintenance, pet control, right-of-way weed control, gasoline, industrial chemicals and chlorinated drinking water.

Management Practices

We were unable to locate documentation of management practices for limiting groundwater quality of irrigated agriculture. Rice cultivation appears to be a major process affecting groundwater quality in the subbasin.

Assessment of Data Adequacy and Need for Added Data

Data from USGS, DPR, and DWR provide somewhat limited picture of the areal variability for groundwater quality in the North American subbasin in that there is not extensive areal coverage for groundwater quality. However, the available data indicate key issues related to human influence on groundwater including fertilizers (containing nitrates), pesticides, dissolved solids and volatile organic compounds.

North Yuba Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The North Yuba subbasin is bounded on the north by Honcut Creek, the Feather River on the west, on the south by the Yuba River, and on the east by the Sierra Nevada. The subbasin is about 55,900 acres (87 mi^2) and is located entirely within Yuba County.

The following description of the hydrogeology in the South American subbasin is taken from DWR Bulletin 118 (DWR 2004).

The North Yuba subbasin aquifer system is comprised of continental deposits of Quaternary to Late Tertiary (Pliocene) age. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 1,000 feet along the western margin of the basin.

Dredger tailing deposits occur along the Feather River in the northwest and the Yuba River in the southeast of subbasin. The coarse gravels and cobbles can be up to 125 feet thick and are highly permeable. Stream channel and floodplain materials occur as coarse sand and gravels along present stream channels of the Yuba River, Feather River, and Honcut Creek. Coarser grained materials occur near streams with thicknesses up to 110 feet. Both grain size and thickness decrease with increased distance from streams. These deposits are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Well yields are reported in the range of 2,000 to 4,000 gpm.

The Pleistocene Victor Formation lies unconformably above the Laguna Formation. The majority of the formation occurs as alluvium throughout the subbasin, but floodplain deposits are present along stream channels above the alluvium.

Pleistocene Floodplain deposits occur as gravelly sand, silt, and clay from flood events along the Feather River and its tributaries. This unit overlies the Older Alluvium, underlies Quaternary Deposits, and ranges in thickness from 5 to 15 feet. These deposits provide a good medium for groundwater recharge, provided the groundwater can pass the lower contact with the Older Alluvium.

Pleistocene Alluvium occurs over more than 50% of the basin surface and at least 60% of its irrigated agricultural lands. Its thickness is highly variable due to its lower contact with the Laguna Formation. The Older Alluvium is comprised of Sierran alluvial fan deposits of loosely compacted silt, sand, and gravel with lesser amounts of clay deposits. The deposits occur as lenticular beds with decreasing thickness and grain size with increasing distance from the Yuba River and the foothills. Hardpan and claypan soils have developed to form an impermeable surface, but below this the Older Alluvium is moderately permeable and provides for most of the groundwater from domestic and shallow irrigation wells. Wells in the older alluvium have yields up to 1,000 gpm.

The Pliocene Laguna Formation is the most extensive water-bearing unit within the subbasin. The formation is comprised of reddish to yellowish or brown silt to sandy silt with abundant clay and minor lenticular gravel beds. It overlies the Mehrten Formation and occurs at the surface intermittently at the east end of the basi. The continental deposits of the Laguna Formation dip to the west beneath the Victor Formation and range in thickness from 400 feet near the Yuba River up to 1,000 feet in the southwest portion of the county. Although the occurrence of thin sand and gravel zones is common, many of them have reduced permeability due to cementation. This, coupled with its fine-grained character, leads to an overall low permeability for the Laguna Formation. Most of the groundwater produced from wells in the Laguna comes from overlying units.

The Miocene-Pliocene Mehrten Formation is a sequence of volcanic rocks of late Miocene through middle Pliocene age. Surficial exposures are limited to a few square miles in the northeast corner of the basin and thickness varies from

200 feet near the eastern margin of the basin to 500 feet near the Feather River. The Mehrten Formation is composed of two distinct units. One unit occurs as intervals of gray to black, well-sorted fluvial andesitic sand (up to 20 feet thick), with andesitic stream gravel lenses and brown to blue clay and silt beds. These sand intervals are highly permeable and wells completed in them can produce high yields. The second unit is an andesitic tuff-breccia that acts as a confining layer between sand intervals.

From 1950 through 1990, average basin groundwater levels remained relatively constant. Based on an analysis of hydrographs the Yuba River and Feather Rivers create a groundwater divide, which act as flow barriers in the shallow subsurface.

Groundwater storage capacity was estimated to be 620,000 acre-feet. This estimate was based on an area of 49,800 acres, an average specific yield of 6.9%, and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (20 inches/year in the southeast to 32 inches/yr in the northeast), irrigation infiltration, and stream infiltration. Stream channel and floodplain deposits present along the Yuba River, Feather River, and Honcut Creek are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Forty percent of the North Yuba subbasin is used for rice cultivation where the fields are typically flooded for 6 months each year, resulting in percolation of partially evaporated irrigation water.

Previous DWR unpublished studies have estimated natural and applied recharge. DWR has also estimated urban and agriculture extractions and subsurface outflow. Inflows include natural recharge of 51,100 acre-feet and applied recharge of 13,900 acre-feet. Groundwater discharge occurs as evapotranspiration, and pumpage. Outflows include urban extraction of 9,000 acre-feet, agricultural extraction of 65,800 acre-feet, and subsurface outflow of 21,800 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1995. Agricultural land use accounts for about 75% of the subbasin, urban land use accounts for about 5% of the subbasin, and native land accounts for about 20% of the subbasin. Table 4-15 provides details of the land uses within the subbasin.

Table 4-15. Land Use in the North Yuba Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	390	0.70
Deciduous Fruits and Nuts	15,100	27.20
Field Crops	230	0.40
Grain and Hay	150	0.30
Pasture	1,760	3.20
Rice	22,000	39.60
Truck, Nursery, and Berry Crops	16	0.03
Idle	1,340	2.40
Semiagricultural and Incidental	410	0.70
Subtotal	41,400	74.50
Urban		
Urban—unclassified	1,900	3.40
Urban Landscape	88	0.20
Urban Residential	480	0.90
Industrial	120	0.20
Vacant	420	0.80
Subtotal	3,000	5.40
Native		
Native Vegetation	7,010	12.60
Barren and Wasteland	1,020	1.80
Riparian	2,150	3.90
Water	1,010	1.80
Subtotal	11,200	20.10
Total	**55,600**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The North Yuba groundwater subbasin is within the Butte Sutter Yuba Subwatershed.

The public agencies within the North Yuba subbasin are: Yuba County Water Agency, Ramirez Water District, Cordua Irrigation District.

In 1992 AB3030 provided a systematic procedure for an existing local agency to develop a formal groundwater management plan. The Cordua Irrigation District and the Yuba County Water Agency have AB3030 groundwater management plans.

The city of Marysville is located within the subbasin Yuba City is located at the southwestern boundary of the subbasin.

This subbasin falls with the area included in the Butte-Sutter-Yuba Coalition.

Water Quality

The generally good water quality characteristics are apparent in the overall salinity of groundwater in the subbasin. In general, TDS concentrations in the subbasin are below 500 mg/L throughout the entire basin. DWR maintains data for 35 water quality wells in the North Yuba Subbasin. Data collected from these wells indicate a TDS range of 149 to 655 mg/L and a median of 277 mg/L. The primary water chemistry in the area indicates calcium magnesium bicarbonate or magnesium calcium bicarbonate groundwater. Some magnesium bicarbonate can be found in the northwest portion of the basin.

Groundwater Quality issues in the North Yuba subbasin include excess nutrients, trace elements, salinity and pesticides. Pesticides are persistent in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring but some are elevated to levels above the national limits. Nitrates are elevated due to on-site sewage systems. However, there is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the North Yuba subbasin. Tables 4-16 and 4-17 summarize the available data.

Table 4-16. Water Quality in the North Yuba Subbasin

Constituent of Concern	Available Information about Groundwater Concentrations for North Yuba Subbasin
Nutrients	Median nitrate concentrations for the southeastern Sacramento Valley, including North Yuba subbasin was 1.4 mg/L. Only one well in the study area exceeded drinking water standards.
Pesticides (insecticides and herbicides) and degradation products	DPR verified bentazon detection in 10 wells with in Yuba County from 1996 to 2003 and one detection of benzol from July 2003 to June 2004. Pesticides detected in one domestic well in 1996 study, but concentration was below drinking water standards.
Salt—primarily as electrical conductivity and total dissolved solids.	
Trace elements	High concentration of arsenic (naturally occurring) in some areas.
Organic carbon and disinfection byproduct precursors	No available data.
Microorganisms	No available data.
Volatile organic compounds	VOCs were detected in 3 of the 4 wells in or near North Yuba subbasin. Concentrations below drinking water standards.

Notes:
mg/L = milligrams per liter.
Sources: Dawson 2001b; DPR 2004.

Table 4-17. Concentrations of Constituents of Concern Detected in the Southeastern Sacramento Valley Aquifers (Includes the North Yuba Subbasin)

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
Nutrients	Nitrate—Ammonia as N	0.02–0.11 mg/L	30 (HAL)
	Nitrate as N	0.06–12 mg/L	10 (MCL[a])
	Nitrite as N	0.01–0.01 mg/L	1 (MCL[a])
	Orthophosphate, as P	0.03–0.4 mg/L	
	Phosphorus, as P	0.03–0.45 mg/L	
Pesticides (insecticides and herbicides) and degradation products*	Atrazine	0.001–0.001 µg/L	3 (MCL[a])
	Bentazon	*0.02–1.3* µg/L	18 (MCL[b])
	Bromacil	0.34 µg/L (one detection)	90 (HAL)
	Desethyl atrazine	*0.004–0.044* µg/L	
	Simazine	0.006–0.077 µg/L	4 (MCL[a])
	Tebuthiuron	0.32 µg/L (one detection)	500 (HAL)
Salt—primarily as electrical conductivity and total dissolved solids.		149 to 655 mg/L, median is 277 mg/L (DWR 2004) 134–1,750 mg/L, median is 258 mg/L	500 (SMCL)

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
Inorganic Constituents			EPA Standard, 2000
	Arsenic	1–46 µg/L	50 (MCL[a])
	Bicarbonate	67–413 mg/L	
	Boron	12–110 µg/L	600 (HAL)
	Bromide	0.02–12 mg/L	
	Calcium	10–210 mg/L	
	Chloride	2.0–620 mg/L	250 (SMCL)
	Fluoride	0.1–0.3 µg/L	4 (MCL[a])
	Iron Fe	3–1,600 µg/L	300 (SMCL)
	Magnesium	5.0–100 mg/L	
	Manganese	1–870 µg/L	50 (SMCL)
	Potassium	0.40–4.1 mg/L	
	Silica	24–86 mg/L	
	Sodium	5.7–120 mg/L	
	Sulfate	1.0–130 mg/L	250 (SMCL)
	Total Hardness as $CaCO_3$	48 (soft)–940 (very hard) mg/L, median is 135 mg/L	
Organic carbon and disinfection byproduct precursors	DOC	0.2–0.7 mg/L, median 0.3 mg/L	
Volatile organic compounds*	1,1-Dichloroethane	*0.02*–0.04 µg/L	
	1,2,4-Trimethylbenzene	*0.01*–0.02 µg/L	
	1,2-Dichloroethane	0.19 µg/L	0.5 (MCL[a])
	Bromodichloromethane	*0.03* µg/L	100 (MCL[a])
	cis-1,2-Dichloroethene	0.43 µg/L	6 (MCL[b])
	Dichlorodifluoromethane	*0.04*–0.29 µg/L	1000 (HAL)
	Methyl tert-butyl ether	*0.06* µg/L	20 (HAL)
	Styrene	*0.06* µg/L	100 (MCL[a])
	Tetrachloroethene	0.58–0.97 µg/L	5 (MCL[a])
	Tetrachloromethane	1.2 µg/L	0.5 (MCL[b])
	Trichloroethene	*0.01*–5.5 µg/L	5 (MCL[a])
	Trichlorofluoromethane	*0.04* µg/L	150 (MCL[b])
	Trichloromethane	*0.03*–1.1 µg/L	100 (MCL[a])

Notes:
* Numbers in *italics* are estimates.
MCL[a] = Maximum Contaminant Level set by EPA (2005).
MCL[b] = Maximum Contaminant Level set by DWR.
µg/l = micrograms per liter.
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).
HAL = Health Advisory Level set by EPA (2005).
Source: Dawson 2001b, unless otherwise indicated.

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the North Yuba basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the North Yuba subbasin is chemically oxidizing. This results in lower concentrations of manganese and iron and the presence of nitrate and sulfate. Agricultural processes include use of fertilizers and pesticides and the evaporation of irrigation water. Groundwater from the North Yuba subbasin discharges to wells and streams. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas that included the North Yuba Subbasin. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. Dawson (2001b) also presented evidence suggesting that nitrate concentrations are being lowered by chemical reactions in the ground-water that reduce nitrate to nitrogen gas. At this time, the data available for the Southeastern Sacramento Valley, an area that includes the North Yuba subbasin, show that shallow wells studied by Dawson (2001b) were impacted by nitrate concentrations above 3 mg/L.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The eastern alluvial plains, in which North Yuba subbasin is located, contain magnesium-calcium-carbonate groundwater. Two processes appear to primarily affect groundwater salinity in the North Yuba subbasin: evaporation of irrigation water and shallow groundwater and mixing of naturally occurring groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a).

Pesticides

Rice pesticides Molinate, Thiobencarb and Carbofuran were detected in wells sampled during the 1997 study by the USGS (Dawson 2001a) that included the North Yuba subbasin. The most prevalent pesticide detected in groundwater was bentazon. This chemical was used in rice fields until it was suspended in 1989 and officially banned in 1992. Its presence in groundwater in studied completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Although present in most wells in the rice growing areas of the Sacramento Valley in the 1997 study (Dawson 2001a), pesticides were only detected in one well in the North Yuba subbasin in the 1996 study (Dawson 2001b). This well was located just east of the Feather River near its confluence with the Yuba River. One pesticide was present in this domestic well at concentrations below the drinking water limits.

Other pesticides shown Table 4-17 include atrazine, bromacil, simizine, and tebuthiuron, which are used for weed control in right-of-way areas and for landscape maintenance. Simazine is used for weed control in right-of-way areas and for landscape maintenance, and also on many crops grown in the study area, including nut and fruit orchards.

Dawson (2001a) investigated the relationship between groundwater quality and rice cultivation land use practices in data collected during 1997. She found that shallower wells had more occurrences of pesticide contamination than deeper wells, indicating the movement of pesticides from the ground surface downward.

Trace Elements

The chemistry of geology formations in the North Yuba subbasin influences the concentrations of trace elements. Dawson (2001a) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of silica were significantly higher in the eastern alluvial plain, which contains the North Yuba subbasin. Elevated concentrations of potassium were also present. The eastern alluvial plains showed higher concentration of arsenic than in the western alluvial plain. Dawson (2001b) presented evidence that the presence and concentration of arsenic is related to the dissolved oxygen concentration (or redox condition) of the groundwater. As the concentration of dissolved oxygen increases, the arsenic concentrations decrease. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Organic Carbon And DPBs

There is some evidence that recent changes in management practices in rice may result in higher dissolved organic carbon concentrations in deep percolation water. Dawson (2001a) did a study of groundwater quality in rice-growing areas of the western Sacramento Valley. Findings showed high dissolved organic carbon content in 43% of the wells in that study area. The median concentration was 2.7 mg/L, which is much higher than the national median of 0.7 mg/L (Leenheer et al. 1974).

Volatile Organic Compounds

VOCs have many different uses including pesticides gasoline, degreasers, solvents, and refrigerants. Some VOCs are byproducts of the chlorination of drinking water. VOCs were detected in three of the four wells in or on the border of the North Yuba subbasin in the 1996 study by Dawson (2001b). The VOCs found in the wells are consistent with the agricultural land uses in the subbasin, in that they were VOCs found in pesticides or gasoline.

Management Practices

Rice field management practices began in 1983, to protect surface water quality. Rice field irrigation water began to be held in the fields after the application of pesticides to allow more time for degradation (Dawson 2001a; Holden 1986). More irrigation water recycling was also encouraged at this time. These practices may have caused more contamination to percolate downward to groundwater. Rice growing, in general, provides opportunity for mobile pesticides to move to groundwater due to large volumes of groundwater recharge. Irrigation practices affect the rate at which pesticides reach groundwater. Troiano et al. (1993) investigated difference irrigation methods and found basin-flooding treatments, as those practiced on rice fields, cause a greater volume of downward percolation of irrigation water and the pesticides contained in that water. We were unable to identify documentation of specific management practices implemented for protection of groundwater quality in the North Yuba Subbasin.

Assessment of Data Adequacy and Need for Added Data

Date from USGS, DPR, DWR provide somewhat limited picture of the spatial variability of groundwater quality in the North Yuba subbasin in that there is not extensive areal coverage for groundwater quality. However, the available data indicate key issues related to pesticides.

Red Bluff Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Red Bluff subbasin is bounded on the west by the Coast Ranges, on the north by the Red Bluff Arch, on the south by Thomes Creek and on the east by the Sacramento River. The Red Bluff Arch is a hydrologic divide between the Redding Basin to the north and the Sacramento Valley. The Red Bluff subbasin is likely contiguous with the Corning subbasin at depth. The subbasin is about 274,700 acres (429 mi^2) in size and is located in Tehama County.

The following description of the hydrogeology in the Red Bluff subbasin is taken from DWR Bulletin 118 (DWR 2004).

The subbasin aquifer system is composed of continental deposits of late Tertiary to Quaternary age. The Quaternary deposits include Holocene stream channel deposits and Pleistocene Modesto and Riverbank formations. The Tertiary deposits consist of Pliocene Tehama and Tuscan formations.

Holocene stream channel deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Tehama Formation and Quaternary stream terrace deposits found at or near the surface along stream and river channels. The thickness varies from 1 to 80 feet. This unit represents the upper part of the unconfined zone of the aquifer. Although it is moderately to highly permeable it is not a significant contributor to groundwater because of its limited areal extent.

The Pleistocene Modesto Formation consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tehama and Riverbank Formations. The deposit ranges from less than 10 feet to nearly 200 feet across the valley floor. The terrace deposits are observed along Thomes, Elder, and Red Bank Creeks.

The Pleistocene Riverbank Formation consists of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. The formation ranges from less than one foot to over 200 feet thick depending on location. Riverbank terrace deposits are observed along Thomes, Pine, Dibble, Reeds, Red Bank, Oat and Elder Creeks.

The Pliocene Tehama Formation consists of sediments originating from the Coast Range and Klamath Mountains, and is the primary source of groundwater for the subbasin. The majority of the Tehama Formation consists of fine-grained sediments indicative of deposition under floodplain conditions. The thickness of coarse-grained beds of sand and gravel, as indicated by drill log data, are typically no more than 5 to 10 feet. The majority of both coarse and fine-grained sediments appear unconsolidated or moderately consolidated. The thickness of the formation is estimated to be up to 1,200 feet north of the City of Corning.

The Pliocene Tuscan Formation consists of volcanic gravel and tuff-breccia, fine- to coarse-grained volcanic sandstone, conglomerate and tuff, and tuffaceous silt and clay; derived predominantly from andesitic and basaltic sources of the Cascade Range. In the subsurface the Tuscan Formation is found juxtaposed with the Tehama Formation in the axis of the valley near the Sacramento River. Permeability is moderate to high with yields ranging from 100 to 1,000 gpm, excluding areas where beds of the impermeable tuff-breccia exist.

Long-term groundwater level data indicate a decline of 3–7 feet associated with the 1976–1977 and 1987–1994 droughts, followed by a recovery to pre-drought conditions of the early 1970s and 1980s. Generally, groundwater level data show a seasonal fluctuation ranging from 5 to 10 feet for unconfined, semiconfined, and composite wells. Wells constructed in confined aquifers can fluctuate up to 50 feet. Overall, there does not appear to be any increasing or decreasing trends in the groundwater levels.

Groundwater storage capacity was estimated to be about 4,209,000 acre-feet. This estimate was based on an average specific yield of 7.9% and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (19–27 inches/year), irrigation infiltration, and stream infiltration.

Estimate of groundwater extraction for agricultural use is estimated to be 81,000 acre-feet. Municipal and industrial use is approximately 8,900 acre-feet. Deep percolation of applied water is estimated to be 20,000 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 12% of the subbasin, urban land use accounts for about 5% of the subbasin, and native land accounts for about 83% of the subbasin. Table 4-18 provides details of the land uses within the subbasin.

Table 4-18. Land Use in the Red Bluff Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	620	0.20
Deciduous Fruits and Nuts	11,000	4.00
Field Crops	1,700	0.60
Grain and Hay	4,540	1.70
Pasture	8,870	3.20
Rice	1,530	0.60
Truck, Nursery, and Berry Crops	70	0.03
Idle	3,750	1.40
Semiagricultural and Incidental	860	0.30
Subtotal	32,910	12.00
Urban		
Urban—unclassified	310	0.10
Urban Landscape	340	0.10
Urban Residential	9,970	3.60
Commercial	680	0.20
Industrial	1,010	0.40
Vacant	2,240	0.80
Subtotal	14,550	5.30
Native		
Native Vegetation	219,000	79.70
Barren and Wasteland	2,300	0.80
Riparian	2,890	1.10
Water	3,030	1.10
Subtotal	227,220	82.70
Total	**274,380**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Red Bluff groundwater subbasin is within the Shasta Tehama Subwatershed.

The public agencies within the subbasin are: Tehama County Flood Control and Water Conservation District. El Camino ID, Elder Creek WD, Gerber-Los Flores Community Service District, Gerber Water Works Inc., Tehama Ranch M.W.C., Proberta WD, Rawson WD, Thomes Creek WD, City of Red Bluff.

Tehama County adopted a groundwater ordinance in 1994 and a countywide AB3030 groundwater management plan in 1996.

The city of Red Bluff is located within the subbasin.

Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance are off-parcel groundwater use, and influence of well pumping restrictions.

This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Calcium-magnesium bicarbonate and magnesium-calcium bicarbonate are the predominant groundwater types in the subbasin. TDS ranges from 120 to 500 mg/L and average 207 mg/L (DWR unpublished data). Impairments include high magnesium, TDS, calcium, ASAR, and phosphorus.

Discharge Pathways and Sources of Contaminants

We were unable to identify information about discharge pathways and sources of contaminants for this subbasin.

Management Practices

A small portion of the land use is irrigated agriculture. We were unable to identify documented management practices that affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

There is no available data indicating groundwater quality problems in the Red Bluff Subbasin.

Solano Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Solano subbasin lies within the southwestern portion of the Sacramento Basin and the northern portion of the Sacramento-San Joaquin Delta. It is bounded by Putah Creek on the north, the Sacramento River on the east (from Sacramento to Walnut Grove), the North Mokelumne River on the southeast (from Walnut Grove to the San Joaquin River), the San Joaquin River on the south (from the North Mokelumne River to the Sacramento River) and a hydrologic divide between the San Francisco Bay and the Sacramento-San Joaquin River Delta on the west. The aquifer system is 664 mi^2 in size and lies in Solano, Sacramento, and Yolo Counties.

The following description of the hydrogeology in the Solano subbasin is taken from DWR Bulletin 118 (2004). The primary water-bearing formations comprising the Solano subbasin are sedimentary continental deposits of Late Tertiary to Quaternary age. Fresh water-bearing units include younger alluvium, older alluvium, and the Tehama Formation. The thickness of the units is nearly 3,000 feet near the eastern margin of the basin, thinning westward until they pinch out near the Coast Range. The Tehama Formation is underlain by saline water bearing sedimentary units that are generally considered the saline water boundary.

Flood basin deposits occur along the eastern margin of the subbasin and in the delta. Eastern flood basin deposits consist primarily of silts and clays, and may be locally interbedded with Sacramento River stream channel deposits. The flood basin deposits in the delta contain a significant percentage of organic material (peat). Thickness of the unit ranges from 0 to 150 feet. These deposits have low permeability and generally yield low quantities of water to wells.

Recent stream channel deposits occur along the Sacramento, Mokelumne and San Joaquin Rivers, and the upper reaches of Putah Creek, and consist of unconsolidated silt, fine- to medium-grained sand, and gravel with intermittent cobbles. The younger alluvium ranges in thickness from 0 to 40 feet but, with the exception of the Delta, generally lie above the saturated zone. The older alluvium ranges in thickness from 60 to 130 feet and has highly variable permeability. Deposits consist of loose to moderately compacted silt, silty clay, sand, and gravel from alluvial fan deposits. The coarser material usually occurs as lenses within the finer material. Well production within the unit can range from 50 to 4,000 gpm.

The Tehama Formation is the predominant water-bearing unit within the Solano subbasin, with thickness ranging from 1,500 to 2,500 feet. The formation consists of moderately compacted silt, clay, and fine silty sand enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate. Because of its large extent, wells completed in the Tehama Formation can yield up to several thousand gallons per minute, although its permeability is generally less than the overlying younger units.

Brackish to saline water-bearing sedimentary units of volcanic and marine origin underlie the Tehama Formation at depths ranging from a few hundred feet on the west to nearly 3,000 feet on the east of the subbasin. The contact between the Tehama Formation and these units is generally considered to coincide with the boundary between fresh and saline water.

According to DWR Bulletin 118 (2004), agricultural and urban development have resulted in significant decreases in groundwater elevations from historical levels. A large pumping depression has formed just north of the Delta. (USGS

1401-A, 1991 and ---.) Subsequent to the onset of surface water deliveries in 1959, however, water levels have recovered slightly or slowed their decline. Periods of drought in the 1970s and 1980s have significantly affected groundwater level trends, but these impacts have been offset by subsequent wet years. Average specific yield is estimated to be 0.07 for the Sacramento Valley and 0.08 for the Delta.

Major Sources of Recharge

The principal sources of stream recharge for the Solano subbasin are Putah Creek and the Sacramento River. Hydrochemical facies analysis indicates that the surface water from Putah Creek contributes to groundwater both near the creek and south into the center of Solano County. (Evenson 1984.) Deep percolation of water applied as crop irrigation is another source of recharge, but is secondary to the combination of streamflow and precipitation, as soils containing hardpan and clay in areas other than along streams impede vertical percolation in the Solano subbasin. (DWR 1978.)

Annual precipitation for the subbasin ranges from approximately 16 to 23 inches, with higher precipitation occurring to the west.

Land Use

Land use surveys were conducted within the subbasin by DWR. Agricultural land use accounts for about 67% of the subbasin, urban land use accounts for about 4% of the subbasin, and native land accounts for about 28% of the subbasin. Table 4-19 provides details of the land uses within the Solano Subbasin.

Table 4-19. Land Use in the Solano Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	48	0.01
Deciduous Fruits and Nuts	10,738	2.52
Field Crops	98,892	23.23
Grain and Hay	73,196	17.19
Idle	5,739	1.35
Pasture	56,667	13.31
Semiagricultural and Incidental	3,154	0.74
Truck, Nursery, and Berry Crops	30,788	7.23
Vineyards	7,145	1.68
Subtotal	286,367	67.26

Urban		
Urban—unclassified	8,606	2.02
Commercial	468	0.11
Industrial	1,621	0.38
Urban Landscape	450	0.11
Urban Residential	2,104	0.49
Vacant	2,455	0.58
Subtotal	15,704	3.69
Native		
Native—unclassified	578	0.14
Native Vegetation	87,444	20.54
Barren and Wasteland	6	0.00
Riparian	7,983	1.87
Water	24,993	5.87
Subtotal	121,004	28.42
Unknown	2,697	0.63
Total	**425,772**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Public water agencies included in the Solano Subbasin include City of Dixon, City of Rio Vista, California Water Service, City of Vacaville, and University of California, Davis. Private water agencies include Maine Prairie Water District, Solano Irrigation District, Solano County Water Agency, North Delta Water Agency, and RDs 501, 536, 1607, 1667, 2060, 2068, 2084, 2093, 2098, 2104, and 2112. (DWR 2004.)

AB3030, a 1992 amendment to the Water Code, provides a systematic procedure for local agencies to develop a groundwater management plan for underlying groundwater basins as defined in DWR Bulletin 118-75 and updates. Agencies adopting a plan have authority, contingent on receiving a majority of votes in a local election, to collect revenues for implementation of groundwater management measures. An AB3030 management plan for the Solano subbasin was adopted by the City of Vacaville and the Solano Irrigation District in February of 1995, and by the Maine Prairie Water District and RD 2068 in January of 1997 (DWR 2004).

This subbasin falls with the area included in the Solano-Yolo Coalition.

Water Quality

Groundwater within the Solano Subbasin is considered to be of generally good quality, and useable for both domestic and agricultural purposes. However, groundwater in some of the southwestern portion of the Sacramento Valley, which includes the Solano Subbasin, is not entirely suitable for human or agricultural use because of the presence of elevated levels of boron, fluoride, chloride, nitrate, and sulfate.

Chemical water types within the basin are variable and classified generally as magnesium bicarbonate in the central and northern areas, sodium bicarbonate in the southern and eastern areas, and calcium magnesium or magnesium calcium bicarbonate around and west of Dixon.

A USGS study (Evenson 1985) analyzed water quality in the Solano and Yolo Counties. Constituents that were measured include: dissolved solids, harness, chloride, fluoride, sulfate, nitrogen, arsenic, boron, iron, and manganese. Unless otherwise noted, the following is a summary of the findings from that report, as they pertain to the Solano Subbasin.

Dissolved Solids

TDS ranges from 250 to 500 mg/L in the northwest and eastern portion of the basin and are found at levels higher than 500 mg/L in the central and southern areas. Data from the DHS in 2000 (DWR 2004) shows the TDS minimum = 150 mg/L, maximum = 880 mg/L, average = 427 mg/L. Hardness, which is mainly a reflection of the amount of calcium and magnesium in water, is considered very high, with values generally greater than 180 mg/L. According to DHS data (DWR 2004), about one half of drinking water well samples taken between 1970 and 2000 analyzed for overall hardness measured above 200 mg/L, but rarely over 400 mg/L. High concentrations of bicarbonate, which cause precipitation of Ca and Mg carbonates, is found in the southern portion of the basin. (Hull 1984.)

Boron

Boron concentrations are less than 0.75 ppm except in the southern and southeastern basin where concentrations average between 0.75 and 2.0 ppm (more than 1.0 ppm will affect sensitive tree crops). Concentrations are high along the Sacramento River and seem to increase in a southwesterly direction.

Iron

Iron concentrations are generally low with respect to federal standards (MCL = 0.3 ppm) in the Solano subbasin. Iron concentrations increase toward the eastern side of the subbasin, from less than 0.02 ppm to greater than 0.05 ppm along the Sacramento River.

Manganese

Manganese concentrations increase from west to east with concentrations from 0.01 ppm to over 0.1 ppm found north of Rio Vista and east of the Solano-Yolo County line. Manganese is found at concentrations above the MCL of 0.05 ppm (as a secondary constituent) along the Sacramento River along the eastern portion of the subbasin. (DWR 2004.)

Arsenic

Arsenic concentrations are typically between 0.02 and 0.05 ppm, with the highest concentrations found along the southeastern margin of the basin. Although this is currently not considered problematic, there could be impacts if the MCL is lowered. The current MCL (as set by the EPA [2005]) for arsenic is 0.05 ppm. (DWR 2004.)

Chloride

Chloride concentrations are highest in the southwestern part of the subbasin, with values greater than 100 mg/L. The lowest levels exist in the eastern central and northwestern sections, with values generally below 25 mg/L. The MCL for chloride is 600 ppm. The EPA secondary standard for chloride is 250 mg/L. According to a study in Sacramento County (DWR 1974), the average chloride ion concentration in the Delta region was measured at 132 mg/L, with a range of 6 mg/L to 904 mg/L.

Fluoride

Fluoride concentrations are generally greater than 0.5 mg/L in the southwestern portion of the basin and less than 0.5 mg/L in the east and north. EPA optimum fluoride concentration for this area is 0.8 mg/L.

Sulfate

Sulfate concentrations are low over the study area with respect to the recommended limits. The highest concentrations are in the southern areas, with values greater than 50 ppm. The MCL for sulfate is 600 ppm.

Nitrogen

There were several domestic wells with nitrogen as nitrate concentrations above the EPA limit of 10 mg/L, ranging from 11 mg/L to 45 mg/L.

Pesticides

According to DPR (2004), there were 2 detections of DBCP (soil fumigant) and 1 detection of Diquat Dibromide (herbicide) in Sacramento County. For the period of 1985 to 2003 (DPR 2003), atrazine, bentazon were detected in Sacramento County, ACET, atrazine, DACT, DEA, diuron, norflurazon, prometon, and simazine were detected in Solano County, and atrazine, bentazon, and simazine were detected in Yolo County. The sampling locations and concentrations were not specified.

Summary of Significant Detections

Of the 71 public supply wells sampled by DWR, DHS and their cooperators (DWR 2004), 1 well had primary inorganics concentrations above the MCL, 8 wells of 96 sampled had nitrate concentrations above the MCL, 3 wells out of 56 sampled had pesticide concentrations above the MCL, 1 well of 57 sampled had VOC/SVOC concentrations above the MCL, and 17 wells of 71 sampled had secondary inorganics concentrations above the MCL.

Discharge Pathways and Sources of Contaminants

Discharge occurs as flow to the Sacramento River and other streams, and from evapotranspiration from vegetation. Irrigated agriculture appears to be a source of pesticide contamination.

Management Practices

An AB3030 management plan for the Solano Subbasin was adopted by the City of Vacaville and the Solano Irrigation District in February of 1995, and by the Maine Prairie Water District and RD 2068 in January of 1997.

Groundwater levels are monitored in the Solano Subbasin by DWR at 35 wells semi-annually and at 7 wells on a monthly basis; by Solano ID at 7 wells semi-annually and at 2 wells on a monthly basis; and by Reclamation at 60 wells semi-annually and at 12 wells on a monthly basis. DWR monitors for miscellaneous water quality parameters at 23 wells, and DHS and its cooperators monitor for Title 22 water quality parameters at 136 wells. We were unable to find any documentation of specific management practices for preventing degradation of groundwater quality.

Assessment of Data Adequacy and Need for Added Data

Available data indicates groundwater quality problems probably related to irrigated agriculture. These include pesticides, nitrates and salinity. There is inadequate information about specific land uses and management practices that have resulted in these water quality effects.

South American Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The South American groundwater subbasin is bound by the Sierra Nevada foothills on the east, the Sacramento River on the west, the American River on the north, and the Cosumnes and Mokelumne Rivers on the south. The subbasin is 388 mi^2 in size and is located entirely within Sacramento County.

The following description of the hydrogeology in the South American subbasin is taken from DWR Bulletin 118 (DWR 2004).

The South American subbasin aquifer system is comprised of continental deposits of Late Tertiary to Quaternary age. These deposits include younger alluvium (consisting of flood basin deposits, dredge tailings and Holocene stream channel deposits), older alluvium, and Miocene/Pliocene volcanics. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 2,500 feet along the western margin of the subbasin. The maximum combined thickness of all the younger alluvial units is about 100 feet. Calculated specific yield values range from about 5.4% in the flood basin deposits to 10% in the stream channel deposits.

The flood basin deposits occur along the western margin of the subbasin adjacent to the Sacramento River. They consist primarily of silts and clays, but along the western margin of the subbasin may be locally interbedded with stream channel deposits of the Sacramento River. The flood basin deposits are generally fine-grained, have low permeability, and generally yield low quantities of water to wells.

Dredge tailings are exposed primarily along the American River in the northeastern corner of the subbasin. They consist of windows of gravel, cobbles, boulders, sand, and silt resulting from the activities of gold dredging operations. The tailings are highly permeable, but well construction is complicated by the presence of cobbles and boulders.

The stream channel deposits include sediments deposited in the channels of active streams as well as overbank deposits of those streams, terraces, and local dredger tailings. They occur along the Sacramento, American, and Cosumnes Rivers and their major tributaries and consist primarily of unconsolidated silt, fine- to medium-grained sand, and gravel. Sand and gravel zones in the younger alluvium are highly permeable and yield significant quantities of water to wells.

The older alluvium deposits consist of loosely to moderately compacted sand, silt and gravel deposited in alluvial fans during the Pliocene and Pleistocene. A number of formational names have been assigned to the older alluvium, including the Modesto Formation, Riverbank Formation, Victor Formation, Laguna Formation, Arroyo Seco Gravels, South Fork Gravels, and Fair Oaks Formation. The older alluvial units are widely exposed between the Sierra Nevada foothills and overlying younger alluvial units near the axis of the Sacramento Valley. Thickness of the older alluvium is about 100–650 feet. It is moderately permeable. The calculated specific yield of these deposits is about 7%.

The Miocene/Pliocene volcanics consist of the Mehrten Formation, a sequence of fragmental volcanic rocks, which crops out in a discontinuous band along the eastern margin of the basin. It is composed of intervals of “black sands,” stream gravels, silt, and clay interbedded with intervals of dense tuff breccia. The sand and gravel intervals are highly permeable and wells completed in them can have high yields. The tuff breccia intervals act as confining layers. Thickness of the unit is between 200 and 1,200 feet.

Groundwater levels declined approximately 20 feet from the mid-1960s to about 1980. From 1980 through 1983 water levels recovered by about 10 feet and remained stable until the beginning of the 1987 through 1992 drought. From 1987 until 1995, water levels declined by about 15 feet. From 1995 to 2000 most water levels recovered by up to 20 feet leaving them generally higher than levels prior to the 1987 through 1992 drought. DWR (2004) estimated the specific yield to be 6.8% and the storage capacity (to a depth of 310 feet) to be 4.8 maf. The bounding rivers form groundwater flow divides in the shallow zone, but there is lateral groundwater flow between adjacent subbasins in the deeper zones.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (14-20 inches/year), irrigation infiltration, and stream infiltration. Average annual recharge for the period 1975-90 was estimated using a groundwater-flow model. Total recharge was 357,000 acre-feet, subsurface outflow was 29,700 acre-feet, pumpage for irrigation was 163,000 acre-feet, and pumpage for public supply was 68,000 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 2000. Agricultural land use accounts for about 26% of the subbasin, urban land use accounts for about 37% of the subbasin, and native land accounts for about 37% of the subbasin. Table 4-20 provides details of the land uses within the subbasin.

Table 4-20. Land Use in the South American Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	60	0.02
Deciduous Fruits and Nuts	2,990	1.20
Field Crops	16,300	6.70
Grain and Hay	6,170	2.50
Pasture	17,500	7.20
Rice	250	0.10
Truck, Nursery, and Berry Crops	4,430	1.60
Vineyards	12,100	5.00
Idle	1,430	0.60
Semiagricultural and Incidental	1,500	0.60
Subtotal	62,730	25.70
Urban		
Urban—unclassified	62,200	25.40
Urban Landscape	3,210	1.30
Urban Residential	7,160	2.90
Industrial	6,790	2.80
Commercial	730	0.30
Vacant	10,500	2.90
Subtotal	90,590	37.10
Native		
Native Vegetation	73,700	30.20
Barren and Wasteland	8,180	3.30
Riparian	5,180	2.10
Water	4,030	1.60
Subtotal	91,090	37.30
Total	**244,410**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The North American groundwater subbasin is within the Placer North Sacramento Subwatershed

The public agencies within the South American subbasin are: Arden Cordova Water Service, City of Folsom, City of Sacramento, County of Sacramento, Elk Grove Water Works, Florin County WD, Fruitridge Vista, Mather Air Force

Base, North Delta Water Agency, Omochumne-Hartnell WD, Rancho Murieta CSD, Tokay Park, Sacramento County WMD, and Sacramento County WMD-Zone 40 (DWR 2004).

The SGA is a joint powers authority formed to manage the North Area Groundwater Basin, which is north of the South American subbasin. The Regional Water Authority (RWA) is a joint powers authority that serves and represents the interests of 21 water providers in the greater Sacramento, Placer and El Dorado County region.

The Sacramento Metropolitan urban is partly located within the subbasin including the cities of Sacramento, Rancho Cordova, Folsom, and Elk Grove.

This subbasin falls with the area included in the Placer-North Sacramento, Amador-Sacramento, and Solano-Yolo Coalitions.

Water Quality

Groundwater is typically a calcium magnesium bicarbonate or magnesium calcium bicarbonate. Other minor groundwater types include a sodium calcium bicarbonate or calcium sodium bicarbonate in the vicinity of Elk Grove and a magnesium sodium bicarbonate or sodium magnesium bicarbonate near the confluence of the Sacramento and American rivers (Bertoldi et al. 1991). TDS ranges from 24 to 581 mg/L and averages 221 mg/L based on 462 records (Montgomery Watson 1993).

Sites with significant groundwater contamination exist within the subbasin. These sites include Aerojet, Mather Field, and the Sacramento Army Depot, the Kiefer Boulevard Landfill, an abandoned Pacific Gas and Electric Company (PG&E) site near Old Sacramento, and the Southern Pacific and Union Pacific Rail Yards in downtown Sacramento.

Discharge Pathways and Sources of Contaminants

Natural, agricultural, and urban land use practices affect groundwater quality in the South American basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology, and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the South American subbasin is chemically oxidizing. This results in lower concentrations of manganese and iron and the presence of nitrate and sulfate. Agricultural processes include use of fertilizers and pesticides and the evaporation of irrigation water. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

The available data for the Southeastern Sacramento Valley, an area that includes the South American subbasin, show that 8 of the 31 wells studied by Dawson (2001b) were impacted by nitrate concentrations above 3 mg/L.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The groundwater in the South American subbasin is mostly calcium magnesium bicarbonate or magnesium calcium bicarbonate. Although some localized areas of sodium calcium bicarbonate or calcium sodium bicarbonate and magnesium sodium bicarbonate or sodium magnesium bicarbonate exist. The high amount of sodium and chloride in some wells may be due to natural or man-made causes.

Two processes appear to primarily affect groundwater salinity in the North American subbasin. The first is evaporation of irrigation water and shallow groundwater. The second is mixing of naturally occurring groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a).

Pesticides

Pesticides were detected in three of the five wells in a study of the Southeast Sacramento Valley (Dawson 2001b). All concentrations were below the drinking water limits.

The most common pesticides detected in Dawson's (2001b) 1996 study of the Southeastern Sacramento Valley were bentazon, simazine, atrazine, bromacil and tebuthiuron. The major uses for atrazine, bromacil, and tebuthiuron are for weed control in right-of-way areas and for landscape maintenance. Simazine is used for weed control in right-of-way areas and for landscape maintenance, and also on many crops grown in the study area, including nut and fruit orchards.

Trace Elements

The chemistry of geology formations in the South American subbasin influences the concentrations of trace elements. In a study of the Southeastern Sacramento Valley (Dawson 2001b), which includes part of the South American subbasin, drinking water standards were exceeded for five inorganic constituents: chloride, boron, iron, manganese, and arsenic.

Dawson (2001b) presented evidence that, within the Southeastern Sacramento Valley, the concentration of arsenic is related to the dissolved oxygen concentration (or redox condition) of the groundwater. She found that as the concentration of dissolved oxygen increases, the arsenic concentrations decrease.

The presence of trace constituents in groundwater in the South American Subbasin do not appear to be related to irrigated agriculture.

Volatile Organic Compounds

VOCs have many different uses including pesticides gasoline, degreasers, solvents, and refrigerants. Some VOCs are byproducts of the chlorination of drinking water. VOCs were detected in two of the five wells in the South American (Dawson 2001b). The VOCs found in the wells are consistent with the land use surrounding each well. Those detected in agricultural areas were VOCs found in pesticides or gasoline while those detected in urban areas were VOCs associated with landscape maintenance, pet control, right-of-way weed control, gasoline, industrial chemicals and chlorinated drinking water. A Superfund site is located in the South American basin and 8 VOCs were detected in the well on that particular site. It is currently undergoing remediation.

Management Practices

We found no documentation of management practices affecting groundwater quality.

Assessment of Data Adequacy and Need for Added Data

Data from USGS and DWR provide somewhat limited picture of groundwater quality in the North American subbasin in that there is not extensive areal coverage for groundwater quality. However, the available data indicate key issues related to human influence on groundwater including fertilizers (containing nitrates), pesticides, dissolved solids and volatile organic compounds.

South Yuba Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The South Yuba subbasin is bounded on the north by the Yuba River, on the west by the Feather River, on the south by the Bear River, and on the east by the Sierra Nevada foothills. The subbasin is 104,400 acres (163 mi^2) in size and is located entirely within Yuba County.

The following description of the hydrogeology in the South Yuba subbasin is taken from DWR Bulletin 118 (DWR 2004).

The South Yuba Subbasin aquifer system is comprised of continental deposits of Quaternary (Recent) to Late Tertiary (Miocene) age. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 1,400 feet along the western margin of the basin. The base of the aquifer system overlies the Pre-Tertiary metamorphosed igneous and sedimentary rocks of the Sierra Nevada block.

Holocene Dredge deposits occur along the Yuba and Bear Rivers within the eastern region of the South Yuba Groundwater subbasin. The coarse gravels and cobbles can be up to 125 feet thick and are highly permeable.

Holocene Stream Channel and Floodplain deposits occur as coarse sand and gravels along present stream channels of the Yuba, Feather, and Bear Rivers. Coarser grained materials occur near streams with thicknesses up to 110 feet. Both grain size and thickness decrease with increased distance from streams. These deposits are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Well yields are reported in the range of 2,000 to 4,000 gpm.

The Pleistocene Victor Formation lies unconformably above the Laguna Formation. The majority of the formation occurs as alluvium throughout the North Yuba Groundwater subbasin, but floodplain deposits are present along stream channels above the alluvium.

Pleistocene Floodplain deposits occur as gravelly sand, silt, and clay from flood events along the Feather River and its tributaries. This unit overlies the Older Alluvium, underlies Quaternary Deposits, and ranges in thickness from 5 to 15 feet. These deposits provide a good medium for groundwater recharge, provided the groundwater can pass the lower contact with the Older Alluvium.

Pleistocene Alluvium occurs at over 50% of the basin surface and at least 60% of its irrigated agricultural lands. Its thickness is highly variable due to its lower contact with the Laguna Formation. The Older Alluvium is comprised of Sierran alluvial fan deposits of loosely compacted silt, sand, and gravel with lesser amounts of clay deposits. The deposits occur as lenticular beds with decreasing thickness and grain size with increasing distance from the Yuba River and the foothills. Hardpan and claypan soils have developed to form an impermeable surface, but below this the Older Alluvium is moderately permeable and provides for most of the groundwater from domestic and shallow irrigation wells. Wells in the older alluvium have yields up to 1,000 gpm.

The Pliocene Laguna Formation is the most extensive water-bearing unit within the South Yuba Groundwater subbasin. The formation is comprised of reddish to yellowish or brown silt to sandy silt with abundant clay and minor lenticular gravel beds. It overlies the Mehrten Formation and occurs at the surface intermittently at the east end of the basin. The continental deposits of the Laguna dip to the west beneath the Victor Formation and range in thickness from 400 feet near the Yuba River up to 1,000 feet in the southwest portion of the county. Although the occurrence of thin sand and gravel zones is common, many of them have reduced permeability due to cementation. This coupled with its fine-grained character, leads to an overall low permeability for the Laguna Formation. Most of the groundwater produced from wells in the Laguna comes from overlying units.

The Miocene-Pliocene Mehrten Formation is a sequence of volcanic rocks of late Miocene through middle Pliocene age. Surficial exposures are limited to a few square miles in the northeast corner of the basin and thickness varies from 200 feet near the eastern margin of the basin to 500 feet near the Feather River. The Mehrten Formation is composed of two distinct units. One unit occurs as intervals of gray to black, well-sorted fluvial andesitic sand (up to 20 feet thick), with andesitic stream gravel lenses and brown to blue clay and silt beds. These sand intervals are highly permeable and wells completed in them can produce high yields. The second unit is an andesitic tuff-breccia that acts as a confining layer between sand intervals.

As early as 1960 groundwater levels showed a well-developed cone of depression beneath the South Yuba basin. Water levels in the center of the cone of depression were just below sea level. Nearly all water levels were well below adjacent river levels on the Bear, Feather, and Yuba Rivers. Groundwater conditions in 1984 reflect a continued reliance on groundwater pumping in the South Yuba Basin. Water levels in the center of the South Yuba cone of depression had fallen to 30 feet below sea level. The water level contours adjacent to the Bear and Yuba Rivers indicated a large gradient and seepage from the rivers. By 1990, water levels in the South Yuba Basin cone of depression rose to 10 feet above sea level. The rise in water levels was due to increasing surface water irrigation supplies and reduced groundwater pumping. Current DWR records indicate groundwater levels continue to increase.

Groundwater storage capacity was estimated to be 1,090,000 acre-feet. This estimate was based on an area of 88,700 acres, an average specific yield of 6.9%, and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from precipitation (20-24 inches/year), irrigation infiltration, and stream infiltration. Stream channel and floodplain deposits present along the Yuba River, Feather River, and Honcut Creek are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Previous DWR unpublished studies have estimated natural and applied recharge. DWR has also estimated urban and agriculture extractions and subsurface outflow. Basin inflows include natural recharge of 53,700 acre-feet, and applied water recharge of 26,000 acre-feet. Outflows include urban extraction of 6,000 acre-feet, agricultural extraction of 93,400 acre-feet, and subsurface outflow of 4,900 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1995. Agricultural land use accounts for about 50% of the subbasin, urban land use accounts for about 9% of the subbasin, and native land accounts for about 41% of the subbasin. Table 4-21 provides details of the land uses within the subbasin.

Table 4-21. Land Use in the South Yuba Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	140	0.10
Deciduous Fruits and Nuts	20,600	19.70
Field Crops	1,410	1.30
Grain and Hay	1,100	1.10
Pasture	9,140	8.70
Rice	16,900	16.20
Truck, Nursery, and Berry Crops	430	0.40
Idle	2,300	2.20
Semiagricultural and Incidental	720	0.70
Subtotal	52,740	50.40
Urban		
Urban—unclassified	4,100	25.40
Urban Landscape	420	1.30
Urban Residential	600	2.90
Industrial	1,230	2.80
Commercial	100	0.30
Vacant	2,540	2.90
Subtotal	8,990	8.60
Native		
Native Vegetation	35,400	30.20
Barren and Wasteland	3,900	3.30
Riparian	2,140	2.10
Water	1,140	1.60
Subtotal	42,580	41.00
Total	**104,310**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The South Yuba groundwater subbasin is within the Butte Sutter Yuba Subwatershed. The public agencies within the South Yuba subbasin are: Yuba County Water Agency, Brophy Water District, Linda County Water District, Wheatland Water District, South Yuba Water District, Plumas Water District, RD 794 (DWR 2004).

The South Yuba Water District completed an AB3030 plan in 1998. No major urban areas exist within the subbasin. The cities of Marysville and Yuba City are located at the northwestern boundary of the subbasin. This subbasin falls with the area included in the Butte-Sutter-Yuba Coalition.

Water Quality

The generally good water quality characteristics are apparent in the overall salinity of groundwater in the subbasin. In general, TDS concentrations in the subbasin are below 500 mg/L throughout the entire basin. DWR maintains data for 27 water quality wells in the South Yuba Subbasin. Data collected from these wells indicate a TDS range of 141 to 686 mg/L and a median of 224mg/L. The primary water chemistry in the area indicates calcium magnesium bicarbonate or magnesium calcium bicarbonate groundwater. Some magnesium bicarbonate can be found in the northwest portion of the basin.

Groundwater quality issues in the South Yuba subbasin include excess nutrients, trace elements, salinity and pesticides. Pesticides occur in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring but some are elevated to levels above the national limits. Nitrates are elevated due to on-site sewage systems. However, there is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the South Yuba subbasin. Tables 4-22 and 4-23 summarize the available data.

Table 4-22. Water Quality in the South Yuba Subbasin

Constituent of Concern	Available Information about Groundwater Concentrations for South Yuba Subbasin
Nutrients	Median nitrate concentrations for the southeastern Sacramento Valley, including South Yuba subbasin was 1.4 mg/L. Only one well in the study area exceeded drinking water standards.
Pesticides (insecticides and herbicides) and degradation products	DPR verified bentazon detection in 10 wells with in Yuba County from 1996 to 2003. Pesticides detected in one domestic well in 1996 study, but concentration was below drinking water standards.
Salt—primarily as electrical conductivity and total dissolved solids.	141 to 686 mg/L, median is 224mg/L.
Trace elements	High concentration of arsenic (naturally occurring) in some areas.
Organic carbon and disinfection byproduct precursors	No available data.
Microorganisms	No available data.
Volatile organic compounds	VOCs were detected in 2 wells in the South Yuba subbasin. Concentrations below drinking water standards.

Notes:
mg/L = milligrams per liter.
Sources: Dawson 2001b; DPR 2004.

Table 4-23. Concentrations of Constituents of Concern Detected in the Southeastern Sacramento Valley Aquifers, including the South Yuba Subbasin

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
Nutrients	Nitrate—Ammonia as N	0.02–0.11 mg/L	30 (HAL)
	Nitrate as N	0.06–12mg/L	10 (MCL[a])
	Nitrite as N	0.01–0.01 mg/L	1 (MCL[a])
	Orthophosphate, as P	0.03–0.4 mg/L	
	Phosphorus, as P	0.03–0.45 mg/L	
Pesticides (insecticides and herbicides) and degradation products*	Atrazine	0.001–0.001 µg/L	3 (MCL[a])
	Bentazon	*0.02–1.3* µg/L	18 (MCL[b])
	Bromacil	0.34 µg/L (one detection)	90 (HAL)
	Desethyl atrazine	*0.004–0.044* µg/L	
	Simazine	0.006–0.077 µg/L	4 (MCL[a])
	Tebuthiuron	0.32 µg/L (one detection)	500 (HAL)
Salt—primarily as electrical conductivity and total dissolved solids.		141–686 mg/L, median is 224mg/L (DWR 2004) 134–1,750 mg/L, median is 258 mg/L	500 (SMCL)

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
Inorganic Constituents			EPA Standard, 2000
	Arsenic	1–46 µg/L	50 (MCL[a])
	Bicarbonate	67–413 mg/L	
	Boron	12–110 µg/L	600 (HAL)
	Bromide	0.02–12 mg/L	
	Calcium	10–210 mg/L	
	Chloride	2.0–620 mg/L	250 (SMCL)
	Fluoride	0.1–0.3 µg/L	4 (MCL[a])
	Iron Fe	3–1,600 µg/L	300 (SMCL)
	Magnesium	5.0–100 mg/L	
	Manganese	1–870 µg/L	50 (SMCL)
	Potassium	0.40–4.1 mg/L	
	Silica	24–86 mg/L	
	Sodium	5.7–120 mg/L	
	Sulfate	1.0–130 mg/L	250 (SMCL)
	Total Hardness as $CaCO_3$	48 (soft)–940 (very hard) mg/L, median is 135 mg/L	
Organic carbon and disinfection byproduct precursors	DOC	0.2–0.7 mg/L, median 0.3 mg/L	
Volatile organic compounds*	1,1-Dichloroethane	*0.02*–0.04 µg/L	
	1,2,4-Trimethylbenzene	*0.01*–0.02 µg/L	
	1,2-Dichloroethane	0.19 µg/L	0.5 (MCL[a])
	Bromodichloromethane	*0.03* µg/L	100 (MCL[a])
	cis-1,2-Dichloroethene	0.43 µg/L	6 (MCL[b])
	Dichlorodifluoromethane	*0.04*–0.29 µg/L	1000 (HAL)
	Methyl tert-butyl ether	*0.06* µg/L	20 (HAL)
	Styrene	*0.06* µg/L	100 (MCL[a])
	Tetrachloroethene	0.58–0.97 µg/L	5 (MCL[a])
	Tetrachloromethane	1.2 µg/L	0.5 (MCL[b])
	Trichloroethene	*0.01*–5.5 µg/L	5 (MCL[a])
	Trichlorofluoromethane	*0.04* µg/L	150 (MCL[b])
	Trichloromethane	*0.03*–1.1 µg/L	100 (MCL[a])

Notes:
* Numbers in *italics* are estimates.
MCL[a] = Maximum Contaminant Level set by EPA (2005).
MCL[b] = Maximum Contaminant Level set by DWR.
µg/l = micrograms per liter.
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).
HAL = Health Advisory Level set by EPA (2005).
Source: Dawson 2001b, unless otherwise indicated.

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the South Yuba basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the South Yuba subbasin is chemically oxidizing. This results in lower concentrations of manganese and iron and the presence of nitrate and sulfate. Groundwater from the South Yuba subbasin discharges to wells and streams. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. There are naturally occurring nitrates in some formations of the Sacramento Valley. However, most nitrogen species that occur above 3 mg/L signify contamination introduced into the groundwater via human activates such as agriculture and urbanized development. At this time, the data available for the Southeastern Sacramento Valley, an area that includes the South Yuba subbasin, show that 8 of the 31 wells studied by Dawson (2001b) were impacted by nitrate concentrations above 3 mg/L.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The eastern alluvial plains, in which South Yuba subbasin is located, contain magnesium-calcium-carbonate groundwater. Two processes appear to primarily affect groundwater salinity in the South Yuba subbasin: evaporation of irrigation water followed by its percolation and shallow groundwater mixing with naturally occurring groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a). Using isotope data, Dawson (2001a) presented evidence that partial evaporation as indicated by the isotope data accounted for some of the measured increase in salinity among shallow groundwater samples. The South Yuba subbasin doe not appear to be adversely affected by saline groundwater, the median concentration of dissolved solids is 224 mg/L.

Pesticides

Rice pesticides Molinate, Thiobencarb and Carbofuran were detected in 7, 3, and 4 of the 28 wells sampled during the 1997 study by the USGS (Dawson 2001a). The most prevalent pesticide detected in groundwater was bentazon. This chemical was used in rice fields until it was suspended in 1989 and officially banned in 1992. Its presence in groundwater in studied completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Pesticides were present in most wells in the rice growing areas of the Sacramento Valley in the 1997 study, but no wells in the South Yuba Subbasin were sampled at that time. In a 1996 study (Dawson 2001a), 5 pesticides (bentazon, simazine, atrazine, bromacil, and tebuthiuron) and one degradation product of atrazine (desethyl atrazine) were detected in the southeastern Sacramento Valley; of those detections, one was found in the South Yuba subbasin. This pesticide was present in a domestic well at concentrations below the drinking water limits.

The major uses for atrazine, bromacil, and tebuthiuron are for weed control in right-of-way areas and for landscape maintenance. Simazine is used for weed control in right-of-way areas and for landscape maintenance, and also on many crops grown in the study area, including nut and fruit orchards.

Trace Elements

The chemistry of geology formations in the South Yuba subbasin influences the concentrations of trace elements. Dawson (2001a) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of silica were significantly higher in the eastern alluvial plain, which contains the South Yuba subbasin. Elevated concentrations of potassium were also present. The eastern alluvial plains showed higher concentration of arsenic than in the western alluvial plain. Dawson (2001b) presented evidence that the presence and concentration of arsenic is related to the dissolved oxygen concentration (or redox condition) of the groundwater. As the concentration of dissolved oxygen increases, the arsenic concentrations decrease. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Organic Carbon and DPBs

There is some evidence that recent changes in management practices in rice may result in higher dissolved organic carbon (DOC) concentrations in deep percolation water. However, there is no DOC data available for South Yuba subbasin.

Volatile Organic Compounds

VOCs have many different uses including pesticides gasoline, degreasers, solvents, and refrigerants. Some VOCs are byproducts of the chlorination of drinking water. VOCs were detected in two wells in the South Yuba subbasin in the 1996 study by Dawson (2001b). The VOCs found in the wells were consistent with the agricultural land uses in the subbasin in that they were VOCs found in pesticides or gasoline.

Management Practices

Rice field management practices began in 1983, to protect surface waters quality. Rice field irrigation water began to be held in the fields after the application of pesticides to allow more time for degradation (Dawson 2001a; Holden 1986). More irrigation water recycling was also encouraged at this time. These practices may have caused more contamination to percolate downward to groundwater. Rice growing, in general, provides opportunity for mobile pesticides to move to groundwater due to large volumes of groundwater recharge.

Assessment of Data Adequacy and Need for Added Data

Data from USGS, DPR, and DWR provide somewhat limited picture of groundwater quality in the South Yuba subbasin in that there is not extensive areal coverage for groundwater quality. However, the available data indicate key issues related to pesticides and possibly VOCs.

Sutter Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography, and Hydrogeology

The Sutter subbasin aquifer boundaries are the confluence of Butte Creek and the Sacramento River and Sutter Buttes on the north, the confluence of the Sacramento River and the Sutter Bypass on the south, the Sacramento River on the west, and the Feather River on the east. The aquifer system is 366 mi^2 in size and is located in Sutter County.

The following description of the hydrogeology in the Sutter subbasin is taken from DWR Bulletin 118 (2004). The geologic formations of the Sutter Subbasin include pre-Cretaceous metamorphic and igneous rocks of the Sierra Nevada block, which extends beneath the valley fill overlain principally by Tertiary sedimentary formations derived from these and other rocks that are exposed in the Sierra Nevada to the east. The sedimentary rocks are of both marine and continental origin and are frequently interbedded with tuff-breccias. Volcanic rocks are also represented in the area in and around Sutter Buttes, which are erosional remnants of an extinct Pliocene volcano. Only the sedimentary rocks can be considered as being water bearing to any appreciable degree.

The Sutter Subbasin aquifer system is comprised of continental deposits of Quaternary (Recent) to Late Tertiary (Miocene) age. The cumulative thickness of these deposits increases from a few hundred feet near the Sierra Nevada foothills on the east to over 2,000 feet along the western margin of the basin (DWR 1978).

The Holocene stream channel and floodplain deposits occur as coarse sand and gravel along present stream channels of the Yuba, Feather, and Sacramento Rivers. Coarser grained materials occur near streams with thicknesses up to about 100 feet. Both grain size and thickness decrease with increased distance from streams. These deposits are highly permeable and provide for large amounts of groundwater recharge within the subbasin. Well yields are reported in the range of 2,000 to 4,000 gpm.

The Pleistocene floodplain deposits occur as gravelly sand, silt, and clay from flood events along the Feather River and its tributaries. This unit overlies the Older Alluvium, underlies Quaternary Deposits, and ranges in thickness up to about 100 feet. These deposits provide a good medium for groundwater recharge, provided the groundwater can pass the lower contact with the Older Alluvium.

The Pleistocene Victor Formation (Old Alluvium) ranges in thickness up to about 100 feet. This formation is comprised of Sierran alluvial fan deposits of loosely compacted silt, sand, and gravel with lesser amounts of clay deposits. The deposits occur as lenticular beds with decreasing thickness and grain size with increasing distance from the Yuba River and the foothills. Hardpan and claypan soils have developed to form an impermeable surface, but below this the Older Alluvium is moderately permeable and provides for most of the groundwater from domestic and shallow irrigation wells. Wells in the older alluvium have yields up to 1,000 gpm.

The Pliocene Laguna Formation consists of compacted layers of sand, silt, and clay with hardpan in surface soils. In the subsurface, this formation has a thickness of about 300 feet but is estimated to be up to 1,000 feet along the valley axis. Although the occurrence of thin sand and gravel zones is common, many of them have reduced permeability due to cementation. This coupled with its fine-grained character, leads to an overall low permeability for the Laguna Formation. This formation is an important source of water for southeastern Sacramento Valley.

The Miocene - Pliocene Mehrten Formation is a sequence of volcanic and volcaniclastic rocks of late Miocene through middle Pliocene age. The formation ranges in thickness from about 200 feet to over 1,000 feet along the axis of the valley. The Mehrten Formation is composed of two distinct units: One unit occurs as intervals of gray to black, well-sorted fluvial andesitic sand (up to 20 feet thick), with andesitic stream gravel lenses and brown to blue clay and silt beds. These sand intervals are highly permeable and wells completed in them can produce high yields. The second unit is an andesitic tuff-breccia that acts as a confining layer between sand intervals. This formation is also an important source of water for southeastern Sacramento Valley.

The Oligocene - Miocene Valley Springs Formation consists of gravel, sand, silt, and clay, siltstone, and tuffaceous beds which all contain rhyolitic material. This unit is reported to have a maximum thickness of about 200 feet. The Valley Springs Formation deposits typically have low permeabilities and therefore, yield only small quantities of water to wells.

Groundwater levels in the Sutter subbasin tend to remain constant. In Bulletin 188-6 (DWR 1978) average annual groundwater recharge was documented to exceed average discharge in the Sutter subbasin. DWR (2004) estimated the storage capacity (200-foot depth) to be 5 maf. The depth to the aquifer in most locations is about 10 feet below ground surface.

Major Sources of Recharge

Stream infiltration, irrigation and precipitation are the principal sources of recharge to the Sutter subbasin. The Sacramento and Feather Rivers provide recharge to the aquifer as well as irrigation from agricultural fields. Annual precipitation ranges from 17 to 21 inches with rainfall increasing across the valley from the southeast to the northwest (DWR 2004). Twenty-three percent of the Sutter subbasin is used for rice cultivation where the fields are typically flooded for 6 months each year. DWR (2004) estimated inflows to the subbasin from natural recharge to be 40,000 acre-feet and from applied water to be 22,100 acre-feet.

Groundwater discharge occurs as evapotranspiration, and pumpage. DWR (2004) estimated outflows include urban extraction at 3,900 acre-feet and agricultural extraction at 171,400 acre-feet.

Land Use

The Sutter subbasin is primarily utilized for fruit orchards, rice cultivation and vegetable crops. There is a very little urban land use in the Sutter subbasin. Table 4-24 provides details on the distribution of land use throughout the subbasin.

Table 4-24. Land Uses in the Sutter Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Citrus and Subtropical	187	0.08
Deciduous Fruits and Nuts	45,556	19.44
Field Crops	38,226	16.31
Grain and Hay	11,676	4.98
Idle	3,400	1.45
Pasture	3,283	1.40
Rice	54,015	23.05
Semiagricultural and Incidental	1,744	0.74
Truck, Nursery, and Berry Crops	32,084	13.69
Vineyards	4	0.002
Subtotal	190,176	81.14
Urban		
Urban—unclassified	7,045	3.01
Commercial	209	0.09
Industrial	1,135	0.48
Urban Landscape	415	0.18
Urban Residential	1,412	0.60
Vacant	1,351	0.58
Subtotal	11,568	4.94
Native		
Riparian	8,507	3.63
Native Vegetation	19,570	8.35
Water	4,559	1.95
Subtotal	32,636	13.92
Total	**234,380**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The public entities within the Sutter subbasin aquifer system are: Sutter Mutual Water Company, Meridian Farms Water Company, Butte Slough Irrigation Company, Tisdale Irrigation District, Pelger Mutual Water Company, Sutter Extension Water District, Feather Water District, Oswald Water District, Tudor Mutual Water Company, Garden Highway Municipal Water Company (DWR 2004).

The private entities within the Sutter subbasin aquifer system are: Garden Highway Municipal Water Company, RD 70, RD 1660, RD 1500 (DWR 2004).

In 1992 AB3030 provided a systematic procedure for an existing local agency to develop a formal groundwater management plan. RD 1500, South Sutter Water District and Sutter Extension Water District have adopted groundwater management plans in accordance with AB3030.

This subbasin falls with the area included in the Placer-North Sacramento and Butte-Sutter-Yuba Coalitions.

Water Quality

Groundwater Quality issues in the Sutter subbasin include excess nutrients, dissolved solids, trace elements, and pesticides. Dissolved solids are elevated in localized areas throughout the subbasin and pesticides are persistent in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring but some are elevated to levels above the national limits. Nitrates are elevated due to on-site sewage systems. However, there is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the Sutter subbasin. Tables 4-25 and 4-26 summarize the available data.

Table 4-25. Water Quality in the Sutter Subbasin

Constituent of Concern	Available Information about groundwater concentrations for Sutter Subbasin
Nutrients	Nitrate concentrations greater than 45mg/L in localized areas (PMC 1996).
Pesticides (insecticides and herbicides) and degradation products	Bentazon and DBCP are present in groundwater (PMC 1996).
	Dawson (2001a) reported pesticides detections in 89% of the 28 wells sampled, 82% of which were pesticides used on rice fields: bentazon, carbofuran, molinate, and thiobencarb. Bentazon was found in 71% of the wells.
	Seven verified detections of simazine and 2 of bentazon in Sutter County from 1986 to 2003 (DPR 2004).
Salt—primarily as electrical conductivity and total dissolved solids.	Dissolved solids exceed SMCL in 3 wells.
	Chloride exceeds 250 mg/L in a large area of the southeast section of the subbasin (PMC 1996).
	High TDS concentrations measured in shallow groundwater in rice growing areas. One well, south of Sutter Buttes, had a concentration of 8,730 mg/L of dissolved solids. (Dawson 2001a).
Trace elements	High concentrations of arsenic, boron, chloride, iron and manganese. Manganese exceeds 50 µg/L in southern half and eastern boundary of Sutter County. Iron exceeds 300 µg/L in localized areas. Arsenic exceeds 10 µg/L to the south and east of Sutter Buttes and in other localized areas. Arsenic exceeds 50 µg/L in localized areas. (PMC 1996).
Microorganisms	No available data.
Volatile organic compounds	VOCs were detected in 12 of the 31 wells studied by Dawson (2001b).

Notes:

mg/L = milligrams per liter.

Sources: Dawson 2001b; Dawson 2001a; and PMC 1996.

Table 4-26. Concentrations of Constituents of Concern Detected in the Sutter Subbasin

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
Nutrients	Nitrate—Ammonia as N	0.02–0.46 mg/L	30 (HAL)
	Nitrate as N	0.06–12mg/L >50 mg/L (PMC 1996)	10 (MCL[a])
	Nitrite as N	0.01–0.01 mg/L	1 (MCL[a])
	Orthophosphate, as P	0.01–0.4 mg/L	
	Phosphorus, as P	0.03–0.45 mg/L	
	Dissolved organic carbon, as C	0.2–6.8 mg/L	
Pesticides (insecticides and herbicides) and degradation products*	Atrazine	0.001–0.026 µg/L	3 (MCL[a])
	Bentazon	*0.02–7.8* µg/L	18 (MCL[b])
	Bromacil	0.34 µg/L (one detection)	90 (HAL)
	Desethyl atrazine	*0.004–0.044* µg/L	
	Simazine	0.006–0.077 µg/L	4 (MCL[a])
	Tebuthiuron	0.32 µg/L (one detection)	500 (HAL)
Salt—primarily as electrical conductivity and total dissolved solids.		133–1,660 mg/L, (DWR 2004)	500 (SMCL)
		134–1,750 (Dawson 2001b)	
Inorganic Constituents			EPA Standard, 2000
	Arsenic	1–46 µg/L	50 (MCL[a])
	Bicarbonate	67–710 mg/L	
	Boron	12–110 µg/L	600 (HAL)
	Bromide	0.02–12 mg/L	
	Calcium	10–810 mg/L	
	Chloride	2.0–4,800 mg/L	250 (SMCL)
	Fluoride	0.1–1.8 µg/L	4 (MCL[a])
	Iron Fe	3–1,600 µg/L	300 (SMCL)
	Magnesium	5.0–480 mg/L	
	Manganese	1–870 µg/L	50 (SMCL)
	Potassium	0.40–9 mg/L	
	Silica	16–86 mg/L	
	Sodium	5.7–1,300 mg/L	
	Sulfate	1.0–1,500 mg/L	250 (SMCL)
	Total Hardness as $CaCO_3$	48 (soft)–940 mg/L (very hard), median is 135 mg/L	
Organic carbon and disinfection byproduct precursors	DOC	0.2–0.7 mg/L, median 0.3 mg/L	
Volatile organic compounds*	1,1-Dichloroethane	*0.02*–0.04 µg/L	
	1,2,4-Trimethylbenzene	*0.01*–0.02 µg/L	
	1,2-Dichloroethane	0.19 µg/L	0.5 (MCL[a])
	Bromodichloromethane	*0.03* µg/L	100 (MCL[a])
	cis-1,2-Dichloroethene	0.43 µg/L	6 (MCL[b])

Constituent Type	Constituent of Concern	Concentration Ranges	Drinking Water Standards
	Dichlorodifluoromethane	*0.04*–0.29 µg/L	1000 (HAL)
	Methyl tert-butyl ether	*0.06* µg/L	20 (HAL)
	Styrene	*0.06* µg/L	100 (MCL[a])
	Tetrachloroethene	0.58–0.97 µg/L	5 (MCL[a])
	Tetrachloromethane	1.2 µg/L	0.5 (MCL[b])
	Trichloroethene	*0.01*–5.5 µg/L	5 (MCL[a])
	Trichlorofluoromethane	*0.04* µg/L	150 (MCL[b])
	Trichloromethane	*0.03*–1.1 µg/L	100 (MCL[a])

Notes:
* Numbers in *italics* are estimates.
MCL[a] = Maximum Contaminant Level set by EPA (2005).
MCL[b] = Maximum Contaminant Level set by DWR.
µg/l = micrograms per liter.
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).
HAL = Health Advisory Level set by EPA (2005).
Source: Dawson 2001a, 2001b, unless otherwise indicated.

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the Sutter basin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the Sutter subbasin is anoxic and chemically reducing. This results in high concentrations of manganese and iron and the presence of ammonia and phosphorus. In some areas of the subbasin, naturally occurring highly saline groundwater is present at varying depths and can influence the water quality of production wells. Agricultural processes include use of fertilizers and pesticides and the evaporation of irrigation water. Groundwater from the Sutter subbasin discharges to wells and streams. Specific processes affecting constituents of concern are discussed in some detail below.

Nutrients

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. There are naturally occurring nitrates in some formations of the Sacramento Valley. However, most nitrogen species that occur above 3 mg/L signify contamination introduced into the groundwater via human activates such as agriculture and urbanized development. At this time, the data available for the Southeastern Sacramento Valley, an area that includes the Sutter subbasin, show that 8 of the 31 wells studied by Dawson (2001b) were impacted by nitrate concentrations above 3 mg/L.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The central flood plains, in which Sutter subbasin is located, contain a mixture of magnesium-calcium-carbonate groundwater (common in the eastern alluvial plain) and sodium-sulfate groundwater (common in the western alluvial plain. Two processes appear to primarily affect groundwater salinity in the Sutter subbasin: evaporation of irrigation water and shallow groundwater and mixing of naturally occurring saline groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001b). Using isotope data, Dawson (2001a) presented evidence that partial evaporation as indicated by the isotope data accounted for some of the measured increase in salinity among shallow groundwater samples.

One well located south of the Sutter Buttes yields groundwater of the sodium-calcium type. This same well had a concentration of 8,730 mg/L dissolved solids in the 1997 study by Dawson (2001a).

Pesticides

Rice pesticides Molinate, Thiobencarb and Carbofuran were detected in 7, 3, and 4 of the 28 wells sampled during the 1997 study by the USGS (Dawson 2001a). The most prevalent pesticide detected in groundwater was bentazon. This chemical was used in rice fields until it was suspended in 1989 and officially banned in 1992. Its presence in groundwater in studied completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Although present in most wells in the rice growing areas of the Sacramento Valley in the 1997 study, pesticide concentrations were only detected in one well in the Sutter subbasin in the 1996 study (Dawson 2001b). This well was located adjacent to and southeast of the Sutter Buttes. Two different pesticides were present in this domestic well at concentrations below the drinking water limits.

Trace Elements

The chemistry of geology formations in the Sutter subbasin influences the concentrations of trace elements. Dawson (2001a) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of silica were significantly higher in the eastern alluvial plain, which contains part of the Sutter subbasin. Concentrations of arsenic and potassium were significantly higher in the central flood basins, which are also part of the Sutter subbasin. Dawson (2001b) presented evidence that the presence and concentration of arsenic is related to the dissolved oxygen concentration (or redox condition) of the groundwater. As the concentration of dissolved oxygen increases, the arsenic concentrations decrease. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Management Practices

We were unable to find documentation for specific practices for prevention of groundwater quality degradation. Rice field management practices began in 1983, to protect surface waters quality. Rice field irrigation water began to be held in the fields after the application of pesticides to allow more time for degradation (Dawson 2001a; Holden 1986). More irrigation water recycling was also encouraged at this time. These practices may have caused more contamination to percolate downward to groundwater. Rice growing, in general, provides opportunity for mobile pesticides to move to groundwater due to large volumes of groundwater recharge.

Assessment of Data Adequacy and Need for Added Data

Data from USGS, DPR, DWR, and Sutter County Planning Department provide somewhat limited picture of the areal extent of groundwater quality in the Sutter subbasin in that there is not extensive areal coverage for groundwater quality, especially for crops besides rice. However, the available data indicate key issues related to pesticides, nutrients and salinity.

Vina Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Vina Subbasin is bounded on the west by the Sacramento River, on the north by Deer Creek, on the east by the Chico Monocline and on the south by Big Chico Creek. Deer Creek and Big Chico Creek serve as hydrologic boundaries in the near surface. The subbasin is contiguous with the Los Molinos and West Butte subbasins at depth. The subbasin is 125,600 acres (195 mi^2) in size and is located in parts of Butte and Tehama Counties.

The following description of the hydrogeology in the Vina subbasin is taken from DWR Bulletin 118 (DWR 2004).

The aquifer system is comprised of continental deposits of Tertiary to late Quaternary age. The Quaternary deposits include Holocene stream channel deposits and Pleistocene Modesto Formation deposits, located along most stream and river channels, and alluvial fan deposits. The Tertiary deposits include the Tuscan Formation.

Holocene Stream Channel deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Tuscan Formation and Quaternary stream terrace alluvial deposits. The thickness varies from 1 to 80 feet. The unit represents the upper part of the unconfined zone of the aquifer and is moderately-to-highly permeable; however, the thickness and areal extent of the deposits limit the waterbearing capability.

Holocene Basin deposits are the result of sediment-laden floodwaters that rose above the natural levees of streams and rivers to spread across low-lying areas. They consist primarily of silts and clays and may be locally interbedded with stream channel deposits along the Sacramento River. Thickness of these deposits can range up to 150 feet and they are observed primarily between Mud Creek and Rock Creek, west of Highway 99. These deposits have low permeability and generally yield low quantities of poor quality water to wells.

The Pleistocene Modesto Formation consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tuscan Formation and Riverbank Formation. The Modesto Formation makes up the majority of the alluvial plain deposits except where older Riverbank Formation terrace deposits occur south of Pine Creek and the overlying basin deposits in the Nord area predominate. Thickness of the formation can range from less than 10 feet to nearly 200 feet across the valley floor.

The Pleistocene Riverbank Formation (older terrace deposits) consists of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. These deposits underlie the region between Pine Creek and Rock Creek. Thickness of the formation can range from less than 10 feet to nearly 200 feet across the valley floor.

The Pliocene Tuscan Formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone and volcanic ash layers. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subbasin and extend in the subsurface west of the Sacramento River.

Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable sediments of Unit B. Unit C is exposed as alluvial upland deposits west of the

Chico Monocline, largely north of Singer Creek. South of Singer Creek, the alluvial upland deposits merge with younger alluvial fan and plain deposits.

The Tuscan Formation reaches a thickness of 1,250 feet over older sedimentary deposits. The dip of the formation averages approximately 2.5 degrees, east of the valley, and steepens sharply to 10 to 20 degrees southwestward towards the valley at the Chico Monocline. The formation flattens beneath valley sediments.

Groundwater levels in the northern part of the Butte County show a decline as a result of the 1976–1977 and 1987–1994 droughts, followed by a recovery of groundwater levels to pre-drought conditions. Year-round extraction of groundwater for municipal use in the Chico area causes several small groundwater depressions that tend to alter the natural southwesterly movement of groundwater in the area. In the Chico area, groundwater level fluctuation in the unconfined portion of the aquifer system is about 5–7 feet during normal precipitation and up to approximately 16 feet during periods of drought. Annual fluctuation in the confined or semi-confined portion of the aquifer system is approximately 15–25 feet during normal years and up to approximately 30 feet during periods of drought. Groundwater levels for the confined or semi-confined portions of the aquifer system indicate a 10–15-foot decline in groundwater levels since the 1950s.

Groundwater storage capacity was estimated to be 1,468,000 acre-feet. This estimate was based on an average specific yield of 5.9% and an assumed thickness of 200 feet.

Major Sources of Recharge

Recharge to the subbasin is from local precipitation (18–22.5 inches/year), subsurface flow from the Sierra Nevada and foothills, irrigation infiltration, and stream infiltration. Source water for irrigation is a mix of surface and groundwater. Natural recharge takes place along streams and outcrops of the Tuscan Formation to the east of the study area. Sources of non-natural uncontrolled recharge include leakage from pipelines, seepage through the boundaries of the groundwater basin, and most significantly, net irrigation return flows. The Chico Monocline forms a geographic boundary; however, a component of basin recharge is located east of the fault structure.

In an isotopic study of shallow monitoring wells on the east side of the Sacramento Valley, Moran et al. (2004) presented evidence was for recent recharge of the Vina groundwater basin by evaporated water from flood irrigation. This study also found that Big Chico Creek significantly recharges the aquifer from the south and groundwater in the Chico area originates in the Sacramento Valley. Tritium concentrations in this same study indicate a pre-1950 recharge date for the groundwater located a distance north of Big Chico Creek.

Estimate of groundwater extraction for agricultural use is estimated to be 130,000 acre-feet. Municipal and industrial use is approximately 20,000acre-feet. Deep percolation of applied water is estimated to be 30,000 acre-feet.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1999. Agricultural land use accounts for about 37% of the subbasin, urban land use accounts for about 8% of the subbasin, and native land accounts for about 55% of the subbasin. Of the agricultural land uses, deciduous fruits and nuts make up 29%. Table 4-27 provides details of the land uses within the subbasin.

Table 4-27. Land Use in the Vina Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	400	0.30
Deciduous Fruits and Nuts	36,000	28.90
Field Crops	3,940	3.20
Grain and Hay	2,300	1.80
Pasture	1,900	1.50
Truck, Nursery, and Berry Crops	180	0.10
Idle	1,130	0.90
Semiagricultural and Incidental	570	0.50
Subtotal	46,420	37.20
Urban		
Urban—unclassified	5,100	4.10
Urban Landscape	390	0.30
Urban Residential	3,190	2.60
Commercial	300	0.20
Industrial	300	0.20
Vacant	650	0.50
Subtotal	9,930	8.00
Native		
Native Vegetation	64,300	51.50
Barren and Wasteland	230	0.20
Riparian	2,650	2.10
Water	1,220	1.00
Subtotal	68,400	54.80
Total	**124,750**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The Vina groundwater subbasin is within the Shasta Tehama Subwatershed. The public agencies within the Vina subbasin are: Butte Basin Water User Association, Deer Creek ID, Stanford Vina Ranch ID, City of Chico, Tehama

County Flood Control and Conservation District. Groundwater management ordinances were adopted in Butte County in 1996 and in Tehama County in 1994. The Butte County ordinance requires export permits for groundwater extraction and substitute pumping, establishes the Water Commission and Technical Advisory Committee, and provides countywide groundwater monitoring programs. Tehama County ordinance 1617 prohibits extraction of groundwater for export outside the county. Other key issues addressed in the ordinance include off-parcel groundwater use and influence of well pumping restrictions. The city of Chico is located partly within the subbasin, on the southern edge. This subbasin falls with the area included in the Shasta-Tehama Coalition.

Water Quality

Calcium-magnesium bicarbonate and magnesium-calcium bicarbonate are the predominant groundwater types in the subbasin. TDS ranges from 48 to 543 mg/L, averaging 285 mg/L. Groundwater quality issues include localized high calcium and nitrate, TDS and VOCs in the Chico area.

Discharge Pathways and Sources of Contaminants

Almost all of the irrigation water used within the Vina subbasin is pumped from groundwater (Moran et al. 2005). Sources and discharge pathways for specific contaminants are discussed below.

Nitrate

A common water quality problem in several of the subbasins, including Vina, is nitrate contamination by septic leachate and by agricultural activities. Nitrate exceeded the MCL in 4 public supply wells in the Vina subbasin. Nitrate contamination was more commonly found in shallow private wells rather than in the long-screened production wells included in the GAMA study by Moran el al. (2005).

Volatile Organic Compounds

According to the DHS database, only 4 public wells had had detections of VOCs above MCLs from 1994 through 2000 and none have had MTBE concentrations above the detection limit for reporting for Title 22 water (5 parts per billion [ppb]).

More recently, in at study by Moran et al. (2005), tetrachloroethylene (also known as perchloroethylene, PCE) was detected in 47 public supply wells in the Chico area; all but 4 detections were at concentrations well below the MCL, which is 5,000 ng/L, and 16 were below the public health goal (PHG) of 56 ng/L.

The Chico area also has a widespread contaminant plume of PCE, a solvent used in dry cleaning and metal cleaning operations. Nineteen of the Chico wells with PCE detections also had detections of trichloroethylene (TCE), which likely occurs as a breakdown product. MTBE co-occurred with PCE even more frequently, with 33 PCE-contaminated wells also having MTBE detections, suggesting a high degree of vulnerability to both recently introduced and decades-old contaminants at those wells. Groundwater contamination with VOCs does not appear to be related to irrigated agriculture.

Management Practices

We were unable to find documentation of management practices for prevention of groundwater contamination.

Assessment of Data Adequacy and Need for Added Data

There is generally insufficient available data within the Vina Subbasin to adequately evaluate the extent of groundwater contamination and processes affecting groundwater quality. Limited data indicate localized groundwater quality problems related to TDS and nitrates.

West Butte Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The West Butte subbasin aquifer is part of the Sacramento Valley groundwater basin. It is bound by Big Chico Creek on the north, the Sacramento River on the south and west, by the Chico Monocline on the northeast and by Butte Creek on the east. The aquifer system is 284 mi^2 in size and is located in parts of Butte, Glenn and Colusa Counties.

The following description of the hydrogeology in the West Butte subbasin is taken from DWR Bulletin 118 (2004).

The West Butte aquifer system is comprised of deposits of Late Tertiary to Quaternary age. The Quaternary deposits include the Holocene stream channel deposits and basin deposits, and the Pleistocene Modesto Formation, Riverbank Formation, and Sutter Buttes alluvium. The Tertiary deposits consist of the Pliocene Tehama Formation and the Tuscan Formation.

These deposits consist of unconsolidated gravel, sand, silt and clay derived from the erosion, reworking, and deposition of adjacent Quaternary stream terrace alluvial deposits. The thickness varies from 1 to 80 feet. The unit represents the upper part of the unconfined zone of the aquifer and is moderately-to-highly permeable; however, the thickness and areal extent of the deposits limit the water-bearing capability.

Basin deposits are the result of sediment-laden floodwaters that rose above the natural levees of streams and rivers to spread across low-lying areas. They consist primarily of silts and clays and may be locally interbedded with stream channel deposits along the Sacramento River. The deposits extend from south of Big Chico Creek to north of Angel Slough. Thickness of the unit can range from 10 to 100 feet (DWR 2001). The deposits have low permeability and generally yield low quantities of water to wells. The quality of groundwater produced from the unit is often poor (Reclamation 1960).

The Modesto Formation (deposited between 14,000 and 42,000 years ago) consists of poorly indurated gravel and cobbles with sand, silt, and clay derived from reworking and deposition of the Tuscan and Riverbank formations. Surface exposures extend south from Big Chico Creek to north of the city of Durham and also extend south of Angel Slough to the Sacramento River. The unit varies in thickness from 50 to 150 feet (DWR 2000). In locations where gravel and sand predominate, groundwater yields are moderate.

The Riverbank Formation (deposited between 130,000 and 450,000 years ago) consists of poorly-to-highly permeable pebble and small cobble gravels interlensed with reddish clay sands and silt. The areal extent of the formation is limited more to the southern portion of the subbasin and underlies surface exposures of the Modesto Formation. The thickness of the formation is approximately 1–200 feet depending on location (DWR 2000). The formation is moderately to highly permeable and yields moderate quantities of water to domestic and shallow irrigation wells.

In the southern extents of the subbasin, Sutter Buttes alluvium is observed in the subsurface and may range in thickness up to 600 feet (DWR 2000). These alluvial fan deposits consist largely of gravel, sand, silt and clay and may extend up to 15 miles north of the Sutter Buttes and westerly beyond the Sacramento River. Utility pump test records for wells located east of the subbasin, but believed to be in the same formation, show the average well yield for the formation to be approximately 2,300 gpm with an average specific capacity of 64 gpm/ft.

The Tehama Formation consists of sediments originating from the coastal mountains and interfingers with sediments of the Tuscan Formation in the vicinity of the Sacramento River at the far western extent of the subbasin (DWR 2000).

The Tuscan Formation is composed of a series of volcanic mudflows, tuff breccia, tuffaceous sandstone and volcanic ash layers. Thickness of the formation is estimated to be 800 feet. The formation is described as four separate but lithologically similar units—A through D (with Unit A being the oldest)—which in some areas are separated by layers of thin tuff or ash units. Units A, B, and C are found within the subsurface in the northern part of the subbasin and Units A and B are found in the southern part of the subbasin. Surface exposures of Units A, B, and C are located in the foothills at the far eastern extents of the subbasin. The surface exposure of Unit B east of the subbasin boundary is a recharge area. Unit A is the oldest water bearing unit of the formation and is characterized by the presence of metamorphic clasts within interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone. Unit B is composed of a fairly equal distribution of lahars, tuffaceous sandstone, and conglomerate. Unit B is olcaniclastic and is the most transmissive portion of the volcanic aquifer system and is the primary aquifer at depth. The surface exposure of Unit B, east of the subbasin boundary, is a recharge area. Although the Tuscan Formation is unconfined where it is exposed near the valley margin, at depth, the formation is confined. Unit C consists of massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. In the subsurface, these low permeability lahars form thick, confining layers for groundwater contained in the more permeable underlying sediments of Unit B.

Groundwater levels in the West Butte subbasin tend to fluctuate by 5 feet in normal and dry years. There is no consistent decreasing trend in the aquifer levels. DWR (2004) estimated the specific yield to by 7.1% and the storage capacity (to a depth of 200 feet) to be 13 maf.

Major Sources of Recharge

Irrigation is the primary source of groundwater recharge to the subbasin. Regionally, stream infiltration and to a lesser extent precipitation are also sources of recharge. Big Chico Creek, Little Chico Creek, and Butte Creek are major streams entering the subbasin. The Sacramento River drains the subbasin. Annual precipitation ranges from 17 to 27 inches with higher precipitation occurring to the west. Almost 30% of land is used for rice cultivation where the fields are typically flooded for 6 months each year. Groundwater discharge occurs as evapotranspiration, loss to streams, and pumpage. Almost all the water used for irrigation in the West Butte subbasin is pumped from groundwater.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1998–1999. The West Butte subbasin is primarily utilized for agricultural purposes with rice fields and orchards covering the highest percentage of land. Table 4-28 provides details on the distribution of land use throughout the West Butte subbasin.

Table 4-28. Land Uses in the West Butte Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Citrus and Subtropical	131	0.07
Deciduous Fruits and Nuts	37,122	20.43
Field Crops	19,309	10.63
Grain and Hay	9,466	5.21
Idle	2,093	1.15
Pasture	4,817	2.65
Rice	52,971	29.16
Semiagricultural and Incidental	563	0.31
Truck, Nursery, and Berry Crops	2,564	1.41
Subtotal	129,036	71.03
Urban		
Urban—unclassified	2,065	1.14
Commercial	463	0.25
Industrial	529	0.29
Urban Landscape	160	0.09
Urban Residential	1,461	0.80
Vacant	951	0.52
Subtotal	5,629	3.10
Native		
Riparian	25,149	13.84
Native Vegetation	16,261	8.95
Water	5,062	2.79
Barren and Wasteland	532	0.29
Subtotal	47,004	25.87
Total	**181,669**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The public entities within the West Butte subbasin aquifer system are: Butte Basin Water Users Association, Buzztail Community Service District, Durham ID, City of Chico, RD 1004, Western Canal WD, M&T Chico Ranch Inc., Sartain MWC (DWR 2004).

The private entities within the West Butte subbasin aquifer system are: Dayton Mutual Water Company, Del Oro Water Company, Durham Mutual Water Company and California Water Service (DWR 2004).

Butte County adopted a groundwater management ordinance in 1996. Glenn County adopted a groundwater management ordinance in 2000. Colusa County adopted a groundwater management ordinance in 1998 (DWR 2004). These ordinances affect primarily the volume of groundwater that can be pumped in the subbasin. Additionally, the Butte County and Glenn County ordinances established Water Commissions and Technical Advisory Committees and countywide monitoring plans.

This subbasin falls with the area included in the Butte-Sutter-Yuba Coalition.

Water Quality

Groundwater Quality issues in the West Butte subbasin include excess nutrients, dissolved solids, trace elements, and pesticides. Dissolved solids are elevated in localized areas throughout the subbasin and pesticides are persistent in groundwater beneath the rice growing areas. Trace elements are thought to be naturally occurring, as well as nitrates in some locations. However, there is evidence of elevated groundwater salinity (dissolved solids) and concentrations of nutrients and pesticides as the result of irrigated agriculture in the West Butte subbasin. Tables 4-29 and 4-30 summarize the available data.

Table 4-29. Water Quality in the West Butte Subbasin

Constituent of Concern	Available Information about groundwater concentrations for West Butte Subbasin
Nutrients	Median NO_3 concentration under rice fields was 2 mg/L (Domagalski et al. 2000).
	Nitrate, ammonia, phosphorus measured in shallow groundwater in rice growing areas (Dawson 2001a).
	“Some nitrates are found in the Chico area” (DWR 2004).
Pesticides (insecticides and herbicides) and degradation products	Dawson (2001a) reported pesticides detections in 89% of the 28 wells sampled, 82% of which were pesticides used on rice fields: bentazon, carbofuran, molinate, and thiobencarb. Bentazon was found in 71% of the wells.
Salt—primarily as electrical conductivity and total dissolved solids.	Localized high EC, TDS, and adjusted sodium absorption ratio (ASAR) (DWR 2004).
	High TDS concentrations measured in shallow groundwater in rice growing areas (Dawson 2001a).
Trace elements	Localized high calcium, EC, boron (DWR 2004).
	Dawson (2001a) found concentrations of inorganic constituents that exceeded primary state and federal drinking water standards at least once in 25% of the wells. The inorganic constituents detected above the primary limits were boron, barium, cadmium, molybdenum or sulfate. Secondary drinking water standards were exceeded at least once in 79% of the wells. The constituents detected above secondary limits were chloride, iron, manganese, specific conductance (EC), or dissolved solids.

Constituent of Concern	Available Information about groundwater concentrations for West Butte Subbasin
Organic carbon and disinfection byproduct precursors	Dissolved organic carbon elevated relative to expected background in some areas (Dawson 2001a).
Microorganisms	No available data.
Volatile organic compounds	One public supply well out of 26 sampled has concentrations above MCL (DWR 2004). According to the DHS database, one public wells had had detections of VOCs above MCLs from 1994 to 2000 (LLNL Gamma report).

Notes:
mg/L = milligrams per liter.

Table 4-30. Concentrations of Constituents of Concern Detected in the West Butte Subbasin

Constituent Type	Constituent of Concern	Concentration ranges	Drinking Water Standards
Nutrients	Nitrate	Median 2 mg/L (Domagalski et al. 2000)	Nitrate was reported to exceed the MCL in two public supply wells in the West Butte subbasin (Moran et al. 2004).
	Ammonia as N	0.02–0.46 mg/L	30 (HAL)
	Ammonia + organic N as N	0.3–0.7 mg/L	30 (HAL)
	Nitrate+Nitrite, as N	0.08–6.2 mg/L	10 (MCL)
	Nitrate as N	0.08–6.2 mg/L	10 (MCL)
	Nitrite as N	0.01–0.1 mg/L	1 (MCL)
	Orthophosphate, as P	0.01–0.36 mg/L	
	Phosphorus, as P	0.03–0.362 mg/L	
	Dissolved organic carbon, as C	0.3–6.8 mg/L	
Pesticides (insecticides and herbicides) and degradation products*	Atrazine	*0.002*–0.026 µg/L	3 (MCL)
	Bentazon	0.06–*7.8* µg/L	18 (MCL)
	Bromacil	0.19min µg/L	90 (HAL)
	Carbofuran	0.016–0.8 µg/L	18 (MCL)
	Desethyl atrazine	*0.001–0.005* µg/L	
	Dichlorprop	*0.1min* µg/L	
	Diuron	0.04–0.09 µg/L	10 (HAL)
	Azinphos-methyl	*0.014min* µg/L	
	Molinate	*0.002*–0.056 µg/L	20 (MCL)
	Simazine	*0.002*–0.027 µg/L	4 (MCL)
	Tebuthiuron	*0.006min* µg/L	500 (HAL)
	Thiobencarb	0.006–0.025 µg/L	70 (MCL)
Salt—primarily as electrical conductivity and total dissolved solids.		120–1,220 mg/L, mean 391 mg/L (DWR 2004) 168–8,730 mg/L, median 532 mg/L (Dawson 2001a)	

Constituent Type	Constituent of Concern	Concentration ranges	Drinking Water Standards
Trace elements	Aluminum	0.002–0.010 mg/L	1 (MCL)
	Arsenic	0.001–0.015 mg/L	
	Barium	0.01–5.05 mg/L	1(MCL)
	Boron	0.02–1.8 mg/L	0.6 (HAL)
	Bromide	0.03–12 mg/L	
	Cadmium	0.006–0.007 mg/L	0.005 (MCL)
	Chromium	0.002–0.016 mg/L	0.05 (MCL)
	Cobalt	0.001–0.004 mg/L	
	Copper	0.001–0.003 mg/L	1.3 (MCL)
	Ferrous Iron Fe^{2+}	Detected in 19/28 wells	
	Fluoride	0.1–1.8 mg/L	4 (MCL)
	Iron Fe	0.003–5.3 mg/L	0.3 (SMCL)
	Manganese	0.1–0.05 mg/L	0.05 (SMCL)
	Molybdenum	0.001–0.051 mg/L	0.04 (HAL)
	Nickel	0.001–0.009 mg/L	0.1 (HAL)
	Selenium	0.003–0.022 mg/L	0.05 (MCL)
	Sulfide	Detected in 14/28 wells	
	Uranium	0.001–0.023 mg/L	2000 (MCL)
	Zinc	0.001–0.017 mg/L	2 (HAL)

Notes:
* Numbers in *italics* are estimates.
MCL = Maximum Contaminant Level set by EPA (2005).
µg/l = micrograms per liter.
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).
HAL = Health Advisory Level set by EPA (2005).
Source: Dawson 2001a, 2001b, unless otherwise indicated.

Discharge Pathways and Sources of Contaminants

Natural and agricultural processes affect groundwater quality in the West Butte subbasin. Natural processes include those that influence the chemistry of the recharge water. The chemistry of the recharge water, surface geology and soils influence the major ion chemistry and concentrations. The groundwater oxidation state also influences the form and presence of constituents. Much of the groundwater in the West Butte subbasin is anoxic and chemically reducing. This results in high concentrations of manganese and iron and the presence of ammonia and phosphorus. In some areas of the subbasin, naturally occurring highly saline groundwater is present at varying depths and can influence the water quality of production wells. Agricultural processes include use of fertilizers and pesticides and the evaporation of irrigation water. Groundwater from the West Butte subbasin discharges to wells and streams. The Sacramento River gains water from the West Butte subbasin and carries it south, toward

Sacramento. Specific processes affecting VOCs are discussed in some detail below.

Nutrients

According to the DHS database, only 4 public wells had had detections of VOCs above MCLs from 1994 to 2000 and none have had MTBE concentrations above the detection limit for reporting for Title 22 water (5 ppb). MCL exceedances of nitrate are reported in 4 public supply wells in the subbasin. Nitrate contamination is more commonly found in shallow private wells rather than in the long-screened production wells included in this study.

Dawson (2001a) presented evidence for movement of nitrate to shallow groundwater in rice growing areas. Specifically, she demonstrated a significant correlation of nitrate concentrations with well depth—higher nitrate concentrations were associated with shallower well depths indicating movement of nitrate from land surface associated with agricultural activities. There are naturally occurring nitrates in some formations of the Sacramento Valley. However, most nitrogen species that occur at levels above contaminant levels are introduced into the groundwater via human activates such as agriculture and urbanized development.

Salinity

The chemistry of the recharge waters strongly affects the chemistry of the groundwater in the Sacramento Valley. The geochemical facies of the groundwater in the West Butte subbasin in a mix of the calcium-magnesium bicarbonate waters in the western alluvial fan and the sodium sulfate waters in the eastern alluvial fan. Two processes appear to primarily affect groundwater salinity in the West Butte subbasin: evaporation of irrigation water and shallow groundwater and mixing of naturally occurring saline groundwater (Hull 1984; Olmsted and Davis 1961; Dawson 2001a). Using isotope data, Dawson (2001a) presented evidence that partial evaporation as indicated by the isotope data accounted for some of the measured increase in salinity among shallow groundwater samples.

Pesticides

Rice pesticides Molinate, Thiobencarb and Carbofuran were detected in 7, 3, and 4 of the 28 wells sampled during the 1997 study by the USGS (Dawson 2001a). The most prevalent pesticide detected in groundwater was bentazon. This chemical was used in rice fields until it was suspended in 1989 and officially banned in 1992. Its presence in groundwater in studied completed in 1997 (Domagalski et al. 2000) suggests it is readily transported in groundwater and does not degrade quickly. Although present in most wells in the rice growing areas of the West Butte subbasin, pesticide concentrations were below state and federal 2000 drinking water standards in all occurrences.

Dawson (2001a) investigated the relationship between groundwater quality and rice cultivation land use practices in data collected during 1998. Dawson (2001a) found that shallower wells had more occurrences of pesticide contamination than deeper wells, indicating the movement of pesticides from the ground surface downward. Concentrations of bentazon showed a statistical relationship to tritium concentrations. Since tritium is used for age-dating groundwater, this relationship suggests that bentazon concentrations may be related to recharge age of the groundwater in which it was found. Tritium concentrations in all wells except one indicate that groundwater in the rice growing areas of the Colusa subbasin were recharge after 1950. To further identify the date at which the pesticides entered groundwater, the first application dates of the pesticides in the Sacramento Valley were studied. This resulted groundwater recharge dating in the late 1970s.

Irrigation practices can have an affect on the amount of pesticides that reach groundwater. Troiano et al. (1993) investigated difference irrigation methods and found that “leaching of pesticides was less in sprinkler applications because water was applied more frequently in smaller applications than for the basin-flooding method. For basin-flooding treatments, as those practiced on rice fields, a large amount of water application was required for each irrigation in order to provide application across the plot. Although irrigations were less frequent, the larger water volume caused greater downward movement of water and atrazine residues.”

Trace Elements

The chemistry of geology formations in the Colusa subbasin influences the concentrations of trace elements. Dawson (2001) found that the geomorphic unit in which the groundwater resides influences the concentration of arsenic, boron, chloride, fluoride, molybdenum, potassium, sulfate, and zinc. Concentrations of arsenic and potassium were significantly higher in wells in the central flood basin, which contains the West Butte subbasin. Concentrations of nitrate were significantly lower in the central flood basin. Trace element concentrations do not generally appear to be influenced by irrigated agriculture.

Management Practices

We were unable to find specific information about management practices for prevention of groundwater quality degradation for the West Butte Subbasin. Rice field management practices began in 1983, to protect surface waters quality. Rice field irrigation water began to be held in the fields after the application of pesticides to allow more time for degradation (Dawson 2001a; Holden 1986). More irrigation water recycling was also encouraged at this time. These practices may have caused more contamination to percolate downward to groundwater.

Rice growing in general provides opportunity for mobile pesticides to move to groundwater due to large volumes of groundwater recharge.

Assessment of Data Adequacy and Need for Added Data

Data from USGS, DPR, and DWR provide somewhat limited picture of groundwater quality in the West Basin subbasin in that there is not extensive areal coverage for groundwater quality, especially for crops besides rice. However, the available data indicate key issues related to rice pesticides, nutrients and salinity.

Yolo Subbasin—Sacramento Valley Basin

General Basin Parameters

Acreage, Physiography

The Yolo subbasin aquifer is bound by Cache Creek in the north, Putah Creek in the south, the Coast Ranges on the west and the Sacramento River on the east. The aquifer system is 400 mi^2 in size and is located in parts of Yolo and Solano Counties. The following description of the hydrogeology in the basin is taken from DWR Bulletin 118 (2004).

The primary water bearing formations comprising the Yolo subbasin are sedimentary continental deposits of Late Tertiary (Pliocene) to Quaternary (Holocene) age. Fresh water-bearing units include younger alluvium, older alluvium, and the Tehama Formation. The cumulative thickness of these units ranges from a few hundred feet near the Coast Range on the west to nearly 3,000 feet near the eastern margin of the basin. Saline water-bearing sedimentary units underlie the Tehama formation and are generally considered the boundary of fresh water.

Younger alluvium includes flood basin deposits and Recent stream channel deposits. Flood basin deposits occur along the eastern margin of the subbasin in the Yolo Flood Basin. They consist primarily of silts and clays, but along the eastern margin of the subbasin may be locally interbedded with stream channel deposits of the Sacramento River. Thickness of the unit ranges from 0 to 150 feet. The flood basin deposits have low permeability and generally yield low quantities of water to wells. The quality of groundwater produced from the basin deposits is often poor.

Recent stream channel deposits consist of unconsolidated silt, fine- to medium-grained sand, gravel and occasionally cobbles deposited in and adjacent to active streams in the subbasin. They occur along the Sacramento River, Cache Creek, and Putah Creek. Thickness of the younger alluvium ranges from 0 to 150 feet.

The younger alluvium varies from moderately to highly permeable, but often lies above the saturated zone. Where saturated, the younger alluvium yields significant quantities of water to wells.

Older alluvium consists of loose to moderately compacted silt, silty clay, sand, and gravel deposited in alluvial fans during the Pliocene and Pleistocene. Thickness of the unit ranges from 60 to 130 feet, about one-quarter of which is coarse sand and gravel. Permeability of the older alluvium is highly variable. Wells penetrating sand and gravel lenses of the unit produce between 300 and 1,000 gpm. Adjacent to the Sacramento River, wells completed in ancestral Sacramento River stream channel deposits yield up to 4,000 gpm. Wells completed in the finer-grained portions of the older alluvium produce between 50 and 150 gpm.

The Tehama Formation is the thickest water-bearing unit underlying the Yolo subbasin, ranging in thickness from 1,500 to 2,500 feet. Surface exposures of the Tehama Formation are limited mainly to the Coast Range foothills along the western margin of the basin, as well as in the Plainfield Ridge. The Tehama consists of moderately compacted silt, clay, and silty fine sand enclosing lenses of sand and gravel, silt and gravel, and cemented conglomerate. Permeability of the Tehama Formation is variable, but generally less than the younger units. Because of its relatively greater thickness, however, wells completed in the unit can yield up to several thousand gallons per minute.

Underlying the Tehama Formation are brackish to saline water-bearing sedimentary units, including the somewhat brackish sedimentary rocks of volcanic origin (Pliocene to Oligocene?) underlain by marine sedimentary rocks (Oligocene? to Paleocene) which are typically of low permeability and contain connate water. The upper contact of these units generally coincides with the fresh/saline water boundary. The contact is found near the Coast Range at depths as shallow as a few hundred feet. Near the eastern margin of the basin it reaches depths of nearly 3,000 feet.

The geologic structure of the groundwater subbasin is dominated by an anticlinal ridge oriented northwest to southeast, which is expressed at the surface as the Dunnigan Hills and Plainfield Ridge. The anticlinal structure impedes subsurface flow from west to east. Subsurface groundwater outflow sometimes occurs from the Yolo subbasin into the Solano subbasin to the south. Subsurface outflow and inflow may also occur beneath the Sacramento River to the east with the South and North American subbasins. Subsurface groundwater inflow may occur from the west out of the Capay Valley Basin.

DWR (2004) estimated the specific yield to be 6.5 to 9.7% and the storage capacity (20–400 feet) to be approximately 6.5 maf.

Major Sources of Recharge

Irrigation is the primary source of groundwater recharge to the subbasin. Regionally, stream infiltration and to a lesser extent precipitation are also sources of recharge. Major streams above the Yolo subbasin are Cache Creek, Putah Creek and the Sacramento River. Annual precipitation ranges from 18 to 24 inches with higher precipitation occurring to the west. Groundwater discharge occurs as evapotranspiration, loss to streams, and pumpage

Land Use

Land use surveys were conducted within the subbasin by DWR in 1997. Agricultural land use accounts for about 69% of the subbasin, urban land use accounts for about 12% of the subbasin, and native land accounts for about 19% of the subbasin. Table 4-31 provides details on the distribution of land use throughout Yolo Subbasin.

Table 4-31. Land Use in the Yolo Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Citrus and Subtropical	226	0.10
Deciduous Fruits and Nuts	11,359	5.03
Field Crops	41,426	18.34
Grain and Hay	33,421	14.80
Idle	4,807	2.13
Pasture	22,609	10.01
Rice	12,951	5.73
Semiagricultural and Incidental	1,714	0.76
Truck, Nursery, and Berry Crops	26,372	11.68
Vineyards	360	0.16
Subtotal	155,244	68.74
Urban		
Urban—unclassified	13,606	6.02
Commercial	1,216	0.54
Industrial	4,625	2.05
Urban Landscape	1,178	0.52
Urban Residential	2,546	1.13
Vacant	4,223	1.87
Subtotal	27,393	12.13
Native		
Barren and Wasteland	534	0.24
Riparian	2,702	1.20
Native Vegetation	37,251	16.49
Water	2,724	1.21
Subtotal	43,211	19.13
Total	**225,848**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

The public entities within the Yolo subbasin aquifer system are: Yolo County Flood Control and Water Conservation District, City of Woodland, City of Davis, City of West Sacramento (DWR 2004). The private entities within the Yolo subbasin aquifer system are RDs 108, 900,2035, and 2068. (DWR 2004.)

In 1992 AB3030 provided a systematic procedure for an existing local agency to develop a formal groundwater management plan. RD 108 adopted an AB3030 plan in February 1995. RD 2035 adopted an AB3030 plan in April 1995. RD 2068 adopted an AB3030 plan in January 1997. Yolo County Flood Control and Water Conservation District is drafting a plan but it is not pursuant to AB3030. RD 900.

This subbasin falls with the area included in the Solano-Yolo Coalition.

Water Quality

Groundwater Quality issues in the Yolo subbasin include high dissolved solids, boron, selenium and nitrate. Hardness, which is mainly a reflection of the amount of calcium and magnesium in water, is considered very high, with values generally greater than 180 mg/L. (Evenson 1984.)

High average concentrations of dissolved solids, calcium, magnesium, sodium, chloride, and fluoride exist in the alluvial fans adjacent to the Coast Range in the southwestern margin of the Sacramento Valley. Boron and bicarbonate concentrations are very high. Silica concentrations are generally low. TDS measured in wells in this area show trends of significant increase in dissolved solids since the 1950s, while wells measured for nitrates showed no significant change over time. (Hull 1984.) Groundwater to the west of the Sacramento River in Yolo County is recharged by eastward flowing streams that drain the marine sediments to the west. This water is predominantly magnesium and magnesium-sodium bicarbonate and is of poorer quality than Sacramento Valley Basin water derived from the east. (DWR 1974.)

A USGS study (Evenson 1985) analyzed water quality in the Solano and Yolo Counties. Constituents that were measured include: dissolved solids, harness, chloride, fluoride, sulfate, nitrogen, arsenic, boron, iron, and manganese. Except where otherwise noted, the following is a summary of the findings as they pertain to the Yolo subbasin.

Using stable isotope data, Davisson and Criss (1993) elucidated the probably processes influencing increasing groundwater salinity in the Davis area. Specifically, their data supported the hypothesis of higher salinity groundwater within about 240 feet of land surface could be attributed to infiltration of irrigation water. The increased isotopic enrichment of this groundwater indicated soil evaporation associated with irrigated agriculture. This isotopic enrichment was also associated with high nitrate concentrations indicating fertilization influence.

Pesticides

According to DPR (2004), for the period of 1985 to 2003, atrazine, bentazon, and simazine were detected in Yolo County. Sampling locations and concentrations were not specified.

Nitrogen

Nitrogen concentrations varied over the subbasin, with some domestic wells sampled having concentrations above the EPA limit of 10 mg/L nitrate-nitrogen. The maximum concentration was 24 mg/L.

Boron

Boron concentrations were greater than 0.75 mg/L from Zamora to Knights Landing. High boron concentrations were generally found in water sampled from wells near Cache Creek; this indicates that surface water from the creek may be a source for high boron levels in the surrounding groundwater.

Arsenic

Arsenic concentrations are less than the EPA primary drinking water regulated limit of 0.05 ppm. The highest concentrations are along the northern and eastern margins of the Yolo subbasin.

Iron

Iron concentrations are generally low with respect to federal standards (MCL = 0.3 ppm) in the Yolo subbasin. Along the Cache Creek and in the eastern part of the study area, values ranged form 0.02 to 0.49 mg/L. In other areas, all wells sampled contained less than 0.02 mg/L.

Manganese

Groundwater sampled near the Sacramento River in the southeastern part of the subbasin had the highest concentrations of manganese (greater than 0.1 mg/L), with concentrations decreasing as a function of distance from the river. Wells sampled in the western half of the Yolo subbasin had levels generally below 0.01 mg/L. The MCL (as a secondary constituent) for manganese is 0.05 ppm.

Discharge Pathways and Sources of Contaminants

Sources of elevated groundwater dissolved solids and nitrates include irrigated agriculture in Yolo County (Davisson and Criss 1993). Pesticides detected in groundwater also appear to originate from irrigated agriculture. We could not find information about specific sources or discharges of contaminants

Management Practices

Groundwater levels are monitored in the Yolo Subbasin by DWR in 10 wells semi-annually and in 4 wells on a monthly basis; by YCFC&WCD in 92 wells semi-annually and in 1 well on a monthly basis; by Sacramento County in 1 well semi-annually; and by Reclamation in 12 wells semi-annually and in 7 wells on a monthly basis. DHS monitors 133 wells annually for water quality parameters. DWR monitors the Yolo Subbasin for ground subsidence continuously at one site.

Based on information in Davisson and Criss (1993), irrigated agriculture can result in increased salinity and nitrates in groundwater. Specific information about practices that affect groundwater quality was not available.

Assessment of Data Adequacy and Need for Added Data

There is limited information about the spatial distribution of nitrates, salinity and pesticides in the Yolo Subbasin. Additional data is required to fully understand the spatial distribution of constituents and processes affecting the distribution.

South Fork Pit River Subbasin—Alturas Area Basin

General Basin Parameters

Acreage, Physiography

The South Fork Pit River groundwater subbasin is located in Lassen and Modoc Counties and is 114,000 acres (178 mi^2) in size. It is bounded on the east by Plio-Pleistocene basalt and Pleistocene Pyroclastic rocks of the Warner Mountains, to the north by Pleistocene basalt of Devils Garden, to the south by Plio-Pleistocene basalt, and to the west by Warm Springs tuff. The South Fork Pit River enters the subbasin near the community of Likely and flows north through the South Fork Pit River Valley to its confluence with the North Fork Pit at the town of Alturas.

The following description of the hydrogeology in the South Fork Pit River subbasin is taken from DWR Bulletin 118 (DWR 2004).

The principal water-bearing formations are Holocene sedimentary deposits (which include alluvial fan deposits, intermediate alluvium, and basin deposits), Pleistocene lava flows and near-shore deposits, and Plio-Pleistocene Alturas Formation and basalts.

The Holocene sedimentary deposits include alluvial fan deposits, intermediate alluvium, and basin deposits—each up to a thickness of 75 feet. Alluvial fan deposits consist of unconsolidated to poorly consolidated, crudely stratified silt, sand and gravel with lenses of clay. These deposits generally have high permeability and are capable of yielding large amounts of water to wells. This unit may include confined as well as unconfined water.

Intermediate alluvium consists of unconsolidated poorly sorted silt and sand with some lenses of gravel. These deposits have moderate permeability and yield moderate amounts of water to shallow wells.

Basin deposits consist of unconsolidated, interstratified clay, silt and fine sand. These deposits have moderate to low permeability and yield small amounts of water to wells.

The Pleistocene near-shore deposits consist of slightly consolidated to cemented, poorly to well stratified pebble and cobble gravel with lenses of sand and silt to a thickness of 200 feet. The most extensive near-shore deposits occur in the northeast corner of the basin where the North Fork Pit River enters the valley. Other minor areas of these deposits occur but are not considered significant as water-bearing areas. These deposits have moderate permeability and may yield fair to moderate amounts of unconfined and confined water to wells.

The Pleistocene volcanic rocks consist of lava flows of layered, jointed basalt ranging in thickness from 50 to 250 feet. These basalt flows serve as recharge zones where exposed in the uplands surrounding the basin. Within the basin, where saturated, scoriaceous zones and joints in the basaltic flows can yield moderate amounts of water to wells. These flows occur interbedded with the upper member of the Alturas Formation in the valley areas.

The Plio-Pleistocene Alturas Formation consists of moderately consolidated, flat-lying beds of tuff, ashy sandstone and diatomite, and are widespread both at the surface and at depth. The upper and lower sedimentary members of the formation are each about 400 feet thick, and are separated by a basalt member and the Warm Springs tuff. The sediments of the Alturas Formation are the principal water-yielding materials in the South Fork Pit River subbasin. These sediments have a moderate to high permeability and, where saturated, can yield large amounts of groundwater to wells. The formation contains both confined and unconfined groundwater.

Exposures of Warm Springs tuff in Sections 10 and 15, Township 42 North, Range 11 East, act as a partial barrier to the westward movement of groundwater from South Fork Pit River Valley to Warm Springs Valley (DWR 1963).

Water levels generally declined up to 10 feet in the northern part of the subbasin during the period from the early 1980s through the early 1990s and have recovered to former levels through 1999.

The groundwater storage capacity to a depth of 800 feet is estimated to be approximately 7,500,000 acre-feet for the entire Alturas Groundwater Basin (which includes the South Fork Pit River Subbasin and the Warm Springs Valley Subbasin) (DWR 1963).

DWR estimates groundwater extraction for agricultural and municipal/industrial uses to be 13,000 and 260 acre-feet respectively. These estimates are based on surveys conducted by the DWR during 1997.

Major Sources of Recharge

Recharge to the subbasin is from precipitation, irrigation infiltration, and stream infiltration. Annual precipitation ranges from 13 to 19 inches. Deep percolation of applied water is estimated by DWR (2004) to be 9,600 acre-feet. The south and north forks of the Pit River influence groundwater in the subbasin.

Most recharge to the Alturas Groundwater Basin occurs in the upland areas of the western slope of the Warner Mountains (DWR 1986). The Pit River and other tributary streams recharge the groundwater in the subbasin as well.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1997. The South Fork Pit River subbasin is overlain with 31% agricultural land uses, 26% of which is rangeland. Table 4-32 provides details of the land uses within the subbasin.

Table 4-32. Land Use in the South Fork Pit River Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Grain and Hay	2,446	2.14
Idle	632	0.55
Pasture	30,077	26.35
Rice	2,754	2.41
Semiagriculture and Incidental	480	0.42
Subtotal	36,389	31.88
Urban		
Commercial	172	0.15
Industrial	264	0.23
Urban Landscape	90	0.08
Urban Residential	2,671	2.34
Vacant	200	0.18
Subtotal	3,397	2.98
Native		
Riparian	2,542	2.23
Native Vegetation	69,372	60.78
Water	2,437	2.13
Subtotal	74,351	65.14
Total	**114,137**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Modoc County adopted a groundwater ordinance in 2000. A key element of the ordinance requires an export permit for groundwater transfers out of the basin (DWR 2004). Alturas is the largest city in the subbasin. Public water agencies involved with the subbasin are the City of Alturas, California Pines Community Service District, and Hot Springs Valley Irrigation District. This subbasin falls with the area included in the Pit River Coalition.

Water Quality

Sodium bicarbonate and sodium-calcium bicarbonate type waters are the predominant water types in the subbasin. TDS ranges from 180 to 800 mg/L, averaging 357 mg/L. Water quality concerns in the Alturas Basin are high concentrations of TDS, nitrate, iron, or boron (DWR 1963).

In 1986, DWR published a study of the Alturas Basin (which includes the South Fork Pit River subbasin) groundwater quality. The study concluded that the general water quality of the Alturas Basin was good but there were some localized problems that were limiting the groundwater's beneficial use. The water quality issues were high concentrations of salts, sulfate, boron, and chloride. Most of the problem wells were wells that draw from the groundwater in the Alturas Formation and groundwater that migrates along faults. Table 4-33 displays the results of this study.

Table 4-33. Data from DWR Study of the Alturas Basin in 1986

Constituent Type	Constituent of Concern	Concentration ranges	Standards
Nutrients	Nitrate as N	0–38 mg/L, median is 4.2 mg/L (16 wells monitored)	10 (MCL)
Salt—primarily as electrical conductivity and total dissolved solids.		100–1,600 mg/L, median is 260 mg/L	500 (SMCL)
	Adjusted sodium adsorption ratio (ASAR)	0–23.9 mg/L, 10 of 118 wells had values of 9 or greater	Ratio of 9 can cause severe problems with sodium buildup in soils
Trace elements	Boron	0–4.6 mg/L, median is 0.03 mg/L	
	Chloride	0–271 mg/L, median is 8 mg/L	250 (SMCL)
	Sulfates	0–626 mg/L, median is 16 mg/L	250 (SMCL)
Hardness		2–506 mg/L (as $CaCO_3$), median is 76 mg/L	

Notes:
MCL = Maximum Contaminant Level set by EPA (2005).
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).

Discharge Pathways and Sources of Contaminants

The groundwater regime between Warm Springs Valley and South Fork Pit River Valley is continuous through a north-to-northwest trending highland, west and south of Alturas, that forms two distinct valleys with separate surface drainage.

Exposures of Warm Springs tuff in Sections 10 and 15, Township 42 North, Range 11 East, act as a partial barrier to the westward movement of groundwater from South Fork Pit River Valley to Warm Springs Valley (DWR 1963).

The Alturas Groundwater Basin is utilized for irrigation. In 1979 DWR estimated pumpage of groundwater to be about 4,400 acre-feet (DWR 1986). The movement of groundwater through the Alturas Basin generally follows the topography.

The South Fork Pit River is the primary stream in the subbasin. It enters the subbasin from the south and continues north until is converges with the North Fork Pit River near Alturas in the northern portion of the subbasin. DWR (1986) states that the Pit River and its tributaries generally recharge the groundwater basin and therefore would not be a pathway for groundwater contaminant transport.

Management Practices

Pasture land comprised 26% of the land uses in South Fork Pit River subbasin. Brush encroachment in rangelands can be controlled by removal of brush through controlled burns and/or mechanical and chemical treatment. Controlled burning in rangeland has been practiced in for a number of years both to improve grazing lands and reduce fire hazards. Herbicide application has been used to control brush as well.

Assessment of Data Adequacy and Need for Added Data

There is little water quality data available for South Fork Pit subbasin. From DWR Bulletin 118 there does not appear to be impairments in this groundwater subbasin.

Warm Springs Valley Subbasin—Alturas Area Basin

General Basin Parameters

Acreage, Physiography

The Warm Springs Valley groundwater subbasin is located in Modoc County and is 68,000 acres (106 mi^2) in size. It is bound on the east by a low mesa of the Plio-Pleistocene Alturas Formation (separating Warm Springs Valley from South Fork Pit River Valley); to the north by the Pleistocene basalt of Devils Garden; to the south by Plio-Pleistocene Warm Springs tuff and basalt and to the west by Pleistocene basalt (Gay 1968).

The groundwater regime between Warm Springs Valley and South Fork Pit River Valley is continuous through a north-to-northwest trending highland, west and south of Alturas, that forms two distinct valleys with separate surface drainage. From the confluence of the North and South Forks of the Pit River, just to the east at Alturas, the Pit River flows westerly through Warm Springs Valley.

The following description of the hydrogeology in the Warm Springs Valley subbasin is taken from DWR Bulletin 118 (DWR 2004).

The principal water-bearing formations are Holocene sedimentary deposits, Pleistocene lava flows, and Plio-Pleistocene Alturas Formation and basalts. The following summary of water-bearing formations is from DWR (1963).

The Holocene sedimentary deposits include alluvial fan deposits, intermediate alluvium, and basin deposits—each up to a thickness of 75 feet. Alluvial fan deposits consist of unconsolidated to poorly consolidated, crudely stratified silt, sand and gravel with lenses of clay. These deposits generally have high permeability and are capable of yielding large amounts of water to wells. This unit may include confined as well as unconfined water.

Intermediate alluvium consists of unconsolidated poorly sorted silt and sand with some lenses of gravel. These deposits have moderate permeability and yield moderate amounts of water to shallow wells.

Basin deposits consist of unconsolidated, interstratified clay, silt and fine sand. These deposits have moderate to low permeability and yield small amounts of water to wells.

The Pleistocene volcanic rocks consist of lava flows of layered, jointed basalt ranging in thickness from 50 to 250 feet. These basalt flows serve as recharge zones where exposed in the uplands surrounding the basin. Within the basin, where saturated, scoriaceous zones and joints in the basaltic flows can yield moderate amounts of water to wells. These flows occur interbedded with the upper member of the Alturas Formation in the valley areas.

The Plio-Pleistocene Alturas Formation consists of moderately consolidated, flat-lying beds of tuff, ashy sandstone and diatomite, and are widespread both at the surface and at depth. The upper and lower sedimentary members of the formation are each about 400 feet thick, and are separated by a basalt member and the Warm Springs tuff. The sediments of the formation are the principal water-yielding materials in the Warm Springs Valley Subbasin. These sediments have a moderate to high permeability and where saturated can yield large amounts of groundwater to wells. The formation contains both confined and unconfined groundwater.

Exposures of Warm Springs tuff in Sections 10 and 15, Township 42 North, Range 11 East, act as a partial barrier to the westward movement of groundwater from South Fork Pit River Valley to Warm Springs Valley (DWR 1963).

Water levels declined approximately 20 feet in the western part of the subbasin during the period between 1985 and the early 1990s and have recovered by approximately 15 feet by 1999.

The groundwater storage capacity to a depth of 800 feet is estimated to be approximately 7,500,000 acre-feet for the entire Alturas Groundwater Basin (which includes the South Fork Pit River Subbasin and the Warm Springs Valley Subbasin) (DWR 1963).

DWR estimates groundwater extraction for agricultural and municipal/industrial uses to be 3,000 and 270 acre-feet, respectively. These estimates are based on surveys conducted by the DWR during 1997.

Major Sources of Recharge

Recharge to the subbasin is from precipitation, irrigation infiltration, stream infiltration and subsurface flow. Most recharge occurs in the upland areas of Devils Garden and Portuguese Ridge (DWR 1986). Upland recharge areas consist of permeable lava flows of Plio-Pleistocene and Pleistocene age. Precipitation falling on these areas infiltrates the lava flows and moves toward the valley floor (DWR 1963). The Pit River and other tributary streams recharge the groundwater in the subbasin as well. The average annual precipitation in the subbasin ranges from 13 to 19 inches increasing toward the west. Deep percolation of applied water is estimated by DWR (2004) to be 3,300 acre-feet.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1997. The Warm Springs Valley subbasin is overlain with 26% agricultural land uses, 21% of which is rangeland (pasture). Table 4-34 provides details of the land uses within the subbasin.

Table 4-34. Land Use in the Warm Springs Valley Subbasin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Grain and Hay	1,731	2.55
Idle	1,873	2.75
Pasture	14,089	20.72
Semiagricultural and Incidental	172	0.25
Subtotal	17,865	26.27
Urban		
Urban—unclassified	316	0.47
Commercial	21	0.03
Industrial	186	0.27
Urban Landscape	4	0.01
Urban Residential	162	0.24
Vacant	89	0.13
Subtotal	777	1.14
Native		
Native Vegetation	47,207	69.41
Water	1,352	1.99
Riparian	807	1.19
Subtotal	49,366	72.59
Total	**68,008**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Modoc County adopted a groundwater ordinance in 2000. Groundwater ordinances generally affect the volume of groundwater that can be pumped and/or exported from the subbasin. A key element of the Modoc County ordinance requires an export permit for groundwater transfers out of the basin (DWR 2004).

Public water agencies involved with the subbasin are the California Pines Community Service District, and Hot Springs Valley Irrigation District. This subbasin falls with the area included in the Pit River Coalition.

Water Quality

Sodium bicarbonate and sodium-calcium bicarbonate type waters are the predominant water types in the Alturas Groundwater Basin. The concentration of TDS ranges from 180 to 800 mg/L, averaging 357 mg/L (DWR 2004).

Kelly Hot Springs has water high in concentrations of TDS, boron, and fluoride. There is also high conductivity; adjusted sodium absorption ratio; and sulfate, iron, nitrate, calcium, manganese, and boron in localized areas of the subbasin. (DWR 2004)

In 1986, DWR published a study of the Alturas Basin (which includes the Warm Springs subbasin) groundwater quality. The study concluded that the general water quality of the Alturas Basin was good but there were some localized problems that were limiting the groundwater's beneficial use. The water quality issues were high concentrations of salts, sulfate, boron, and chloride. Most of the problem wells were wells that draw from the groundwater in the Alturas Formation and groundwater that migrates along faults. Table 4-35 displays the results of this study.

Table 4-35. Data from DWR Study of the Alturas Basin in 1986

Constituent Type	Constituent of Concern	Concentration ranges	Standards
Nutrients	Nitrate as N	0–38 mg/L, median is 4.2 mg/L (16 wells monitored)	10 (MCL)
Salt—primarily as electrical conductivity and total dissolved solids.		100–1,600 mg/L, median is 260 mg/L	500 (SMCL)
	Adjusted sodium adsorption ratio (ASAR)	0–23.9, 10 of 118 wells had values of 9 or greater	Ratio of 9 can cause severe problems with sodium buildup in soils
Trace elements	Boron	0–4.6 mg/L, median is 0.03 mg/L	
	Chloride	0–271 mg/L, median is 8 mg/L	250 (SMCL)
	Sulfates	0–626 mg/L, median is 16 mg/L	250 (SMCL)
Hardness		2–506 mg/L (as $CaCO_3$), median is 76 mg/L	

Notes:
MCL = Maximum Contaminant Level set by EPA (2005).
mg/L = milligrams per liter.
SMCL = Secondary Maximum Contaminant Level set by EPA (2005).

Discharge Pathways and Sources of Contaminants

The groundwater regime between Warm Springs Valley and South Fork Pit River Valley is continuous through a north-to-northwest trending highland, west and south of Alturas, that forms two distinct valleys with separate surface drainage.

Exposures of Warm Springs tuff in Sections 10 and 15, Township 42 North, Range 11 East, act as a partial barrier to the westward movement of groundwater from South Fork Pit River Valley to Warm Springs Valley (DWR 1963).

The Alturas Groundwater Basin is utilized for irrigation. In 1979 DWR estimated pumpage of groundwater to be about 4,400 acre-feet (DWR 1986). The movement of groundwater through the Alturas Basin generally follows the topography.

From the confluence of the North and South Forks of the Pit River, just to the east at Alturas, the Pit River flows westerly through Warm Springs Valley. DWR (1986) states that the Pit River and its tributaries generally recharge the groundwater basin and therefore would not be a pathway for groundwater contaminant transport.

Management Practices

Pasture land comprised 21% of the land uses in Warm Springs Valley subbasin. Brush encroachment in rangelands can be controlled by removal of brush through controlled burns and/or mechanical and chemical treatment. Controlled burning in rangeland has been practiced in for a number of years both to improve grazing lands and reduce fire hazards. Herbicide application has been used to control brush as well.

Assessment of Data Adequacy and Need for Added Data

There is little water quality data available for Warm Springs Valley subbasin. From DWR Bulletin 118 there does not appear to be any human-induced impairments in this groundwater subbasin.

American Valley Basin

General Basin Parameters

Acreage, Physiography

The American Valley Basin is 11 mi^2 in size and is located in Plumas County. The following information about the physiography and hydrogeology of the basin is taken from DWR Bulletin 118 (2004). The American Valley Groundwater Basin is bounded to the southwest and northeast by a northwest trending fault system. The basin is bounded to the northeast by Paleozoic metavolcanic rocks and is bounded on all other sides by Paleozoic marine sedimentary and meta-sedimentary rocks of the Sierra Nevada Mountains. Spanish Creek drains the valley and is tributary to the North Fork Feather River to the northwest.

Hydrogeologic information was not available for the Water-Bearing Formations and groundwater level Trends for the American Valley Basin. Storage capacity is estimated to be 50,000 acre-feet for a saturated depth interval of 10–210 feet.

Well yields for municipal/irrigation wells in the basin average 40 gal/min, based on 2 well completion reports. Total depths of domestic wells range from 20 to 561 feet, with an average of 127 feet, based on 286 well completion reports. Total depths of municipal/irrigation wells range from 44 to 250 feet, with an average of 125 feet, based on 15 well completion reports. According to a 1997 DWR survey of land use and sources of water, the estimated groundwater extraction for municipal and industrial uses in the American Valley Basin is estimated to be 1,400 acre-feet. Deep percolation of applied water is estimated to be 800 acre-feet.

Major Sources of Recharge

The primary source of groundwater recharge is precipitation ranges from 43 to 49 inches per year, increasing to the southwest.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1997. Agricultural land use accounts for over 42% of the subbasin, urban land use accounts for about 20% of the subbasin, and native land accounts for about 37% of the subbasin. Table 4-36 provides details on the distribution of land use throughout the American Valley Basin.

Table 4-36. Land Use in the American Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Deciduous Fruits and Nuts	3	0.05
Pasture	2,857	42.02
Semiagricultural and Incidental	33	0.49
Subtotal	2,893	42.55
Urban		
Commercial	136	2.01
Industrial	235	3.45
Urban Residential	931	13.69
Vacant	63	0.93
Subtotal	1,365	20.08
Native		
Riparian	226	3.32
Native Vegetation	2,303	33.88
Water	12	0.17
Subtotal	2,541	37.37
Total	**6,799**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

There are no known groundwater management plans, groundwater ordinances, or basin adjudications for the American Valley Groundwater Basin. Public water agencies in the basin include Quincy Community SD and East Quincy Services District. This basin falls with the area included in the Upper Feather Upper Yuba Coalition.

Water Quality

Between 1994 and 2000, groundwater in the American Valley Basin was sampled for primary inorganics, radiologicals, nitrates, pesticides, VOCs and SVOCs, and secondary inorganics, as required under DHS Title 22 program. VOCs/SVOCs were detected at concentrations above the MCL in 1 of 13 wells sampled, and secondary inorganics were detected above the MCL in 7 of 29 wells sampled. Primary inorganics, radiologicals, nitrates, and pesticides were not detected above the MCL in any of the wells sampled (DWR 2004).

Discharge Pathways and Sources of Contaminants

Groundwater generally discharges to Spanish Creek and groundwater wells.

Management Practices

Miscellaneous water quality parameters are monitored by DWR in 4 wells bi-yearly and by DHS in 11 wells. We found not documentation of practices for protection of groundwater quality or information about how current practices affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

The available data is generally inadequate for assessing effects of agricultural practices on groundwater quality.

Antelope Creek Basin

General Basin Parameters

Acreage, Physiography

The area of the Antelope Creek Groundwater Basin is 3 mi^2 (2,040 acres) and it is located in Colusa County. The following description of the hydrogeology in the basin is taken from DWR Bulletin 118 (2004).

The Antelope Creek Groundwater Basin is located east of Black Mountain in Antelope Valley. The basin consists of Quaternary alluvium and is bounded on all sides by Upper Cretaceous marine deposits. Several northeast trending faults may transect the valley. The basin is drained to the north by Antelope Creek.

Hydrologic information was not available from DWR for the water-bearing formations, groundwater level trends, and groundwater storage in the basin. Based on a 1993 DWR survey of land use and water sources, groundwater extraction for municipal/industrial use is estimated to be 2 acre-feet. Deep percolation of applied water is estimated to be 1 acre-foot.

Major Sources of Recharge

Annual precipitation is approximately 18 inches and is the primary source of recharge in the basin.

Land Use

Land use surveys were conducted within the basin by DWR in 1998. Agricultural land use accounts for about 3% of the basin, urban land use accounts for about 3% of the basin, and native land accounts for about 94% of the basin. Table 4-37 provides details on the distribution of land use throughout the Antelope Creek Basin.

Table 4-37. Land Use in the Antelope Creek Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Grain and Hay	97	4.77
Subtotal	97	4.77
Urban		
Urban Residential	30	1.48
Subtotal	30	1.48
Native		
Native Vegetation	1,912	93.69
Water	1	0.07
Subtotal	1,913	93.75
Total	**2,041**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Colusa County adopted a groundwater management ordinance for the Antelope Creek Basin in 1998. There are no public or private water agencies in the basin. This basin falls with the area included in the Colusa Coalition.

Water Quality

We were unable to find any water-quality information for this basin.

Discharge Pathways and Sources of Contaminants

The basin is drained to the north by Antelope Creek.

Management Practices

We were unable to find any information about management practices for preventing water-quality degradation or how agriculture affects groundwater quality.

Assessment of Data Adequacy and Need for Added Data

There is no available data for groundwater quality in this basin.

Ash Valley Basin

General Basin Parameters

Acreage, Physiography

The Ash Valley Groundwater Basin is an alluvial filled valley located within a region of northwest trending faults. The basin is bounded to the east and west by Miocene basalt, to the north by Pliocene basalt, and to the north by Tertiary pyroclastic rocks and Pliocene basalt. The valley is drained to the northwest by Ash Creek. The area of the basin is 4,870 acres and is located in northeastern Lassen County.

DWR estimated the groundwater extraction for the Ash Valley Basin from a 1997 survey. The survey included land use and sources of water. Groundwater extraction for municipal and industrial uses was estimated to be 3 acre-feet annually. Deep percolation of applied water was estimated to be 560 acre-feet annually.

Major Sources of Recharge

Recharge to the basin is from infiltration of precipitation and irrigation. Annual precipitation in the valley ranges from 17 to 21 inches, increasing to the north. Deep percolation of applied water was estimated to be 560 acre-feet by DWR in 1997. The valley is drained to the northwest by Ash Creek.

Land Use

Land use surveys were conducted within the basin by DWR in 1997. Agricultural land use accounts for about 37% of the basin and native land accounts for about 63% of the basin. There is no urban land in the Ash Valley basin. Table 4-38 provides details of the land uses within the basin.

Table 4-38. Land Use in the Ash Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Pasture	2,250	37.40
Subtotal	2,250	37.40
Native		
Native Vegetation	3,750	62.40
Water	10	0.20
Subtotal	3,760	62.60
Total	**6,010**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Lassen County enacted a groundwater ordinance in 1999 that requires a permit for groundwater exported from the county. No known groundwater management plans or basin adjudications. This basin falls with the area included in the Pit River Coalition.

Water Quality

We were unable to identify groundwater quality data in this basin.

Discharge Pathways and Sources of Contaminants

We were unable to identify groundwater discharge pathways or information about sources of contamination.

Management Practices

We were unable to find information about how management practices affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

We were unable to identify groundwater quality data in this basin.

Bear Valley Basin

General Basin Parameters

Acreage, Physiography

The Bear Valley Groundwater Basin is an elongated north-south trending valley located adjacent to the Stony Creek Fault. The basin consists of Quaternary alluvium bounded by Mesozoic lower Cretaceous marine sedimentary rocks and the Knoxville Formation (Jennings 1960). The basin is located in Colusa County and is 9,110 acres (14 mi^2) in size.

DWR (2004) estimated groundwater extraction and percolation of applied water based on a 1993 survey. Groundwater extraction for municipal and industrial uses is estimated to be 5 acre-feet. Deep percolation of applied water is estimated to be 200 acre-feet.

Major Sources of Recharge

Recharge to the basin is from infiltration of precipitation, infiltration of irrigation water and stream infiltration. Annual precipitation ranges from 21 to 23 inches. Deep percolation of applied water is estimated by DWR (based on a 1993 survey) to be 12 acre-feet. The basin is drained to the south by Bear Creek. Other creeks in the basin are Mill Creek, Trout Creek, Rathbone Creek, Arrasatre Creek, Metcalf Creek, and Grout Creek.

Land Uses

Land use surveys were conducted within the basin by DWR in 1998. Agricultural land use accounts for about 6% of the basin and native land use accounts for about 94% of the basin. Table 4-39 provides details of the land uses within the Bear Valley basin.

Table 4-39. Land Use in the Bear Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Grain and Hay	120	1.32
Pasture	380	4.17
Semiagricultural and Incidental	10	0.11
Subtotal	510	5.59
Native		
Native Vegetation	1,380	97.87
Barren and Wasteland	50	0.55
Subtotal	8,610	94.41
Total	**9,120**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Colusa County enacted a groundwater ordinance in 1998. This ordinance limits the amount of groundwater exported from the county. There are no cities and no water agencies in the Bear Valley Basin. This basin falls with the area included in the Colusa Coalition.

Water Quality

We were unable to identify groundwater quality data in this basin.

Discharge Pathways and Sources of Contaminants

We were unable to identify groundwater discharge pathways or information about sources of contamination.

Management Practices

We were unable to find information about how management practices affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

We were unable to identify groundwater quality data in this basin.

Berryessa Valley Basin

General Basin Parameters

Acreage, Physiography

The Berryessa Valley Basin aquifer system is 2 mi^2 in size and is located in Napa County. The following description of the hydrogeology in the Berryessa Valley Basin is taken from DWR Bulletin 118 (2004). The Berryessa Valley Basin is located on the eastern shores of Lake Berryessa in a sparsely populated region of Napa County along the western flanks of Rocky Ridge in the Coast Ranges, approximately 14 miles northwest of the town of Winters. Two narrow swaths of shallow alluvium along the banks of Lake Berryessa, each about 2.5 miles in length, define the basin. This alluvium extends into the lower elevations of the Berryessa Valley, which was flooded by Lake Berryessa after the construction of Monticello Dam in 1957.

Putah Creek, which flows into Lake Berryessa, is the primary surface water source for the Berryessa Valley, other than the lake. Additionally, several intermittent streams flow into Berryessa Valley Basin from the east. The basin is located within the Upper Putah Creek watershed.

Water Bearing Formations include Alluvium, described as poorly sorted stream and basin deposits. Beneath the alluvium lies the basement rock of the Lower Cretaceous Great Valley Sequence, comprised of marine mudstone, sandstone, and conglomerate. This basement rock is generally considered to be non-water bearing, but it does provide water through fractures.

No information related to groundwater level trends was available for this basin, however it can be generally assumed that the groundwater level elevation mimics the lake surface elevation.

Major Sources of Recharge

The Berryessa Valley Basin receives approximately 18 inches to 24 inches of precipitation annually (DWR 2004) and this is the major source s of groundwater recharge. There is also stream recharge.

Land Use

Most of the lands in the Napa County area are low intensity brushlands, rangelands, and lands used in years past for quicksilver and gold mining (Sac Coalition, Napa 2004). Wine grape production encompasses the majority of intensive agricultural acreage in the county, with olive production providing the balance. The majority of land in wine grape and olive production is probably irrigated. Drip irrigation is almost exclusively the mode of water delivery to these crops, although a small percentage of lands utilize overhead sprinklers for early spring frost protection in wine grapes. Dryland pastures and oat hay acreages exist in the county as well. None of these lands are irrigated.

Land use surveys were conducted within the basin by DWR in 1999. Agricultural land use accounts for less than 1% of the basin, and native land use accounts for about 99% of the basin. Table 4-40 provides details on the distribution of land use throughout the Berryessa Valley Basin.

Table 4-40. Land Use in the Berryessa Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Semiagricultural and Incidental	11	0.80
Subtotal	11	0.80
Native		
Native Vegetation	1,159	84.30
Water	205	14.90
Subtotal	1,159	99.20
Total	**1,170**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

There is currently no groundwater management plan in effect for the Berryessa Valley Basin. No public or private water agencies exist within the basin. This basin falls with the area included in the Lake Napa Coalition.

Water Quality

We were unable to find information for groundwater quality in the Berryessa Groundwater Basin.

Discharge Pathways and Sources of Contaminants

There is no information for pathways and sources of contaminants. Discharge pathways probably include flow to Putah Creek.

Management Practices

Average annual application of irrigation waters varies from about 2 inches to 8 inches per acre. Nearly all winegrape producers practice “deficit irrigation”, under the recommendations of UC California researchers. This management scheme accounts for the relatively low irrigation applications, which are intended to boost wine grape quality (Sac Coalition, Napa 2004). We were unable to find information about management practices for prevention of groundwater quality degradation.

Assessment of Data Adequacy and Need for Added Data

We found no groundwater quality data in this basin.

Big Valley (5-15) Basin

General Basin Parameters

Acreage, Physiography

The Big Valley Basin is bordered by Plio-Pleistocene extrusive rocks of Mt. Konocti and Camelback Ridge on the east and southeast, the Jurassic-Cretaceous Franciscan Formation to the west and south, and Clear Lake to the north. The basin shares a boundary with the Scott Valley Basin to the northwest and may be hydrologically contiguous. The basin area is 38 mi^2 and it is located in Lake County.

The following description of the hydrogeology in the Big Valley Basin is taken from DWR Bulletin 118 (2004). For the purpose of this basin summary, the valley has been divided into five subbasins based on geologic conditions, groundwater boundaries, and topography. These areas are referred to as the Western Upland, the Adobe Creek-Manning Creek Subbasin, the Kelseyville Subbasin, the Central Upland and Upper Big Valley Subbasin, and the Cole Creek Upland.

The Western Upland is a one-half to one-mile wide topographic bench located along the western margin of the basin. The Adobe Creek - Manning Creek Subbasin is located east of the Western Upland, extends north to the Big Valley Fault, and is hydrologically connected to the Kelseyville Subbasin. The Kelseyville Subbasin is located north of the Big Valley Fault and extends north to Clear Lake. The Central Upland and Upper Big Valley Subbasin includes the eastern half of the basin south of the Big Valley Fault and is geologically similar to the Western Upland but is separated topographically by the Adobe Creek—Manning Creek Subbasin and separated structurally by the Adobe Creek Fault system. The Cole Creek Upland is located east of the Central Upland and Upper Big Valley system and is bounded to the north by the Mt. Konocti volcanics and to the south by Camel Back Ridge.

The Big Valley Basin is comprised of extensive Quaternary to late Tertiary alluvial deposits, including fan deposits, lakebed and flood plain deposits, and terrace uplands. The primary water-bearing formations in the basin are Quaternary alluvium, lake, and terrace deposits and Upper Pliocene to Lower Pleistocene volcanic ash deposits.

Surface distribution of younger alluvium is observed throughout the Adobe Creek—Manning Creek and Kelseyville aquifer systems. The younger alluvium generally extends to depths of 40–90 feet and consists of alternating strata of gravel, sand, silt, and clay. Alluvial fan deposits extend from the eastern boundary to the northeast-southwest trending Adobe Creek Fault Zone.

Quaternary terrace deposits are observed south of the east-west trending Wight Way Fault system and along the western margin of the valley within the Western Upland. The deposits consist of red-brown, poorly stratified, sand, clay, and moderately well rounded gravels. Permeability of the formation is generally low. The deposits range in thickness from 50 to 100 feet.

Plio-Pleistocene lake deposits underlie all terrace deposits and younger alluvium in most places. The deposit consists of blue clay with alternating strata of shale and limestone. Permeability of the formation is generally low; however, groundwater flow through sedimentary strata and volcanic deposits can be significant. Thickness of the formation ranges up to 500 feet.

An unconsolidated coarse ash deposit ranging in depth from 70 to 240 feet has been encountered in a number of wells. The volcanic ash is a thin bed of lithic tuff confined within older semi-consolidated sediments and occupies the Western Upland, Adobe Creek-Manning Creek, and most of the Central Upland and Upper Big Valley aquifer system situated south of the Big Valley Fault. The ash layer is offset by the northeast/southwest trending Adobe fault system. Groundwater contained within the deposit is confined with pressure heads ranging from 100 to 150 feet. Thickness of the deposit averages 2 feet.

Groundwater levels in the Big Valley Basin tend to fluctuate from 5 to 15 feet in normal and dry years. There is no consistent decreasing trend in the aquifer levels; however, there are identified locations where overdraft conditions have occurred during drought years (Big Valley Plan 1999). DWR (2004) estimated the storage capacity (to a depth of 100 feet) to be 105,000 acre-feet. Useable storage is estimated to be 60,000 acre-feet. Estimates of groundwater extraction for agricultural and municipal/industrial uses are 24,000 and 410 acre-feet respectively. Deep percolation from applied water is estimated to be 5,600 acre-feet (DWR 2004).

Major Sources of Recharge

According to DWR (2004), recharge in the northern portion of the Big Valley Basin is primarily infiltration from Kelsey Creek and by underflow from the Adobe Creek-Manning Creek Subbasin. Underflow occurs mainly from more permeable zones at depths of 25–45 feet and 70–90 feet. A limited amount of underflow probably enters the basin from the Central Upland system and from Mt. Konocti. Some recharge by infiltration of rain, applied water, and creek water occurs in areas other than the Kelsey Creek flood plain; however, direct surface recharge is inhibited by clayey soil and the near surface clay layer. Recharge within the Adobe Creek-Manning Creek Subbasin is from percolation from the channels of Highland and Adobe Creeks and from underflow from the Western Upland and Central Upland areas. Precipitation in the basin ranges from 22 to 35 inches annually, decreasing to the northeast.

Land Use

Land use surveys were conducted within the basin by DWR in 2001. Agricultural land use accounts for about 43% of the basin, urban land use accounts for about 1% of the basin, and native land accounts for about 56% of the basin. Table 4-41 provides details on the distribution of land use throughout the Big Valley Basin.

Table 4-41. Land Use in the Big Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Grain and Hay	7,501	8.15
Idle	4,648	5.05
Pasture	25,794	28.02
Rice	933	1.01
Semiagrcultural and Incidental	634	0.69
Truck, Nursery, and Berry Crops	45	0.05
Subtotal	39,555	42.96
Urban		
Urban—unclassified	302	0.33
Commercial	19	0.02
Industrial	266	0.29
Urban Landscape	28	0.03
Urban Residential	242	0.26
Vacant	16	0.02
Subtotal	873	0.95
Native		
Riparian	6,056	6.58
Native Vegetation	44,731	48.59
Water	853	0.93
Subtotal	51,640	56.09
Total	**92,067**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Lake County adopted a groundwater management ordinance and an AB3030 groundwater management plan in 1999. A key element of the Lake County ordinance is the requirement of an export permit for groundwater extraction and substitute pumping (DWR 2004). The County of Lake is the only public water agency within the Big Valley Basin (DWR 2004).

In 1992, Lake County adopted the Lake County Aggregate Resource Management Plan (ARMP), which updates and replaces the Creek Management Plan of 1981. The purpose of these plans is to limit in-channel gravel mining activities that compromise groundwater storage capacity and groundwater recharge to the aquifer (Big Valley Plan 1999).

Lake County adopted County Ordinance No. 1823 in 1989 that sets minimum standards for the construction of water wells and requires destruction of unused wells in a manner that adequately protects the source aquifer.

This basin falls with the area included in the Lake Napa Coalition.

Water Quality

The groundwater chemistry in the Big Valley Basin is predominantly magnesium bicarbonate. TDS ranges from 270 to 790 mg/L, averaging 535 mg/L. High levels of boron are present in groundwater along the eastern, southern, and northern perimeters of the valley, at concentrations that may be injurious to crops. (DWR 2004, 1975.) Elevated levels of iron and boron have been detected in groundwater adjacent to faults that underlie the aquifer and are believed to be the result of intrusion of geothermal waters (Big Valley Plan 1999). Boron and iron levels tend to be higher in the fall when groundwater levels are lower.

Contaminated groundwater has not been documented in the aquifer (Big Valley Plan 1999), however, analysis in 1993 showed some increases in nitrate levels in individual wells. The nitrate source or contamination trends were not identified due to an insufficient number of wells analyzed.

Secondary inorganics were detected at concentrations above the MCL in 6 of 8 public supply wells sampled by DWR (2004). There were no detections above the MCL in the public supply wells sampled for primary inorganics, radiologicals, nitrates, pesticides, or VOCs/SVOCs.

Discharge Pathways and Sources of Contaminants

The Big Valley Basin is drained by Adobe Creek (DWR 1975), which is a major groundwater discharge mechanism. Groundwater is also pumped for crop water use.

Management Practices

Groundwater levels have been monitored by DWR in 16 wells semi-annually (April and October), and by Lake County in 49 wells on a monthly basis. DWR monitors 11 wells biennially for miscellaneous water quality parameters, and the DHS and its coordinators monitor 7 wells for Title 22 water quality parameters (sampling frequency not specified) (DWR 2004).

According to the Sacramento River Watershed Evaluation Report (Sac Coalition 2004), agricultural producers in Lake County integrate best management practices (BMPs) including engineered drainage systems, cover crops, soil erosion prevention programs and buffer zones. Chemical Application Methods are almost exclusively ground sprayer or chemigation. Virtually all producers use Pest Control Advisors (PCAs) that monitor orchard and vineyard pest populations and make formal written recommendations to control damaging pests. All PCAs are registered with the State of California.

Assessment of Data Adequacy and Need for Added Data

Available data indicates some groundwater quality degradation due to pesticides and fertilizers. More information is required to identify specific land use, hydrologic conditions and management practices that contribute to groundwater quality degradation.

Big Valley Basin (5-4)

General Basin Parameters

Acreage, Physiography

The Big Valley groundwater basin is located in Modoc and Lassen Counties and encompasses 92,000 acres. It is a broad flat plain extending about 13 miles north-to-south and 15 miles east-to-west consisting of a series of depressed fault blocks surrounded by tilted fault block ridges. The basin is bounded to the north and south by Pleistocene and Pliocene basalt and Tertiary pyroclastic rocks of the Turner Creek Formation, to the west by Tertiary rocks of the Big Valley Mountain volcanic series, and to the east by the Turner Creek Formation.

The following description of the hydrogeology in the Big Valley Basin is taken from DWR Bulletin 118 (DWR 2004). The primary water-bearing formations in Big Valley are Holocene sedimentary deposits, Pliocene and Pleistocene lava flows, and the Plio-Pleistocene Bieber Formation.

The Holocene sedimentary deposits include basin deposits, intermediate alluvium, and alluvial fans - each having a thickness of up to 150 feet. Basin deposits, located predominately in lowlying areas in the central part of the valley, consist of unconsolidated interbedded clay, silt, and organic muck, all having low permeability. These deposits are not considered to be a significant water-bearing formation. Intermediate alluvium, found along the perimeter of the valley, consists of unconsolidated silt and sand with some clay and gravel. These deposits are generally moderately permeable with gravel zones being highly permeable. Alluvial fans consist of unconsolidated poorly stratified silt, sand, and gravel with some clay lenses. Because the fans occur in only a few small areas, they are not considered a significant source of water. Locally they may yield moderate amounts of water to wells.

Pliocene volcanic rocks consist of jointed and fractured basalt flows occurring to the north and south of Big Valley. Deposits range in thickness to 1,000 feet. The lavas are moderately to highly permeable and serve as recharge areas in the uplands and contain unconfined and confined zones in the valley.

Pleistocene volcanic rocks consist of jointed and fractured basalt flows having moderate to high permeability. Deposits range from 50 to 150 feet thick. These flows serve as recharge areas and yield moderate to large amounts of confined and unconfined groundwater to wells in the southern part of the valley.

The Bieber Formation consists of lake deposited diatomite, clay, silt, sand, and gravel. These interbedded sediments are unconsolidated to semi-consolidated and are moderately permeable. The formation ranges in thickness from 1,000 to 2,000 feet and underlies all of Big Valley. The principal water-bearing zones consist of white pumiceous sand and black volcanic sand and yield large amounts of water to wells where there’s sufficient thickness and continuity.

Water levels of the confined aquifer system declined 12–15 feet during the period between the mid-1980s and the early 1990s. Water levels through 1999 had recovered 10–12 feet.

Storage capacity for the Big Valley Groundwater Basin is estimated to be 3,750,000 acre-feet to a depth of 1,000 feet (DWR 1963). DWR (1963) notes that the quantity of useable water in storage is unknown. DWR estimates groundwater extraction for agricultural and municipal/industrial uses to be 29,000 and 300 acre-feet, respectively. This estimate is based on surveys conducted by the DWR during 1997.

Major Sources of Recharge

Recharge to the Basin is from precipitation, irrigation infiltration, and surface water infiltration. The average annual precipitation ranges from 13 to 17 inches. Deep percolation of applied water is estimated by DWR (2004) to be 7,900 acre-feet. The Pit River is the major river passing through Big Valley. Big Swamp and several other reservoirs lie in the Valley.

Land Use

Land use surveys were conducted within the subbasin by DWR in 1999. Big Valley Basin is overlain with 43% agricultural land use, 28% of which is rangeland (pasture). Urban land uses make up about 1% and native land comprise 56% of the Basin. Table 4-42 provides details of the land uses within the basin.

Table 4-42. Land Use in the Big Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agricultural		
Grain and Hay	7,501	8.15
Idle	4,648	5.05
Pasture	25,794	28.02
Rice	933	1.01
Semiagricultural and Incidental	634	0.69
Truck, Nursery, and Berry Crops	45	0.05
Subtotal	39,555	42.96
Urban		
Urban—unclassified	302	0.33
Commercial	19	0.02
Industrial	266	0.29
Urban Landscape	28	0.03
Urban Residential	242	0.26
Vacant	16	0.02
Subtotal	873	0.95
Native		
Riparian	6,056	6.58
Native Vegetation	44,731	48.59
Water	853	0.93
Subtotal	51,640	56.09
Total	**92,067**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Modoc County adopted a groundwater ordinance in 2000. Groundwater ordinances generally affect the volume of groundwater that can be pumped and/or exported from the basin. A key element of the Modoc County ordinance requires an export permit for groundwater transferred out of the basin (DWR 2004). Public water agencies involved with the basin are the Lassen County WD No. 1. Lassen-Modoc County Flood Control and Water Conservation District. This basin falls with the area included in the Pit River Coalition.

Water Quality

Sodium-magnesium bicarbonate and sodium bicarbonate type waters are present in the basin. The concentration of TDS ranges from 141 to 633 mg/L, averaging 260 mg/L.

Two hot springs and one well with sodium sulfate type water have been identified in the basin east of Bieber. There are high concentrations of nitrates, manganese, fluoride, iron, sulfate, conductivity, calcium, adjusted sodium absorption ratio, and TDS in localized areas of the basin. Some groundwater has high concentrations of ammonia and phosphorus.

Discharge Pathways and Sources of Contaminants

The Pit River flows through Big Valley Basin, entering in the northeast and exiting to the southwest and represents the major discharge mechanism. Groundwater also discharges from wells for crop water use.

Management Practices

Pasture land comprises 53% of the land uses in Big Valley Basin. Brush encroachment in rangelands can be controlled by removal of brush through controlled burns and/or mechanical and chemical treatment. Controlled burning in rangeland has been practiced in for a number of years both to improve grazing lands and reduce fire hazards. Herbicide application has been used to control brush as well.

Assessment of Data Adequacy and Need for Added Data

There is little water quality data available for Big Valley Basin. From DWR Bulletin 118, there does not appear to be any groundwater wells that exceed federal or State standards.

Blanchard Valley Basin

General Basin Parameters

Acreage, Physiography

The Blanchard Valley Groundwater Basin is 3 mi^2 (2,200 acres) in size and is located in Colusa County. The following description of the hydrogeology in the basin is taken from DWR Bulletin 118 (2004). The Blanchard Valley

Groundwater Basin consists of two elongated north-south trending subbasins located in Antelope Valley. Both subbasins are bounded on all sides by Upper Cretaceous marine deposits.

Additional hydrologic information was not available from DWR for the water-bearing formations, groundwater level trends, and groundwater storage in the basin. Based on a 1993 DWR survey of land use and sources of water, groundwater extraction for municipal/industrial use in the Blanchard Valley Basin is estimated to be 2 acre-feet. Deep percolation of applied water is estimated to be 1 acre-foot.

Major Sources of Recharge

Annual precipitation is approximately 21 to 23-inches and is the primary source of groundwater recharge.

Land Uses

Land use surveys were conducted within the subbasin by DWR in 1998. Agricultural land use accounts for about 10% of the subbasin and native land accounts for about 90% of the subbasin. Table 4-43 provides details on the distribution of land use throughout the Blanchard Valley Basin.

Table 4-43. Land Use in the Blanchard Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Grain and Hay	231	10.40
Subtotal	231	10.40
Native		
Native Vegetation	1,983	89.22
Water	8	0.38
Subtotal	1,992	89.60
Total	**2,223**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Colusa County adopted a groundwater management ordinance in 1998. There are no public or private water agencies in the basin. This basin falls with the area included in the Colusa Coalition.

Water Quality

We could find no information for groundwater quality for this basin.

Discharge Pathways and Sources of Contaminants

We were unable to identify groundwater discharge pathways or information about sources of contamination.

Management Practices

We were unable for find any information for management practices directed at reducing agricultural impacts of groundwater quality.

Assessment of Data Adequacy and Need for Added Data

We did not identify any groundwater quality data.

Burney Creek Valley Basin

General Basin Parameters

Acreage, Physiography

The Burney Creek Valley Groundwater Basin is bounded to the west by north trending faults. The basin is bounded on all sides by Pleistocene basalt. Burney Creek drains the valley to the north. The area of the basin is 2,350 acres and is located in eastern Shasta County. The water-bearing formation in the basin consists of Quaternary lake deposits. Groundwater extraction for municipal and industrial uses is estimated by DWR (2004) to be 790 acre-feet.

The 1984 DWR study of the Eastern Upland area of Shasta County showed potential groundwater supply limitations in the area north of State Highway 299 in the Eastern Upland planning area.

Major Sources of Recharge

Recharge to the Burney Creek Valley aquifer is mostly by infiltration precipitation into the alluvium. Annual precipitation is about 27 inches. DWR

(2004) estimated recharge by deep percolation of applied water is estimated to be 490 acre-feet.

Land Use

Land use surveys were conducted within the basin by DWR in 1999. The foothills situated in the Eastern Upland region of Shasta County, which contains Burney Creek Valley basin contain a high percent of rangelands. Of the 60% land uses that are agricultural in this basin, 41% is pasture. Fifteen percent of the basin is urban and 25% is native. Table 4-44 provides details of the land uses within the basin.

Table 4-44. Land Use in the Burney Creek Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Idle	430	18.30
Pasture	970	41.28
Semiagricultural and Incidental	10	0.43
Subtotal	1,410	60.00
Urban		
Urban—unclassified	320	13.62
Urban Residential	30	1.28
Vacant	10	0.43
Subtotal	360	15.32
Native		
Riparian	10	0.43
Native Vegetation	570	24.26
Subtotal	580	24.68
Total	**2,350**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Shasta County adopted a groundwater management ordinance in 1998. This ordinance requires a permit for groundwater exportation from the county. Along with Shasta County, the Burney Water District is the only water agency that manages the water in the Burney Creek Valley basin. This basin falls with the area included in the Pit River Coalition.

Water Quality

There is insufficient water quality data available to determine the effects of irrigated agriculture.

Discharge Pathways and Sources of Contaminants

Groundwater discharges to wells for irrigation.

Management Practices

Herbicide application has been used to control brush. We did not identify information about the relation of management practices and groundwater quality.

Assessment of Data Adequacy and Need for Added Data

There is no water quality data available for Burney Creek Valley basin. Based on information in the Shasta County General Plan, there do not appear to be groundwater quality problems.

Burns Valley Groundwater Basin

General Basin Parameters

Acreage, Physiography

The area of Burns Valley Basin is 4 mi^2 and it is located in Lake County. The following description of the physiography and hydrogeology in the Burns Valley Basin is taken from DWR Bulletin 118 (2004).

Burns Valley Basin is located along the southeastern edge of Clear Lake and consists of low-lying alluvial plains and upland terrace deposits. The basin is bounded by basalt flows to the northwest and the Plio-Pleistocene Cache Formation on all other sides with the exception of Olivine basalt to the southeast. The west side of the basin opens to Clear Lake. The Cache Formation underlies the majority of the basin. Assuming that there is hydraulic continuity between the alluvium and the Cache Formation, groundwater is in hydraulic continuity in all directions beyond the alluvial plain with the exception being to the northwest. Basement rock consists of the Jurassic-Cretaceous Franciscan Formation and volcanics.

Quaternary alluvium, upland terrace deposits, and the Plio-Pleistocene Cache Formation are the primary water-bearing deposits in the valley. Lowlands in the valley are composed of stream channel gravel and adjacent floodplain deposits of several unnamed creeks. The Quaternary alluvium of the lowland deposits is composed of silt, sand, and gravel. Its maximum thickness at the lower end of the valley is approximately 50 feet. Groundwater is essentially unconfined and yields water for domestic use.

On either side of the alluvial plain are remnants of a least two levels of terrace deposits. The deposits are approximately 15 feet above the valley floor and slope up the valley and merge with the Cache terrain. The deposits consist almost entirely of clastic debris from the Cache formation.

Plio-Pleistocene Cache formation deposits underlie all alluvial and terrace deposits. The formation is largely made up of lake deposits with the potential for included stream deposits. The formation consists of fine sands, silts, and thin interbeds of marl and limestone to a thickness of 200 feet. Near the top of the formation, water-laid tuffs and tuffaceous sands become dominant with intercalated clay, marl, limestone, and diatomite. The formation has low permeability and yields water to wells at rates up to a few hundred gallons per minute.

Storage capacity is estimated to be 4,000 acre-feet based on an area of 1,000 acres, a saturated thickness of 50 feet, and a specific yield of 8%. A 1960 estimate of useable storage capacity is 1,400 acre-feet. Estimates of groundwater extraction for the Burns Valley Basin are based on a survey conducted by the DWR in 1995 (DWR 2004). The survey included land use and sources of water. An estimate of groundwater extraction for agricultural use is 900 acre-feet. Deep percolation from applied water is estimated to be 210 acre-feet.

Major Sources of Recharge

Almost all of the groundwater of Burns Valley is derived from rain that falls within a 12.5 square mile drainage area. Annual precipitation in the basin is approximately 27 inches. (DWR 2004.)

Land Uses

Land use surveys were conducted within the basin by DWR in 2001. Agricultural land use accounts for about 20% of the basin, urban land use accounts for about 17% of the basin, and native land accounts for about 63% of the basin. Table 4-45 provides details on the distribution of land use throughout the Burns Valley Basin.

Table 4-45. Land Use in the Burns Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Agriculture		
Deciduous Fruits and Nuts	382	13.30
Idle	31	1.08
Vineyards	169	5.88
Subtotal	582	20.26
Urban		
Commercial	48	1.68
Industrial	28	0.96
Urban Landscape	6	0.20
Urban Residential	401	13.96
Vacant	7	0.24
Subtotal	490	17.05
Native		
Native Vegetation	1,772	61.64
Water	30	1.05
Subtotal	1,802	62.69
Total	**2,875**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

Groundwater management for the Burns Valley Basin is under Lake County. Highland Mutual Water Company is the sole (private) water agency in the basin. This basin falls with the area included in the Lake Napa Coalition.

Water Quality

DWR monitors 5 wells biennially for miscellaneous water quality parameters. Groundwater in the basin consists of magnesium-calcium type waters. TDS ranges from 280 to 455 mg/L, averaging 335 mg/L. Groundwater in the basin has high sodium and iron concentrations. Locally high manganese, magnesium, calcium, and phosphorus also occur. High boron concentrations may be an issue for groundwater for agricultural irrigation. (DWR 2004, 1975.)

Discharge Pathways and Sources of Contaminants

We were unable to identify groundwater discharge pathways or information about sources of contamination.

Management Practices

Lake County monitors groundwater levels in a single well on a semi-annual basis in the Burns Valley Basin. According to the Sacramento River Watershed Evaluation Report (Sac Coalition 2004), agricultural producers in Lake County integrate BMPs including engineered drainage systems, cover crops, soil erosion prevention programs and buffer zones. Chemical Application Methods are almost exclusively ground sprayer or chemigation. Virtually all producers use PCAs that monitor orchard and vineyard pest populations and make formal written recommendations to control damaging pests. All PCAs are registered with the State of California.

Assessment of Data Adequacy and Need for Added Data

We were unable to find any information that indicates groundwater quality degradation due to agricultural irrigation.

Butte Creek Valley Basin

General Basin Parameters

Acreage, Physiography

The Butte Creek Valley groundwater basin is located in Lassen County and is 3,230 acres (5 mi^2) in size. The basin is located to the west of Crater Lake Mountain and to the northwest of Project Peak in southwest Lassen County. The basin is an alluvium filled valley bounded on all sides by Pleistocene basalt. Highway 44 (Feather Lake Highway) traverses the valley.

Major Sources of Recharge

Recharge to the basin is from precipitation, intermittent lake and stream infiltration and surface runoff. The average annual precipitation in the basin ranges from 17 to 19 inches.

Land Use

Land use surveys were conducted within the basin by DWR in 1997. Native vegetation comprises 99% of the basin, with industrial urban use occupying the remaining 1% of land. Table 4-46 provides details of the land uses within the basin.

Table 4-46. Land Use in the Butte Creek Valley Basin

Land Use	Acreage of Land Use	Percent of Land Use
Urban		
Industrial	30	0.93
Subtotal	30	0.93
Native		
Native Vegetation	3,200	99.07
Subtotal	3,200	99.07
Total	**3,230**	**100.00**

Coalitions, Water Districts, Major Urban Areas—Pertinent Ordinances or Regulations

There are no known groundwater management plans, groundwater ordinances, or basin adjudications. There are no water agencies in the basin. This basin falls with the area included in the Pit River Coalition.

Water Quality

We were unable to identify groundwater quality data in this basin.

Discharge Pathways and Sources of Contaminants

We were unable to identify groundwater discharge pathways or information about sources of contamination.

Management Practices

We were unable to find information about how management practices affect groundwater quality.

Assessment of Data Adequacy and Need for Added Data

We were unable to identify sufficient groundwater quality data in this basin. From DWR Bulletin 118 there does not appear to be any impairments in this groundwater basin.