APPENDICES

APPENDIX A
SUMMARY OF AGENCY MANAGEMENT PLANS FOR LANDS AND RESOURCES IN BEAR CREEK WATERSHED

Land and resource management plans, prepared by government agencies and non-governmental organizations for Bear Creek watershed, are important to this watershed assessment because they identify issues that bear on the entire watershed. The existing plans also outline land management activities currently underway on lands in the watershed.

Colusa County General Plan
The most recent Colusa County General Plan was completed in January 1989 and has a planning range extending to 2010. The Plan's Housing Element was updated 2004. The General Plan provides the basis for county decisions regarding growth and land development in Bear Creek watershed and elsewhere in Colusa County, with the intent of "encouraging economic development while managing growth, conserving agricultural lands, protecting the environment, and preserving the qualities that make Colusa County unique" (Plan pg 17). Continuity of current land uses and protection of the landscape quality are the principal focus of the General Plan for Bear Creek watershed. The County Plan assumes that population growth will be ten percent or less in the watershed for the plan period, with greater population growth, however, occurring just north of the watershed in the Stonyford-Lodoga area. The limited availability of water constrains economic and residential development. Dryland farming and grazing continue to be the most extensive land uses in Bear Valley. Elsewhere in the watershed, steeper rangeland and hillside areas are to remain undeveloped as well. Mineral extraction and geothermal developments are to be permitted if environmental studies conclude that projects pose no harm to other resources or may be mitigated.

The General Plan calls attention to current or likely issues in the watershed. Two issues are especially prominent in the Plan: (1) the need to maintain the existing county road structure in the face of ongoing fiscal limitations and associated safety issues; and (2) the potential for mining operations to alter the visual quality of the scenic Coast Range slopes in Bear Creek watershed. Increases in the prices of precious metals such as gold could spur reconsideration of the economic feasibility of mining at existing mine sites as well as exploration for new sites in the watershed. The Plan cites Bear Valley Buttes as meriting conservation for its significant habitat for raptor birds.

The County of Colusa Department of Building and Planning is currently preparing a new version of the General Plan.

Colusa County Resource Conservation District Long-Range Plan, 2008-2013

Colusa County Resource Conservation District (CCRCD) is a non-governmental organization that assists local landowners in the Bear Valley watershed and elsewhere in Colusa County to protect, conserve, and restore natural resources on their lands. In its mission to provide information and technical assistance to local landowners, CCRCD advocates for landowners to protect individual landowner's rights and supports local decision making for conservation planning that promotes social and economic sustainability for local communities. The CCRCD's current Plan (2008) addresses the following topics directly related to issues in Bear Creek watershed:

1. limiting sediment discharges into streams to protect water quality
2. protecting stream banks and establishing riparian buffer strips
3. eradicating and managing invasive species
4. promoting sound grazing practices
5. developing off-stream watering systems for livestock and wildlife
6. bringing together stakeholders to advance locally led conservation stewardship
7. facilitating creation of conservation easements on agricultural lands
8. assisting stakeholders in securing funding for conservation projects

The CCRCD actively promotes excellent resource management and improvement projects in Bear Creek watershed.

California State Lands Commission Management Plans

A management plan for the lands in Bear Creek watershed under jurisdiction of the California State Lands Commission is not currently in place. Management for these lands is based on individual environmental impact reports that govern changes in uses for Commission lands.

Land Management of Federal Public Lands

Federal laws commit the two federal agencies that manage public lands in Bear Creek watershed to multiple uses for the public lands. The direction for planning for multiple uses on federal public lands is set forth in the National Forest Management Act of 1976 for the US Forest Service and the Federal Land Policy and Management Act (FLPMA) of 1976 for the BLM. Striking the appropriate balance of land uses on public lands for the benefit of local and regional stakeholders and the American people as a whole is a core task for the federal land management agencies.

Mendocino National Forest Plan (1995, as amended in 2007)

The portion of the Mendocino National Forest within Bear Creek watershed lies entirely within the Sullivan Management Area (Area #4). Timber management for commercial harvest is not part of current National Forest System management for the lands inside the watershed. Management for recreation activity is at a low level because of the remoteness of the National Forest lands in the watershed. Designated recreational access and travel routes run along the watershed boundary on Love Lady Ridge. To the west and north of the watershed, in contrast, the Mendocino National Forest has created routes and recreation infrastructure to facilitate sustainable off-highway motorized recreation. Other recreational uses foreseen for the National Forest lands in Bear Creek watershed are game hunting and angling. Although technically part of the Little Stony grazing allotment, the portion of the Mendocino National Forest in Bear Creek watershed has topography and soils that do not supply suitable forage for livestock. The allotment has been inactive since 1999. No inholdings or permitted summer homes occur on the National Forest lands. No federally listed threatened or endangered or Forest Service sensitive animal species are known to occur in the area. A number of US Forest Service sensitive plant species are present or are potentially present. No US Forest Service wilderness areas, roadless areas, or Late Forest Successional Reserves are designated in Bear Creek watershed.

The Mendocino National Forest uses three key processes to implement its Forest Plan: interagency coordination, adaptive management, and watershed analysis (page V-1 of the Plan). Watershed analysis/assessment is the analytical process used as the technical basis for implementing ecosystem management.

Management activity for the area involves at present completion of an inventory of the existing trail system, designation of permanent off-highway vehicle (OHV) trails, rehabilitation of unauthorized trails to natural conditions, and closure of abandoned mines. Rehabilitation of closed OHV trails is a lower priority now because closed trails closer to roads at lower-elevation trails to the north and west merit attention first.

BLM Ukiah Field Office Resource Management Plan (2006)

The public lands in Bear Creek watershed managed by the Ukiah BLM Field Office belong to two management units: the Cache Creek Management Unit which includes all BLM lands south of or immediately adjacent to State Route 20; and the Indian Valley Management Unit which covers the public lands on the east side of Walker Ridge and on the west and north slopes of Bear Valley. The BLM Ukiah Field Office manages public lands under its Resource Management Plan (RMP) to balance recreational opportunities and environmentally responsible commercial activities with the conservation of natural and cultural resources. Overarching management goals that apply to Bear Creek watershed are (1) maintaining scenic quality and visual integrity of the diverse natural landscapes and ecosystems characteristic of the watershed and (2) inclusion of local communities and residents in conservation and sustainable uses of the BLM public lands appropriate to the landscapes and watersheds where the lands occur. Commercial timber harvesting and livestock grazing, except to promote native vegetation, are not currently part of management on lands in both management units. Habitat management for special status species, game and non-game species in upland and riparian areas, and non-motorized recreation opportunities are the major emphases for current management. Actions planned for the management units are described below.

Cache Creek Management Unit

1. Restoration of the Bear Creek riparian corridor south of Highway 20. The area does not currently meet BLM standards for proper functioning condition of riparian ecosystems as the result of infestations of non-native tamarisk (*Tamarix* spp.) shrubs that have altered the natural stream course and distribution of stream sediments.
2. Inventory and site documentation of cultural resources on newly acquired BLM Bear Creek Ranch.
3. Prescribed burning on a rotational basis to approximate natural fire intervals.
4. Closure to wind energy development and to fluid mineral leasing and other minerals-related economic activity, with a proposal for withdrawal from all future mining.
5. A comprehensive trail plan to integrate multiple types of dispersed, low-density recreation, including equestrian and mechanical recreation.
6. Further development of the Cowboy Camp trailhead for multiple-use public access.
7. Stabilization of headcuts and other erosion sites on Bear Creek and its tributaries.
8. Restoration of native fisheries in lower Bear Creek.

Indian Valley Management Unit

1. Identify areas with naturally occurring asbestos and any trails and roads that generate sediment and dust likely to contain asbestos.
2. Restrict infrastructure for telecommunications.
3. Collaborate with federal and state agencies to halt soil and water contamination from mercury created from human activities.
4. Prescribed fire on a small-scale for chamise and other chaparral species with high fuel loads.

In keeping with national energy priorities, the Field Office is considering all of the energy development potential on the public lands in the Indian Valley Management Unit. The RMP underscores that the Indian Valley Management Unit lands in the northern half of Bear Creek watershed are potentially available to energy and mining development in coming years. Geothermal energy is a possibility in the subwatersheds that drain to the east from Walker Ridge, at the eastern margin of the Geysers Known Geothermal Resource Area (KGRA). Oil and gas resources on BLM lands east of the Stony Creek Fault are classified as highly valuable and therefore potentially having future economic importance. Walker Ridge is an area of interest for the BLM Ukiah Field Office for the development of wind energy. The RMP does not contain specific plans for projects to develop energy resources.

BLM Cache Creek Coordinated Resource Management Plan (2004)

The Cache Creek Coordinated Resource Management Plan (CRMP) covers the Cache Creek Natural Area that spans Colusa, Lake, and Yolo counties. Specifically, for Bear Creek watershed, the CRMP covers the BLM Bear Creek Ranch. The CRMP lays the foundation for the management for the BLM public lands in the southern half of the watershed comprising the Cache Creek Management Unit Zones D and E (roughly equivalent to the Cache Creek Management Unit and a portion of the Indian Valley Management Unit in the 2006 BLM Ukiah Field Office RMP). The management prescriptions for the BLM Cache Creek Natural Area in the CRMP are incorporated as part of the BLM Ukiah Field Office RMP and are summarized in Appendix N of the RMP.

Work described in detail in the CRMP for the Bear Creek Ranch involves: final details of a non-motorized trail network design for multiple sport recreation activities; integrated pest management for control of upland weed species; elk herd management; prohibiting non-hunting shooting; creation or repair of permanent water sources; development of research sites to study weed control methods; and protection measures for rare plant species and Townsend's big-eared bat.

APPENDIX B

SUMMARY OF PLANS FROM REGULATORY AGENCIES FOR PUBLIC RESOURCES IN BEAR CREEK WATERSHED

Regulations are complex and often confusing for stakeholders. Landowners, land managers, and other stakeholders involved in Bear Creek watershed must comply with regulatory requirements established by Federal, State of California, and County of Colusa agencies. The regulations of interest in this watershed assessment govern protection and enhancement of water and air resources.

Water Resources

The impetus for preparing the watershed assessment for Bear Creek and its tributaries is the regulatory requirement for the watershed to meet water quality standards established by the US Environmental Protection Agency (US EPA), the California State Water Resources Control Board, and the Central Valley Regional Water Quality Control Board (CVRWQCB). This section discusses the laws and regulations regarding water from these agencies that apply to Bear Creek watershed.

Federal Clean Water Act

The Federal Clean Water Act of 1972, as amended, regulates the discharge of pollutants into surface waters. Under the Act, the US EPA:

1. sets national policies regarding control of industrial wastewater;
2. establishes minimum national standards for maximum allowable concentrations of contaminants in water (water quality standards); and
3. implements programs to control pollution caused by industrial wastewater.

The Clean Water Act delegates the authority for regulation and enforcement of water quality to the states. Clean Water Act sections that affect Bear Creek watershed are discussed in the following paragraphs.

<u>Section 303(d)</u>

Section 303(d) requires the State of California to identify “impaired” water bodies that do not meet water quality objectives and do not support uses of the water bodies. Every two years, the State of California submits an updated 303(d) list of Water Quality Limited Segments to the US EPA, citing the pollutant or stressor causing the impairment. The State also prioritizes and plans projects to address the impairment of water quality in these water bodies. In 2004, California promulgated its Water Quality Control Policy to provide a transparent, objective process to list water bodies as impaired. The current list of 303(d)-impaired water bodies in California includes Bear Creek and its tributary Sulphur Creek.

In cases where water quality objectives are not being met, the 303(d) List also identifies where a Total Maximum Daily Load (TMDL), established by the State and approved by US EPA, is required for a water body not now meeting water quality standards. A TMDL is defined as the largest concentration (load) of a pollutant allowed in a water body that still does not violate state water quality standards. California follows a five-step process to produce a regulatory TMDL:

1. Stakeholder involvement: all interested parties, including individual citizens, contribute input concerning TMDL development
2. Assessment of the water body to identify pollution sources, amounts, and overall effects
3. Determination of total allowable amounts and allocations of allowed amounts among pollutant sources
4. Development of an implementation plan to achieve total allowable amounts and allocations
5. Amendments to the Water Quality Plan for the Sacramento and San Joaquin River Basins.

Two TMDLs, one for Bear Creek as a whole and one specifically for Sulphur Creek, are in place. The TMDL for the entire Bear Creek watershed refers to controlling the concentration of methylmercury. A second TMDL for lower Sulphur Creek alone covers total mercury.

<u>Section 404</u>

The US Army Corps of Engineers issues permits under the Clean Water Act Section 404 for dredging and filling in water bodies, including wetlands. These permits, however, must conform to the State of California State Water Quality Control Board objectives for water quality and the California EPA Office of Environmental Health Hazard Assessment public health drinking water standards, to protect isolated wetlands, riparian areas, and stream headwaters. The California Department of Transportation has Section 404 permits for its bridge construction work on Highway 20 at Bear Creek.

The Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act (California Water Code Division 7: Water Quality Section 13000 et seq.) governs water quality in the State of California. Further, the Act assigns responsibility for water rights and water quality to the California State Water Resource Control Board, and it delegates authority to nine statewide Regional Water Quality Control Boards (RWQCBs) to develop and enforce water quality standards within regional jurisdictions. The CVRWQCB (Region 5) has jurisdiction over Bear Creek watershed.

California water quality standards consist of three elements: beneficial uses; water quality objectives, consisting of both numeric and narrative criteria; and policies and procedures to counteract degradation of water quality. These standards apply to "waters of the state", which are defined by the Water Quality Control Act as "any surface water or ground water, including saline waters, within the boundaries of the state." The Act covers both surface water and ground water. The CVRWQCB has delegated authority over water quality on federal public lands as well, including lands managed by the US Forest Service and the BLM in Bear Creek watershed. Chapter 5 of this assessment discusses the three elements in depth.

To achieve water quality objectives in Bear Creek watershed, the CVRWQCB carries out the following steps:

1. identifies potential water quality problems in the watershed;
2. confirms and characterizes water quality problems through assessments for source, frequency, duration, extent, fate, and severity of a pollutant causing water contamination;
3. remedies water quality problems by enforcing appropriate response measures; and
4. monitors known problem areas in Bear Creek watershed to assess effectiveness of remedial measures.

The Water Quality Plan for the Sacramento and San Joaquin River Basins (October 2007)
The CVRWQCB has concerns about water quality that bear on the beneficial and potential beneficial uses for Bear Creek watershed. The principal impairment to the watershed is the high concentrations of mercury found in water, sediments, and tissues of aquatic animals in Bear Creek watershed. Non-point discharges from abandoned mercury mine sites are the principal sources for levels of ambient mercury above natural background levels in the watershed. These concerns are expressed in the Water Quality Plan. The CVRWQCB has amended the Water Quality Plan for the Sacramento River and San Joaquin River Basins twice, in 2005 and 2007 to deal with TMDLs for methylmercury and total mercury in Bear Creek watershed.

Agreements between the State Water Quality Control Board and Federal Land Management Agencies
A 1981 Management Agency Agreement (MAA) with the US Forest Service waives discharge requirements from the State Water Quality Control Board for certain nonpoint source discharges over all US Forest Service lands in California, provided that the US

Forest Service implements Board-approved best management practices (BMPs) and procedures along with the provisions of the MAA. Implementation of the BMPs, monitoring, and performance review requirements approved by the State and Regional Water Boards, is the primary method of meeting the Basin Plan water quality objectives. The MAA in no way limits the authority of a RWQCB to carry out its legal responsibilities for management or regulation of water quality.

In September 1985, the CVRWQCB Executive Officer signed Memoranda of Understanding (MOUs) with the three BLM Districts that at the time oversaw federal public lands in parts of the Central Valley (the Ukiah District, the Susanville District, and the Bakersfield District). The MOUs, which are identical for each District, expanded coordination between the two agencies for the control of water quality problems resulting from mineral extraction activities on BLM administered lands. On 27 January 1993, the State Water Board signed a MOU to address water quality issues from nonpoint sources on public lands managed by BLM.

Cache Creek Watershed Mercury Program

The Cache Creek Watershed Mercury Program for methylmercury and total mercury applies to the Cache Creek Basin, defined as the main stem of Cache Creek from Clear Lake to the Yolo Settling Basin outflow; North Fork Cache Creek from Indian Valley Reservoir Dam to the main stem Cache Creek; Bear Creek (including Sulphur Creek); and Harley Gulch. This implementation program is intended to reduce loads of methylmercury and total mercury to achieve all applicable water quality objectives for mercury and methylmercury. The program includes monitoring mercury in fish, water, and sediment.

Mercury Program Actions to achieve water quality objectives and the methylmercury allocations in the Bear Creek methylmercury and Sulphur Creek mercury TMDLs are:

1. reduce loads of total mercury at inactive mines
2. implement projects to reduce total mercury loads in creek channels and creek banks downstream of discharges from historic mines
3. reduce erosion of soils with enriched total mercury concentrations
4. limit land use activities in the watershed that increase methylmercury in creeks and, where feasible, reduce discharges of methylmercury from existing sources
5. evaluate other remediation actions that are not directly linked to activities of a discharger.

Sacramento Valley Integrated Regional Water Management Plan (Preliminary Final Version November 2006)

Although this document is not in its final form, the direction of the Regional Water Management Plan is clear from the preliminary final document. Impending management actions that are relevant to Bear Creek watershed include:

1. Completion of a Colusa County Groundwater Management Plan
   Colusa County has completed its groundwater management plan. The plan will permit management for economic uses of groundwater resources in Colusa County. The management plan covers conjunctive use, groundwater assessment, options for groundwater recharge, protection of groundwater quality, control of non-point source pollutants that contaminate groundwater, and a systematic monitoring program.

2. Control and reduction of high loads of mercury in Bear Creek that may put people in the Lower Cache Creek and the Delta at risk if they consume large quantities of fish and fish-eating wildlife.

3. Measures for preventing extreme flood events from winter storms to avoid worsening downstream flooding in the Western Yolo Floodplain and in the City of Woodland, which the Federal Emergency Management Agency has found to have protection only for a ten-year flood event.

Northern Sacramento Valley (Four County) Drinking Water Quality Strategy Document (June 2005)

Butte, Tehama, Glenn, and Colusa counties have jointly prepared a policy and action document that provides an integrated approach to water quality management in the four-county region.

Sacramento River Basinwide Water Management Plan (2004)

This document covers the Sacramento River Subregion and includes an in-depth discussion of the Cache Creek Basin of which Bear Creek watershed is a part. Bear Creek is not specifically mentioned in the document. Although this management plan contains current and future projections of water supply and water use for many Colusa County water districts, Bear Creek watershed is not part of the analysis and planning because no water district covers the watershed.

Air Resources

Federal Clean Air Act

The Federal Clean Air Act (FCAA) requires that the State of California determine whether an entire air basin or a part of an air basin is meeting the National Ambient Air Quality Standards established in the Clean Air Act. The National Standards consist of maximum amounts set by the FCAA for key air pollutants. In the event that an air basin does meet the National Standards, the State of California is responsible for preparing and enacting an air quality plan for the air basin. The air basin plan lays out a management framework and specific actions to reduce the concentrations of emitted pollutants in the air basin.

Presently, Colusa County has rankings of attainment or unclassified for all FCAA standards.

California Clean Air Act

The federal government has delegated to the California Air Resources Board (ARB) the authority to manage air quality in the state of California. The ARB regulates sources of mobile emitted pollutants and provides guidance to county Air Pollution Control Districts (APCDs) and regional Air Quality Management Districts (AQMDs). In many instances, the ARB has instituted air quality standards applicable to California that are stricter than the federal standards for criteria air pollutants. Evaluation of attainment of these standards is a process parallel to determining attainment of National Ambient Air Quality Standards.

Bear Creek Watershed is under the jurisdiction of the Colusa County APCD and the Sacramento Valley AQMD (and included as part of the Northern Sacramento Valley Air Basin for planning purposes). Colusa County and its watersheds collectively are considered to be in attainment or unclassified for all state standards except those for ozone and PM_{10}.

The Districts adopt and enforce controls on stationary sources of air pollutants through permit and inspection. They also regulate agricultural burning. Other District responsibilities include monitoring air quality, preparing clean air plans, and responding to air quality complaints from citizens.

The AQMDs of the Northern Sacramento Air Basin (2003) have jointly prepared and adopted a uniform air quality attainment plan addressing ozone and PM_{10}.

Details of air quality standards are presented in Appendix F.

APPENDIX C
PRINCIPAL ROCK TYPES FOUND IN BEAR CREEK WATERSHED

Great Valley Geomorphic Province Rock Types

Rock Type	Associated Minerals	Notes
Great Valley Sequence Sedimentary Rocks		
mudstones		dark gray, derived from clay and silt sediments, jumbled
shale	Stony Creek petrofacies often contain fossil hydrocarbons (oil and gas)	red, brown, black, or gray; orderly layering of sediments
siltstone		silt and some clay; not easily fractured
graywacke sandstone	quartz, feldspar, sodium chlorite, magnesium chlorite; storing underground water	gray to dark gray; sand cemented with smaller sediment particles, poorly sorted by sediment size
breccias		angular rocks and minerals of different sizes in a cement of sediments; formed by submarine avalanches and mud flows
conglomerates		gravels, pebbles, and cobbles in a cemented matrix of other smaller sediments; rocks in matrix are rounded
Great Valley Sequence Metasedimentary Rocks		
argillite	silica as the cementing crystal; sericite, chlorite; aluminum	weakly metamorphosed from clay mudstones and shale, jumbled
slate	quartz, chlorite, sericite	derived from shale, easily cleaved into flat plates
phyllite	quartz, sericite, chlorite	gray or gray-black; wavy and corrugated with a sheen, not easily cleaved
metasiltstone		derived form siltstones under high pressure
metagraywacke		derived from graywackes under high pressure
chalcedony	quartz, moganite, often with gold deposits	usually red or green conglomerates derived from multiple rock types embedded in cemented sand or clay sediments; frequent fossils

Coast Ranges Geomorphic Province Rocks

Rock Type	Associated Minerals	Notes
Tehama-Colusa Serpentinite Mélange (TCSM) Sedimentary Rock Types		
radiolarian chert		sedimentary; red; local; sediment rock that overlay mid-Pacific ophiolite
hydrothermal breccias	copper, silver, gold ores from magma	originating under the Stony Creek petrofacies in the Sulphur Creek subwatershed from geothermal water under high pressure causing rock fractures into which liquid magma ("epithermal") ore deposits pour
Tehama-Colusa Serpentinite Mélange (TCSM) Igneous Rock Types		
basalt	calcic feldspar and pyroxene with 50% silicon dioxide minerals(SiO_2)	gray or dark gray; volcanic origin but breaching the ocean crust to form pillow-shaped rocks; non-mafic
diabase	feldspars (62%) most common minerals, often in a finer matrix of clinopyroxene and olivine	volcanic origin, in submarine mantle; ultramafic; rare; appear as sliver-shaped rock bodies
gabbro	clinopyroxene, feldspar, and olivine; often containing precious metals	coarser grained than diabases; ultramafic; intermittent north of Sulphur Creek
peridotite	90% olivine; 10% orthopyroxene - mostly harzburgite	lowest in the ophiolite layer; ultramafic; most dominant rock type in TCSM
pyroxenites	90% orthopyroxene	Principal source of serpentinite
Tehama-Colusa Serpentinite Mélange (TCSM) Metamorphic Rock Types		
serpentinite	lizardite, brucite	metamorphosed under low heat and low pressure; formed by addition of water; increases rock volume
greenschist	clinopyroxene, feldspar, analcite, chlorite, epidote	mafic or ultramafic; green; derived from basalt and gabbro
blueschist	glaucophane, epidote, albite	blue, green-blue, or gray; Non-mafic; derived from basalt deep in the earth
Franciscan Volcanic and Metavolcanic Rocks		
andesite		poorly known; silicic minerals erupt amid basaltic lava flow
Franciscan Sedimentary and Metasedimentary Rocks		
graywacke	albite (feldspar), chlorite	light green to gray; clay mortar
phyllonite	phyllosilicates, often coated with chlorites	formed from degraded graywacke sediments, on crest and east flank of Walker Ridge
Other Sedimentary Rocks		
Quaternary Alluvial and Terrace Sedimentary Rocks		
breccias		young rocks consisting of poorly sorted, diverse clay, silt, sand, and gravel, in Bear Valley

Sources: Barnes et al. 1973a, b; Bergfeld et al. 2001; Goff and Guthrie 1999; Moiseyev 1968; McLaughlin et al. 1989; Sherlock 2005

APPENDIX D

COMPARATIVE SYNOPSIS OF FEATURES OF THE PRINCIPAL SOIL SERIES IN BEAR CREEK WATERSHED

Comparative synopsis of features of the principal soil series in Bear Creek watershed, part 1

	Soil Series	Depth	Drainage	Permeability	Runoff Rate	Surface Soil Texture Class	Topographic Position	Percent Slope	Watershed Location
Non-Magnesic	Boar	very deep	well-drained	slow	medium to very high	loam	hill toe slopes	15 – 50	north part of Bear Creek Ranch near the Lake County line
	Contra Costa	moderately deep	well-drained	slow	low to very high	loam	foothills and mountains	9 – 75	widespread east of Bear Valley (northern watershed) and on the east side of lower Bear Creek
	Etsel	very shallow or shallow	somewhat excessively drained	moderate to moderately rapid	low to high	gravelly sandy loam	mountain side slopes	30 – 75	locally along Walker Ridge and in the Mendocino National Forest
	Hillgate	very deep	well to moderately well-drained	very slow to slow	medium	loam	old terraces	0 – 9	hydric zones in lower Bear Valley and central Sulphur Creek
	Livermore	very deep	somewhat excessively drained	moderately rapid	low	very gravelly loam	alluvial fans	5 – 9	Leesville area
	Maymen	shallow	somewhat excessively drained	moderate to moderately rapid	high to very high	sandy loam	mountain side slopes	30 – 75	locally along Walker Ridge and in the Mendocino National Forest
	Millsholm	shallow	well-drained	moderate	low to very high	loam	hills	5 – 75	widespread on either side above Bear Valley floor; NE and southern third of southern watershed; calcareous
	Salt Canyon	very deep	well-drained	moderately slow	very slow to medium	loam	alluvial fans	1 - 9	eastern foothill-Bear Valley edge and locally in lower Bear Creek along Highway 16
	Sehorn	moderately deep	well-drained	slow	low to very high	silty clay	Foothills	9 – 50	as a minor component on the eastern boundary of the watershed
	Skyhigh	moderately deep	well-drained	slow	medium to very high	loam	Hills	15 – 50	Sulphur Creek subwatershed, Bear Creek Ranch and just south of Bear Valley
	Sleeper	deep	well-drained	slow	medium to very high	loam	Hills	15 – 50	Sulphur Creek subwatershed, Bear Creek Ranch and just south of Bear Valley
Ultramafic (Magnesic)	Bear Valley	very deep	somewhat excessively drained	moderately rapid	very low	gravelly sand loam	alluvial fans	2 - 5	south end of Bear Valley
	Dubakella	moderately deep	well-drained	slow	medium to very high	stony loam	Mountains	15 - 50	locally on Walker Ridge and headwaters of Mill Creek subwatershed
	Haploxerts, Unidentified	deep to very deep	well-drained	moderate to slow	high	clay loam	mountain sides	30-50	along Highway 20 west of intersection with Highway 16
	Henneke	shallow	well-drained	moderately slow to slow	high to very high	sandy loam	mountain sides	15 - 75	Mill Creek subwatershed and locally on Walker Ridge
	Leesville	very deep	well-drained	moderate to slow	very low	clay loam	alluvial fans	0 – 5	lower west side of Bear Valley
	Montara	shallow	well-drained	moderately rapid	high	gravelly sandy loam	mountain sides	15 – 50	Mill Creek subwatershed
	Okiota	shallow	well-drained	moderately slow	high to very high	gravelly loam	mountain sides	15 – 75	Walker Ridge crest and eastern slope
	Venado	very deep	poorly drained	slow	very low	Clay	basin floor	0 - 2	Bear Valley floor , including riparian areas

Comparative Synopsis of Features of the Principal Soil Series in Bear Creek watershed, part 2

	Soil Series	Soil Genesis	Parent Rock	Soil pH at surface and 1-m depth	Mg:Ca ratio	Aver ppt mm y^{-1}	Aver annual temp ºC	Vegetation	Noteworthy Characteristics
Non-Magnesic	Boar	residuum	from sandstone, shale and siltstone	no data	--	76	14	wild oats, annual grasses, filaree,, blue oak and live oak	a very deep soil compared to associated Sleeper and Millsholm soils
	Contra Costa	weathered	fine-grained shale sandstone	6.9 - 6.5	--		18	annual grasses	a widespread soil derived from the Central Valley formation
	Etsel	weathered	sandstone or shale	6.0 - 6.3	--	114	14	chaparral with chamise and species of manzanita, ceanothus, and scrub oak	presence of an ochric epipedon; no cambic horizon
	Hillgate	alluvium	mixed sources	6.2 - 6.2	--	41	18	annual grasses and forbs with open stands of valley and blue oaks	scattered manganese accumulations; ochric epipedon; smectitic, superactive; slightly sodic
	Livermore	alluvium	sedimentary and metasedimentary	6.1 - 6.6	--	43	17	blue oak with annual grasses, foothill pine, and ceanothus	mollic epipedon, fertile CEC/clay > 0.80 at all levels
	Maymen	weathered	sandstone, shale and conglomerate	6.0 - 6.0	--	107	14	chamise and other chaparral shrubs	shallow soil (<45 cm deep)
	Millsholm	residuum	sandstone, and shale	7.0 - 7.5	--	64	17	oak savannah with annual grasses	20 -30% clay
	Salt Canyon	alluvium	mixed sources	7.0 - 7.5	--	51	16	annual grasses and forbs	clay 25 - 35%
	Sehorn	residuum	sandstone and shale	7.0 - 7.0	--	64	18	blue oak and annual grasses	intermixed with Contra Costa and Millsholm soils
	Skyhigh	residuum	sandstone and shale	5.7 - 5.7	--	89	14	blue oak and annual grasses	smectic, dry soil crack to 1.0 cm and down to 25 cm depth
	Sleeper	residuum	sandstone and shale	7.5 - 7.8	--	81	16	blue oak, annual grasses, foothill pine, and ceanothus	smectic, deeper than Skyhigh
Ultramafic (Magnesic)	Bear Valley	alluvium	serpentinite	6.6 - 7.5	3 to 6:1	48	17	sparse annual grasses and forbs	unique soil found only in Bear Creek watershed; high gravel content
	Dubakella	residuum	peridotite	7.0 - 7.0	--	76	11	manzanita, leather oak, McNab cypress, foothill pine	capable of timber production; ochric epipedon to 27 cm
	Haploxerts, Unidentified	residuum	serpentinite	7.4 - 8.0	--	--	16	annual grasses and forbs	require more detailed classification
	Henneke	residuum	peridotite	6.7 - 7.0	--	76	13	manzanita, leather oak, McNab cypress, foothill pine	shallow soil (<50 cm deep)
	Leesville	alluvium	serpentinite	7.2 - 8.2	3 to 6:1	48	15	annual grasses and forbs	deep soil (> 150 cm deep)
	Montara	residuum	serpentinite	8.0 - 8.0	>1:1	71	14	manzanita, leather oak, McNab cypress, foothill pine	shallow soil (<50 cm deep)
	Okiota	residuum	hard-ftractured peridotite	6.3 - 6.1	Na	94	16	manzanita, leather oak, McNab cypress, foothill pine	highest organic matter in the surface horizon (3%) of all ultramafic soils found locally
	Venado	alluvium	serpentinite	7.2 - 8.6	5 to 11:1	48	15	annual grasses and forbs	> 35% clay; polygonal cracking pattern; much erosion from downcutting as the result of channel dynamiting in the late 19th century

APPENDIX E
LIST OF PLANT ALLIANCES KNOWN OR SUSPECTED TO OCCUR IN BEAR CREEK WATERSHED

Globally rare plant alliances are highlighted in red.

Major Species Common Name(s)	Scientific Names	Alliance	Soil Categories	Soil Types	Notes
		Chaparral (37.000.00)			
Chamise	*Adenostoma fasciculatum*	37.101	Mafic, Ultramafic	Henneke Okiota	**>** 60 percent chamise cover, on dry slopes and ridges
Wedgeleaf Ceanothus	*Ceanothus cuneatus*	37.211	Ultramafic	Henneke, Montara, Okiota	**M**ostly north-facing slopes and ridges, sandy soils
Jepson's Ceanothus	*Ceanothus jepsonii*	37.212	Ultramafic	Henneke, Okiota	**D**escribed by Rivas Martinez (1997) from Bear Creek watershed
Whiteleaf Manzanita	*Arctostaphylos viscida*	37.305	Ultramafic	Henneke, Okiota	**D**escribed by McCarten and Rogers (1991); dominant in Bear Creek watershed
Leather Oak	*Quercus durata*	37.306	Ultramafic	Henneke, Montara, Okiota	**O**ccurs in a mosaic with other chaparral alliances; often with chamise, toyon, foothill pine, and cypresses
Scrub Oak	*Quercus berberdifolia*	37.407	Non-Ultramafic	Millsholm, Skyhigh	**W**idespread in Bear Creek watershed gentle to very steep northwest- and northeast-facing slopes
Scrub Oak Alderleaf Mountain-mahogony	*Quercus berberidifolia* *Cercocarpus montanus*	37.408	Non-Ultramafic	?	**S**uspected but not identified in the watershed
Scrub Oak Chamise	*Quercus berberdifolia* *Adenostoma fasciculatum*	37.409	Non-Ultramafic	Contra Costa, Millsholm	**S**uspected but not identified in the watershed
Interior Live Oak	*Quercus wislizeni*	37.420	Non-Ultramafic	Contra Costa, Millsholm, Skyhigh	**L**ocally on shallow, moderately to excessively drained soils

Toyon	*Heteromeles arbutifolia*	37.911	Non-Ultramafic	Contra Costa, Millsholm	**S**uspected but not identified in the watershed
Pacific Poison Oak	*Toxicodendron diversilobum*	37.940	Non-Ultramafic, Ultramafic	unknown	**S**uspected but not identified in the watershed
		Native Grasslands (41.000)			
Meadow Barley	*Hordeum brachyantherum*	41.052	Mafic, Non-Ultramafic	?	**I**n ephemerally moist to hydric soils at springs, in meadows and swales in Bear Valley; clayey, silty, or fine loamy soil
Beardless Wildrye	*Leymus triticoides*	41.080	Non-Ultramafic	Arand, Millsholm, Skyhigh	**O**n clay or clay loam soils at edges of hydric zones Dominant in Bear Creek and Sulphur Creek floodplains, now rare
Purple Needlegrass	*Nassella pulchra*	41.150	Non-Ultramafic	Etsel, Maymen, Millsholm, Skyhigh	**O**n Love Lady Ridge per Mc Carten and Rogers (1991); formerly extensive, occurs in many settings and often with many other native and non-native grass species
Sandburg's Bluegrass	*Poa secunda*	41.180	Mafic	Leesville, Venado	**W**idespread but rarely dominant in the watershed
Saltgrass	*Distichlis spicata*	41.200	Saline	Arand	**W**idespread dominant in Sulphur Creek and Bear Creek floodplains; also found in alkaline seeps
Tufted Hairgrass	*Deschampsia caespitosa*	41.220	Saline	?	**R**are; found at one wetland site on Walker Ridge
Squirreltail	*Elymus elymoides*	41.230	Ultramafic	?	**O**n Love Lady Ridge per Mc Carten and Rogers (1991) and elsewhere in small patches

Blue Wildrye	*Elymus glaucus*	41.640	Ultramafic	?	Rarely if ever in large patches
Big Squirreltail	*Elymus multisetus*	41.650	?	?	Found in small patches
		Non-Native Grasslands (42.000)			
Barb Goatgrass	*Aegilops triuncialis*	42.003	Non-Ultramafic Ultramafic	All except saline soils	Widespread in many settings, adapted to severe disturbances
Annual Bromes	*Bromus diandrus, B. hordaceus, B. madritensis, B. rubens*	42.026	Non-Ultramafic, Ultramafic	Many soils	Poorly characterized alliance
California Annual Grasslands	*Aira caryophylla*, *Bromus hordeaceus*, *Erodium botrys*	42.040	Non-Ultramafic Ultramafic	Contra Costa, Milholm, Skyhigh, Sleeper; Henneke, Okiota	Poorly characterized alliance
Yellow Starthistle	*Centaurea solstitialis*	42.042	Non-Ultramafic Ultramafic	All except saline soils	Widespread including severely disturbed mercury mine sites
Tall Wheatgrass	*Thinopyrum ponticum*	42.100	Non-Ultramafic	Many soils	Found in roadsides and in riparian zones
		Meadows and Seeps (45.000)			
Baltic Sedge	*Juncus balticus*	45.562	Not known	Hydric soils including saline soils	Occurs in alkali meadows and at seeps and springs; often indicates overgrazing
		Marshes (52.000)			
Broadleaved Cattail	*Typha latifolia*	52.040	Non-Ultramafic	Hydric soils, submerged	Found locally along Bear Creek
Broadleaved Pepperweed	*Lepidium latifolium*	52.205	Non-Ultramafic	Riparian and hydric soils	Found along lower Bear Creek and its tributaries; not native
		Riparian Forest and Bottomland (61.000) and Riparian Scrub (63.000)			
Fremont Cottonwood	*Populus fremontii*	61.111	Non-Ultramafic	Hillgate	Remnant riparian woodland in Little Valley in the Leesville subwatershed

Sandbar Willow	*Salix exigua*	61.209	Non-Ultramafic, Hydric	?	**O**ccurs in and along Bear Creek, Mill Creek, and the Leesville subwatershed
Brewer's Willow	*Salix breweri*	61.213	Ultramafic, Hydric	?	?
Western Azalea	*Rhododendron occidentale*	63.310	Ultramafic, Hydric	Henneke, Okiota	**P**ossibly occurs in Mill Creek subwatershed
Tamarisk	*Tamarix* sp.	63.810	Non-Ultramafic, Hydric	Riverwash	**W**idespread in riparian zones along Bear Creek and Sulphur Creek
		Oak Woodland (71.000)			
Blue Oak	*Quercus douglasii*	71.020	Non-Ultramafic, sometimes overlying Ultramafic	Boar, Contra Costa, Millsholm, Skyhigh, Sleeper	**W**idespread at the eastern edge and in lower Bear Creek watershed, often on infertile, fast draining soils
Valley Oak	*Quercus lobata*	71.040	Non-Ultramafic, Riparian	Boar, Contra Costa, Corval, Millsholm, Salt Canyon, Skyhigh, Sleeper	**U**nique stand at the south end of Bear Valley plus several clusters along Lower Bear Creek and in the upper part of the Leesville subwatershed
Interior Live Oak	*Quercus wislizeni*	71.080	Non-Ultramafic	Boar, Contra Costa, Millsholm, Skyhigh, Sleeper	**S**mall patches are found locally in the watershed
		Coniferous Upland Forest and Woodland (80.000)			
McNab Cypress	*Cupressus macnabiana*	81.300	Gabbro, Ultramafic	Henneke, Montara, Okiota	**F**ound on infertile soils, especially on ridges, usually in single-species stands of the same age
Sargent Cypress	*Cupressus sargentii*	81.500	Ultramafic	Henneke, Okiota	**F**ound on infertile soils, not in the same areas as McNab cypress, in moister canyon sites
Knobcone Pine	*Pinus attenuata*	87.100	Non-Ultramafic, Ultramafic	Etsel, Henneke, Maymen, Montara, Okiota	**O**ccurs on ridges and upper slopes on infertile, droughty soils, usually in

					single-species stands of the same age
Foothill Pine	*Pinus sabiniana*	87.130	Non-Ultramafic Ultramafic	Contra Costa, Henneke, Millsholm, Okiota	**W**idespread on upland slopes, usually on infertile, on chaparral sites it is a canopy emergent
Mixed Conifer	*Pinus lambertiana, P. ponderosa, Pseudotsuga menziesii*	?	?	Henneke, Montara	**M**ultiple woodland conifer communities that require closer study east of Love Lady Ridge

? = not known or undescribed

Sources: Colusa County Soil Survey (Reed, 2006), NatureServe Explorer (2009), USDA Forest Service Region 5 (multiple years) obtained from CalFlora (2008), Biogeographic Data Branch (2003, 2007)

APPENDIX F
AIR QUALITY REGULATIONS

Federal and State of California Standards for Air Quality

The US Environmental Protection Agency (US EPA) and the California Air Resources Board each set standards air quality standards for major or "criteria" pollutants based on known thresholds for adverse health effects for people. These ambient air quality standards are levels of contaminants that represent safe limits to avoid specific adverse health effects associated with each pollutant. Table F.1 provides a compares the standards currently in effect under each agency. California Air Resources Board standards are more stringent to provide a wider margin of safety.

US EPA regulations consist of national primary standards and national secondary standards. Primary standards are the measures of air quality that provide an adequate safety margin to protect the public's health. Secondary standards for air quality protect the public from any known or anticipated adverse effect of a criteria pollutant.

California ambient air quality standards are listed in the Table of Standards in Section 70200 of Title 17 of the California Code of Regulations.

Table F.1 – State and national ambient air quality standards for criteria pollutants

Pollutant	Averaging Time	California Standards not to equal or exceed unless noted otherwise		Federal Standards not to be exceeded more than once a year except as noted		
		Concentration(1)	Method	Primary (1)	Secondary(1)	Method
Ozone (O_3)	1 Hour	0.09 ppm (180 µg/m^3)	Ultraviolet Photometry	-	Same as Primary Standard	Ultraviolet Photometry
	8 Hour	0.07 ppm (137 µg/m^3)		0.075 ppm (147 µg/m^3) (2)		
Respirable Particulate Matter (PM_{10})	24 Hour	50 µg/m^3	Gravimetric or Beta Attenuation	150 µg/m^3 (3)	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	20 µg/m^3		-		
Fine Particulate Matter ($PM_{2.5}$)	24 Hour	No Separate State Standard		35 µg/m^3 (4)	Same as Primary Standard	Inertial Separation and Gravimetric Analysis
	Annual Arithmetic Mean	12 µg/m^3	Gravimetric or Beta Attenuation	15 µg/m^3		

Pollutant	Averaging Time	California Standards not to equal or exceed unless noted otherwise		Federal Standards not to be exceeded more than once a year except as noted		
		Concentration[1]	Method	Primary [1]	Secondary[1]	Method
Carbon Monoxide (CO)	8 Hour	9.0 ppm (10 mg/m^3)	Non-dispersive Infrared Photometry	9 ppm (10 mg/m^3)	None	Non-dispersive Infrared Photometry
	1 Hour	20 ppm (23 mg/m^3)		35 ppm (40 mg/m^3)		
Nitrogen Dioxide (NO_2)	Annual Arithmetic Mean	0.030 ppm (57 µg/m^3)	Gas Phase Chemi-luminescence	0.053 ppm (100 µg/m^3)	Same as Primary Standard	Gas Phase Chemi-luminescence
	1 Hour	0.18 ppm (339 µg/m^3)		-		
Lead (Pb)	30 days average	1.5 µg/m^3	Atomic Absorption	-	-	-
	Calendar Quarter	-		1.5 µg/m^3	Same as Primary Standard	High Volume Sampler and Atomic Absorption
Sulfur Dioxide (SO_2)	Annual Arithmetic Mean	-	Ultraviolet Fluorescence	0.030 ppm (80 µg/m^3)	-	Spectro-photometry (Pararosaniline Method)
	24 Hour	not to exceed 0.04 ppm (105 µg/m^3)		0.14 ppm (365 µg/m^3)	-	
	3 Hour	-		-	0.5 ppm (1300 µg/m^3)	
	1 Hour	0.25 ppm (655 µg/m^3)		-	-	
Visibility Reducing Particles	8 Hour (10 am to 6 pm, PST)	In sufficient amount to produce an extinction coefficient of 0.23 per kilometer-visibility of ten miles or more due to particles when the relative humidity is less than 70 percent.		No Federal Standards		
Sulfates	24 Hour	25 µg/m^3	Ion Chromatography			
Hydrogen Sulfide	1 Hour	0.03 ppm (42 µg/m^3)	Ultraviolet Fluorescence			

Source: California Air Resources Board (2008); US Enviornmental Protection Agency (2008)

Notes:

1. Equivalent units given in parentheses are based upon a reference temperature of 25° C and a reference pressure of 760 mm of mercury.
2. The ozone standard is attained when the fourth highest eight hour concentration in a year, averaged over three years, is equal to or less than the standard.

3. For PM_{10}, the 24 hour standard is attained when 99 percent of the daily concentrations, averaged over three years, are equal to or less than the standard.
4. For $PM_{2.5}$ the 24 hour standard is attained when 98 percent of the daily concentrations, averaged over three years, are equal to or less than the standard.

APPENDIX G
DRINKING WATER OBJECTIVES APPLICABLE TO BEAR CREEK WATERSHED

Primary maximum contaminant levels are legal requirements for toxic chemical elements and compounds in drinking water. Secondary maximum contaminant levels are recommended thresholds, not enforceable by law, for chemicals or visual and odor characteristics in water that make the water unpleasant to use as drinking water.

Table G.1 – Water quality numeric criteria for chemical elements in California

Beneficial Use	Constituent	Maximum Contaminant Dissolved Concentration (mg liter^{-1})		California Public Health Goal (ppb)	Notification Level (mg liter^{-1})	Response Level (mg liter^{-1})
		Primary	Secondary			
Chemical Elements						
MUN	Aluminum	1.000	0.600	600	-	-
MUN	Antimony	0.006	-	0.020*	-	-
MUN	Arsenic	0.010	-	0.004	-	-
MUN	Barium	1.000	-	2,000	-	-
MUN	Beryllium	0.004	-	1	-	-
AGR	Boron	-	-	-	1.000	10.000
MUN	Cadmium	0.005	-	0.04	-	-
MUN	Chloride	-	250.0	-	-	-
MUN	Chromium (total)	0.050	-	-	-	-
MUN	Copper†	1.300	1.000	300	-	-
MUN	Fluoride‡	1.400-2.400	-	1,000	-	-
	Iron	-	0.300	-	-	-
MUN	Lead	0.015	-	0.2	-	-
	Manganese	-	0.050		0.500	5.000
MUN	Mercury	0.002	-	1.2	-	-
MUN	Nickel	0.100	-	12	-	-
MUN	Selenium	0.050	-	-	-	-
	Silver	-	0.100	-	-	-
MUN	Thallium	0.002	-	0.1	-	-
	Vanadium	-	-	-	0.050	0.500
	Zinc	-	5.000	-	-	-
COLD	Dissolved Oxygen	7.000	-	-	-	-
SPWN	Dissolved Oxygen	7.000	-	-	-	-
WARM	Dissolved Oxygen	5.000	-	-	-	-

Source: Water Quality Control Plan for the Sacramento and San Joaquin River Basin, as amended 2007 and the Department of Environmental Health Hazard Assessment (current as of September 2009)
*currently under review
†The copper concentration occurs in>10 percent of tap water samples collected.

‡The acceptable contaminate level for fluoride varies inversely with increasing temperature from 2.4 mg liter^{-1} at temperatures less than 53.7°F to 1.4 mg liter^{-1}at 90.5°F.

Table G.2 – Water quality numeric criteria for ionic compounds applicable in California

Beneficial Use	Constituent	Maximum Contaminant Dissolved Concentration (mg liter^{-1})		California Public Health Goal (ppb)	Notification Level (mg liter^{-1})	Response Level (mg liter^{-1})
		Primary	Secondary			
Chemical Ions						
All Beneficial Uses	Nitrogen: Ammonia (as NH_3)	0.025				
MUN	Nitrogen: Nitrate (as NO_3)	45		10,000		TITLE22
MUN	Nitrogen: Nitrate + Nitrite sum	10		10,000		TITLE22
MUN	Nitrogen: Nitrite (as NO_2)	1		1,000		TITLE22
MUN	Sulfate		250.0			

Source: Water Quality Control Plan for the Sacramento and San Joaquin River Basin, as amended 2007 and the Department of Environmental Health Hazard Assessment (current as of September 2009)

Mercury

The Basin Plan calls for a 95 percent reduction in the amount of total mercury discharging from abandoned mines.

Table G.3 – Target reductions of mercury discharges at abandoned mercury mines

Mine or Mine Complex	Ownership	Current Load kg yr^{-1}	Target Load kg yr^{-1}
Central, Cherry Hill, Empire, Manzanita, West End	private	5.0	0.25
Clyde	BLM	0.4	0.02
Elgin	private	3.0	0.15
Rathburn Petray	BLM, private	25.0	1.25
Wide Awake Mine	private	0.8	0.04
Total		**34.2**	**1.71**

Sources: California Geological Survey for estimate for the Ratburn Petray mine complex; other estimates come from the staff of the Central Valley Water Board

Table G.4 – Total daily maximum loads for mercury and methylmercury (MeHg) established by the CVRWQCB for Bear Creek and its tributary Sulphur Creek

Bear Creek TMDL	**MeHg in Water**		**MeHg in Fish**	
	Basin Plan MeHg Target	**TMDL MeHg, unfiltered**	**Fish Trophic Level**	
			3	**4**
	g yr^{-1}, averaged	**ng $liter^{-1}$, instaneous maximum**	**mg per kg of Wet Fish Wt**	
Mouth of Sulphur Creek	0.8			
Bear Creek @ Bear Valley Road	0.9			
Bear Creek @ Highway 20	3.0	0.06	0.12	0.23
Sulphur Creek TMDL	Total Mercury, instantaneous maximum			
	Flow ≤ 3 cfs	Flow > 3cfs		
	ng $liter^{-1}$	mg per kg of suspended solids		
Mouth of Sulphur Creek	1,800	35		

Sources: CVRWQCB (2007), Central Valley Water Board Resolutions R5-2005-0146 and R5-2007-0021

Table G.5 – Standards for maximum amounts of fecal coliform bacteria for safe drinking water in the region covered by the CVRWQCB

Beneficial Use	**Basis for Count**	**Bacteria Count per 100 ml**	**Maximum Limit**
REC-1	Geometric Mean	400	Using five or more samples for any 30-day period **AND** ≤ 10 percent of samples with > 400 bacteria
	Geometric Mean	200	Using five or more samples for any 30-day period
REC-2	Average	4000	Samples for any 30-day period **AND** ≤ 10 percent of samples with > 400 bacteria
	Average	2000	Samples for any 30-day period

Source: CVRWQCB (2007)

Table G.6 – CVRWQCB limits for agricultural water quality

Element	Limit mg liter^{-1}
Aluminum	5.000
Arsenic	0.100
Boron	0.700 – 0.750*
Cadmium	0.010
Chloride	106.000
Chromium (VI)	0.100
Cobalt	0.050
Copper	0.200
Fluoride	1.000

Element	Limit mg liter^{-1}
Iron	5.000
Lead	5.000
Manganese	0.200
Molybdemum	0.010
Nickel	0.200
Selenium	0.020
Sodium	69.000
Vanadium	0.100
Zinc	2.000
pH	6.5 – 8.4

Source: Ayers and Westcott (1985)
*upper value from the US EPA (1986)

Table G.7– California Toxics Rule criteria for protection of freshwater aquatic life protection in inland surface waters

Constituent	Continuous Concentration (4-day Average)	Maximum Concentration (1-hour Average)	Notes
	total recoverable, mg liter^{-1}		
Arsenic	0.150	0.340	
Cadmium	0.00083 - 0.0073	0.00095 - 0.022	exact values depend on water alkalinity
Chromium (III)	0.067 – 0.640	0.560 – 5.400	
Chromium (VI)	0.011	0.016	
Copper	0.0029 – 0.030	0.0038 – 0.052	exact values depend on water alkalinity
Lead	0.00054 – 0.019	0.014 – 0.480	
Nickel	0.016 – 0.170	0.150 – 1.500	
Selenium	0.005	0.020	
Silver	--	0.0037 – 0.440	exact values depend on water alkalinity
Zinc	0.037 – 0.390	0.0037 – 0.390	

APPENDIX H

NARRATIVES OF WATER QUALITY OBJECTIVES FOR SURFACE WATER AND GROUND WATER

The CVRWQCB uses narratives for water quality objectives for both surface water and ground water. Table H.1 refers to constituents and characteristics in surface water; table H.2 lists and describes the narratives referring to ground water.

Table H.1: Narrative water quality objectives for constituents and characteristics of surface water in Bear Creek watershed

Constituent or Characteristic	Descriptive Water Quality Objectives
Bacteria	MUN: For drinking water from surface water sources, the fecal coliform counts based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 20 per 100 ml. The total coliform counts under the same sampling conditions shall not exceed a geometric mean of 100 per 100 ml. REC-1: In waters designated for contact recreation, the fecal coliform counts based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200 per 100 ml, nor shall in more than ten percent of the total number of samples taken during any 30-day period exceed 400 per 100 ml of water. The total coliform values shall exceed a median of 240 per 100 ml, nor shall any sample exceed 10,000 per 100 ml.
Biostimulatory Substances	Water shall not contain biostimulatory substances (fertilizers) which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses.
Color	Water shall be free of discoloration that causes nuisance or adversely affects beneficial uses.
Dissolved Oxygen	For surface water bodies outside the legal boundaries of the Delta, the monthly median of the mean daily dissolved oxygen concentration shall not fall below 85 percent of saturation in the main water mass, and 95 percentile concentration shall not fall below 75 percent of saturation. The dissolved oxygen concentrations shall not be reduced below the following minimum levels at any time: waters designated WARM 5.0 mg $liter^{-1}$; waters designated COLD 7.0 mg $liter^{-1}$; waters designated SPWN 7.0 mg $liter^{-1}$.
Floating Material	Water shall not contain floating material in amounts that cause nuisance or adversely affect beneficial uses.
Methylmercury	Refer to Table G.3 and the related TMDL documents from the CVRWQCB.
Oil and Grease	Waters shall not contain oils, greases, waxes, or other materials in concentrations that cause nuisance, result in a visible film or coating on the surface of the water or on objects in the water, or otherwise adversely affect beneficial uses.
pH (percent hydrogen ions in solution)	The pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses. In determining compliance with the water quality objective for pH, appropriate averaging periods may be applied provided that beneficial uses will be fully protected.
Pesticides	No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses. Total identifiable persistent chlorinated hydrocarbon pesticides shall not be present in the water column at concentrations detectable within the accuracy of analytical methods approved by the Environmental Protection Agency or the executive Officer. Pesticide concentrations shall not

Constituent or Characteristic	Descriptive Water Quality Objectives
	exceed those allowable by applicable antidegradation policies (see State Water Resources Control Board Resolution No. 68-16 and 40 C.F.R. Section 131.12). Pesticide concentrations shall not exceed the lowest levels technically and economically achievable. Waters designated for domestic or municipal supply (MUN) shall not contain concentrations of pesticides in excess of the Maximum Contaminant Levels set forth in California Code of Regulations, Title 22, Division 4, Chapter 15. Waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of thiobencarb in excess of 1.0 µg $liter^{-1}$.
Radioactivity	Radionuclides shall not be present in concentrations that are harmful to human, plant, animal or aquatic life nor that result in the accumulation of radionuclides in the food web to an extent that presents a hazard to human, plant, animal or aquatic life. At a minimum, waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of radionuclides in excess of the maximum contaminant levels (MCLs) specified in Table 4 (MCL Radioactivity) of Section 64443 ofTitle 22 of the California Code of Regulations.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in the deposition of material that causes nuisance or adversely affects beneficial uses.
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Tastes and Odors	Water shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to domestic or municipal water supplies or to fish flesh or other edible products of aquatic origin, or that cause nuisance, or otherwise adversely affect beneficial uses.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5°F above natural receiving water temperature.
Toxicity	All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board. The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors shall not be less than that for the same water body in areas unaffected by the waste discharge, or, when necessary, for other control water that is consistent with the requirements for "experimental water" as described in *Standard Methods for the Examination of Water and Wastewater*, latest edition.
Turbidity	Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water quality factors shall not exceed the following limits: (1) Where natural turbidity is between 0 and 5 Nephelometric Turbidity Units (NTUs), increases shall not exceed 1 NTU. (2) Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. Where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs. Where natural turgidity is greater than 100 NTUs, increases shall not exceed 10 percent. In determining compliance with the above limits, appropriate averaging periods may be applied provided that beneficial uses will be fully

Constituent or Characteristic	Descriptive Water Quality Objectives
	protected. Exceptions to the above limits will be considered when a dredging operation can cause an increase in turbidity. In those cases, an allowable zone of dilution within which turbidity in excess of the limits may be tolerated will be defined for the operation and prescribed in a discharge permit.

Source: CVRWQCB (2007)

Table H.2 – Narrative water quality objectives for constituents and characteristics of ground water in Bear Creek watershed

Constituent or Characteristic	Descriptive Water Quality Objectives
Bacteria	In ground waters used for domestic or municipal supply (MUN) the most number of coliform organisms based on a minimum of not less than five samples for any 30-day period shall be less than 1.1 per 100 ml.
Radioactivity	At a minimum, ground waters designated for use as domestic or municipal suppy (MUN) shall not contain concentrations of radionuclides in excess of the MCLs specified in Table 4 (MCL Radioactivity) of Section 64443 of Title 22 of the California Code of Regulations.
Tastes and Odors	Ground waters shall not contain taste- or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses.
Toxicity	Ground waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life associated with designated beneficial use(s). This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances.

Source: CVRWQCB (2007) and State Water Quality Control Board standards as of November, 2009

APPENDIX I

BACKGROUND TO THE CHEMICAL AND BIOLOGICAL SIGNIFICANCE OF MERCURY IN BEAR CREEK WATERSHED

The CalFed Program to research and restore ecosystems of the Sacramento-San Joaquin Delta and San Francisco Bay has invested in ecological studies in Bear Creek watershed and elsewhere in the Cache Creek Basin.

Mercury Dispersal

Mercury mining and processing around the world have released previously inert stocks of mercury into the soil, water, and air from multiple points. The increasing availability and dispersal of mercury occurs through physical, chemical, and biotic pathways: physically in stream flows and the atmospheric currents; in chemical reactions facilitated by aquatic bacteria; and by movements of organisms that contain mercury in their cells, tissue, or organs. Controlling this dispersal to reduce the exposure of mercury to people and other species challenges resource managers worldwide. The problem of mercury dispersal is especially acute at the original sources of the dispersion, such as Bear Creek watershed (Domalgaski et al. 2004b). Dilution of mercury unfortunately is not the solution to mercury pollution exiting the watershed because the process of bio-accumulation of toxic forms of mercury in estuaries, bays, and deltas concentrates mercury in bacteria, plants, and animals throughout aquatic ecosystems. Containment of mercury at its source is an essential part of mercury management.

Effects of Mercury

Mercury can impair the cognitive, neurological, motor, reproductive, and immunosuppressant abilities of people (Batten and Scow 2003). Fetuses and small children are particularly vulnerable on account of their relatively small size and still developing bodies. The major agent of mercury toxicity to people is methylmercury. The human body absorbs methylmercury more readily into tissue and organs than it can absorb elemental mercury. Methylmercury concentrations from 0.3 microgram to 1 microgram are toxic, even deadly. Most mercury exposure for people stems from consumption of fish or shellfish. Harnly et al. (1997), for example, found that Native Americans living at Clear Lake (Lake County) and consuming fish from Clear Lake had levels of inorganic mercury in their urine equivalent to background levels of mercury in the soil. On the other hand, average concentrations of organic mercury (methylmercury) in their blood samples averaged 15.6 micrograms liter^{-1}, a high amount compared to average levels reported in people who do not consume fish, i.e., 2 micrograms liter^{-1} (Brunne et al. 1991).

Fish and wildlife are also vulnerable to the toxicity of environmental mercury. In aquatic and riparian food web, the percentage amount of mercury in animal tissues increases (“biomagnifies”) at each higher level of predation. Being at the highest trophic (food consumption) level in aquatic or riparian ecosystems, fish-eating fishes, birds, and mammals accumulate methylmercury in their bodies at higher concentrations than their prey. This “bio-magnification of mercury levels” in animal tissues can negatively impact growth, reproduction, and survival of species. Fish-eating birds and mammals resident in Bear Creek watershed at risk include bald eagle (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and river otter (*Lontra canadensis*).

Mercury Chemistry

Mercury exists in several different forms, each having distinctive properties for reactivity and mode of transport through Bear Creek watershed and downstream.

Elemental Mercury

Elemental mercury (chemical symbol Hg^0) is a liquid and can be found naturally as droplets in mercury mines. It is unusual among in that it can vaporize into the atmosphere. This form of mercury is the most common form of mercury (98 percent) found in the atmosphere at concentrations of 1 to 2 nanograms per cubic meter (Gray 2003). People can inhale elemental mercury in the air, which then passes into the blood stream and spreads throughout the body. Red blood cells, the liver, and the central nervous system transform Hg^0 to mercuric mercury (Hg^{2+}) and methylmercury (CH_3Hg^+) (Björg 2003). Light energy transforms a small percentage of quicksilver to mercuric ions.

Mercuric Ions

The mercuric (Hg^{2+}) form of mercury is reactive chemically and, of all forms of inorganic mercury, most readily reacts to form methylmercury. In the human body, ionic mercury can bind to sulfur atoms on essential cell proteins and thus disturb vital functions of cells causing damage to the central nervous system, neuromuscular malfunction as well as damage people’s kidneys and intestines (Björg 2003). Most mercury deposited back to the earth surface from the atmosphere arrives in this form (Gray 2003) and readily methylates once it reaches suitable conditions in an aquatic environment.

Mercurous Ions

Mercurous ions (Hg^+) like quicksilver react only to form inorganic compounds and are not methylated. The role of mercurous ions in the mercury cycle worldwide is poorly known.

Organic Compounds of Mercury

Organic compounds of mercury are the most toxic forms of mercury as they accumulate in people as well as fish and wildlife. Sediments in aquatic benthic environments provide the conditions for transforming elemental and ionic mercury into organic compounds. These compounds are readily soluble in lipids (blood fats) and easily move through the body and across the blood/brain barrier.

Methylmercury

Once inside the body, methylmercury slowly breaks down to Hg^{2+}, triggering delayed cumulative poisoning. In oxygen-deprived ('anoxic") conditions as in waterlogged or hydric soils, methylmercury can accumulate high concentrations. Mercuric ions (Hg^{2+}) combine with a methyl radical (CH_3^-) to form methylmercury (CH_3Hg^+). In Bear Creek watershed, methylmercury tends to reach its highest amount in January, when powerful storms transport large sediment loads overland and into streams (high flow – high load); in April and May; and in late-summer when the stream flows are the lowest of the year and methylmercury concentrations in these low flows are highest of the year.

Dimethylmercury

Dimethylmercury ($(CH_3)_2Hg$) is rare in nature (Barkay and Wagner-Döbler 2005) and is particularly toxic, with just a drop or two in contact with the skin can cause death after ten months (Björg 2003). Because of its volatility to gas, dimethylmercury is less apt to enter the food web of an aquatic environment.

Major Mercury-Containing Minerals in Bear Creek watershed

Cinnabar

Cinnabar (α-HgS), or mercury sulfide, is a red solid compound of mercury naturally found in ores and stream sediments in Bear Creek watershed. Most mercury from Bear Creek watershed exists as cinnabar and is associated with serpentinite, altered sedimentary rock near serpentinite, and the vent zones of hot springs (Studemeister 1984). It is not toxic to animals and people because cinnabar cannot be absorbed into blood. Cinnabar is the source of the pigment vermilion. Under natural conditions, cinnabar weathers and alters chemically only very slowly. When transported into aquatic ecosystems as a suspended solid, it may ionize slowly to a mercuric ion, which then may transform to methylmercury (Domalgaski et al. 2004a). The reaction rates from cinnabar to mercuric ion to methylmercury are not presently known.

Metacinnabar

Metacinnabar (ß-HgS) has a black color and consists of a complex of linked cinnabar molecules formed during retorting (heating to about 600°C) of cinnabar in the industrial process to extract pure elemental mercury from cinnabar ore. It is found in the "calcines" (waste rock and sediment piles) at mercury production sites and it is highly insoluble in water. The presence of metacinnabar is an indicator of the presence of human-caused mercury contamination.

Other Mercury Compounds as By-Products

When producers retorted cinnabar to extract elemental mercury, they also generated unnaturally high concentrations of other mercury minerals, in addition to metacinnabar as by-products in the calcines left in the Sulphur Creek subwatershed. At nearby mercury mining and retorting sites in Napa and Lake counties, the following mercury compounds, more soluble that cinnabar and metacinnabar, were present in unnaturally high percentages: corderoite ($Hg_3S_2Cl_2$), schuetterite ($HgSO_4$), terlinguite (Hg_2OCl), and mercuric chloride ($HgCl_2$). These by-products can release Hg^{2+} more readily to start the process of methylation (Kim et al 2000). The composition of calcines from retort sites in the Sulphur Creek subwatershed has not been studied in depth.

Key Chemical Processes with Forms of Mercury

Sulfide Reactions

Sulfur-containing ionic compounds and gases are prominent constituents of thermal spring waters in the Sulphur Creek subwatershed. The proximity of sulfur to large stores of mercury controls mercury chemistry, particularly in anerobic (oxygen-less) conditions found in stream sediments. Increasing concentrations of sulfide ions, particularly from dissolved hydrogen sulfide (H_2S), a common gas in Sulphur Creek thermal springs, creates acidic conditions where cinnabar becomes more soluble. Under these conditions, cinnabar forms soluble mono- and bisulfide ions, HgS_2H_2, $Hg_2S_2H^-$, and HgS_2^{2-}. Iron sulfide or pyrite (FeS_2) also makes the sediment environment more acidic and thus activates cinnabar to form sulfides (Boszke et al. 2003). Other iron compounds called oxyhydroxides provide bonding sites in stream sediments for the mercury bisulfides that then wash downstream, particularly during winter highwater flows.

Methylation

Bacteria are responsible for methylation of mercury mono- and bisulfides to mono- and dimethylmercury. The rate of bacteria-mediated methylation depends on temperature, water pH, amount of soluble mercury ions, and the type and amount and type of organic matter lodged in the soil sediment just below the water/sediment interface. The greatest methylation by bacteria takes place in late summer when low-flow conditions cause Bear Creek water to be low in oxygen and thus make aquatic habitats more conducive to methylating bacteria. The species believed to contribute most to methylmercury production in Bear Creek are *Desulfobacter* and *Desulfovibrio,* based on findings at the Abbott Mine in the North Fork Cache Creek watershed adjacent to Bear Creek watershed (Batten and Scow 2003). Ambient concentrations of dissolved calcium (Ca^{2+}), magnesium (Mg^{2+}) and high salinity (Cl^{-}) act to inhibit Hg methylation.

Demethylation

Bacteria also demethylate mercury with enzymes to precipitate solid cinnabar (mercury sulfide) under both anaerobic and aerobic conditions in stream water, depending on the species of bacteria. These reactions are now intensively studied for applications in environmental remediation to remove methylmercury and mercury from mercury-contaminated water and sediments.

Mercury in Soils

Churchill and Clinkenbeard (2003) undertook extensive sampling of local background conditions of soils in the Sulphur Creek subwatershed for mercury concentrations. These data cover a more extensive area and include samples from Skyhigh and Millsholm soils on the floor of the Sulphur Creek valley floor northwest of Wilbur Springs as well as Henneke soil sites near the Elgin and Rathburn-Petray mine works at higher elevations. The range of mercury concentrations differed greatly among sites: from low values of 0.79 and 1.72 up to 280 ppm near the Cherry Hill Mine alone. The highest concentrations locally exceed the threshold for very high risk to human health. Mapping of naturally occurring mercury concentrations in soils of Bear Creek watershed is not available and is less well understood than the distribution of mercury in sediments in Sulphur Creek and in mine wastes at abandoned mines in the Sulphur Creek subwatershed.

APPENDIX J

SUMMARY OF THE STATUS OF CHEMICAL ELEMENTS WITH MCLS IN BEAR CREEK WATERSHED

Aluminum

Ultramafic soils usually have low concentrations of aluminum compared to non-ultramafic soils. Despite this pattern, water flow from abandoned mines, and to a lesser extent from spring waters, causes concentrations of total aluminum to exceed the primary aluminum MCL in Sulphur Creek. The recommended lower concentration from the secondary MCL is exceeded in virtually all water samples from the Sulphur Creek subwatershed collected in February 2001 (Suchanek et al. 2002). Time of year or water flow may affect concentrations. For example, data from Sulphur Creek in May 1994 were lower by at least a factor of four than the February 2001 data. Data from the lower main stem of Bear Creek show, however, diluted concentrations well below the primary MCL at all times (Department of Water Resources data, 2003-2006).

Antimony

Data on antimony are few and differ greatly over time and among springs. Highest reliable readings of antimony concentrations in water come from the Jones Fountain of Life and Wilbur Spring - up to 0.085 mg liter^{-1} (Suchanek et al. 2002), in the immediate floodplain of Sulphur Creek. Water in creeks flowing from Cherry Hill Mine into Sulphur Creek had ten times the concentration of the antimony MCL. Concentrations of antimony in lower Sulphur Creek and Bear Creek indicate very low concentrations, well below the MCL.

Antimony usually occurs at concentrations of < 1 mg kg^{-1} in soils and frequently in association with arsenic (Lehr et al. 2007). The locally high concentration of antimony found in Soboba soil in Sulphur Creek valley had an antimony concentration > 9 mg kg^{-1}. (Morrison et al. 2008) This high concentration is greater than any found in a national survey of soils by the US Geological Survey (Shacklette and Boerngen 1984). The high antimony concentrations were in the C soil horizon, at > 4 cm depth. Most other soil samples taken from Sulphur Creek show an evenly distributed and low concentration of antimony throughout the soil horizon. Given the immobility of antimony, absence of antimony in the Soboba A soil horizon is odd if the source of antimony were anthropogenic mining products. Antimony concentrations are high (> 35 ppm) in two Sulphur Creek sediment samples taken downstream of mine sites (Morrison et al. 2008).

Knowledge about how antimony behaves at these higher concentrations is poorly known in hydric soils (Tighe et al. 2005). Bacteria can methylate antimony and chemically reduce antimony (V) to antimony (III) in anaerobic sediments to form water-soluble and toxic antimony acids. Initial study of antimony methylation indicates that soil pH, water content, and temperature do not correlate with the rate of antimony biomethylation observed with antimony (Duester et al. 2005).

Arsenic

Most arsenic enters water supplies from natural deposits or springs in the earth or from leaching from mine waste rock and sediment. Concentrations of arsenic measured at Blanck Spring, Jones Fountain of Life, and Wilbur Spring are above the arsenic MCL (0.010 mg liter^{-1}) for drinking water (Suchanek et al. 2002). Dilution effects in Sulphur Creek put the concentration well below the MCL. Levels of arsenic measured by the Department of Water Resources between 2001 and 2006 near the mouth of Bear Creek approached but never exceeded the MCL for arsenic.

The source of arsenic in soils may in part be the result of flooding and drainage of water laden with arsenic (principally arsenite, the arsenic ion form As(III)) that comes from geothermal springs and commercial mining (Manning and Suarez 2000). Arsenic adsorbs to clay minerals in soil where oxidation of arsenic (III) to arsenic (V) occurs, especially with increasing pH (Lin and Puls 2000). Oxidation can also take place by methylation, which may reduce arsenic toxicity (Bentley and Chasteen 2002).

Barium

Goff et al. (2001) and Suchanek et al. (2002) provide consistent data for barium. All thermal springs measured in the Sulphur Creek watershed had barium concentrations higher than the barium MCL. Most concentrations were slightly above the MCL except for Blanck and Elgin springs, which had concentrations three times higher. Stream flow and perhaps seasonality may affect barium concentrations. Suchanek et al. (2002) readings in Sulphur Creek during February 2001 were roughly one-eighth of the readings during May 1994 (Goff et al. 2001), with most Sulphur Creek readings being below the MCL for barium. Readings from Bear Creek from May 1994 were about a third of the concentrations found in Sulphur Creek at the same time.

Chloride

Chloride, the dissolved ionic form of chlorine, is an indicator of salinity. It is present in thermal springs at concentrations higher than any other element. High values of chloride indicate the ancient marine environment of the region. Readings taken at all seasons have shown that chloride concentrations in Sulphur Creek subwatershed springs range consistently from 36 to 39 percent of total dissolved solids by weight. Amounts range as high as 13.39 grams per liter at Elbow Spring (Goff et al. 2001). These amounts are more than 100 times higher that the secondary MCL for chloride.

Chloride and sodium ions contribute a significant proportion to the dissolved solids in stream water. Data from the California Department of Water Resources water quality station in lower Bear Creek show seasonal patterns in the concentrations of chloride similar to those of sodium. Concentrations of chloride are highest in the driest months when water in thermal springs contributes a larger share of water flow.

In Sulphur Creek, chloride as a percentage by weight of total dissolved solids is the same as for springs but the concentrations of chloride are about half those of Sulphur Creek springs. Even with dilution from Bear Creek water, the concentrations of chloride and total dissolved solids in lower Bear Creek exceed the secondary recommended MCLs for chloride (250 mg 1^{-1}) and total dissolved solids (500 mg 1^{-1}) from May through October (USGS data from gage station 11451720 collected from 1969 to 1979; Department of Water Resources data from gage station A1825000 collected from 2000 to 2006). Percent of chloride by weight of total dissolved solids ranges widely from 16 to 33 percent in lower Bear Creek.

Chromium

Currently the California Department of Public Health has an MCL for total chromium (element symbol Cr). From the standpoint of drinking water and human health, the concern is for Cr(VI), a known cancer-causing contaminant made famous by the film *Erin Brockovich*. The California Office of Environmental Health Hazard Assessment issued a draft public health goal for Cr(VI) in advance for setting a separate MCL for Cr(VI).

Total chromium concentrations in Sulphur Creek springs and stream water in data from Suchanek et al. (2002) do not exceed the MCL. Data collected by the California Department of Water Resources close to the mouth of Bear Creek (2000-2006) confirm that chromium does not exceed the MCL; concentrations at the mouth of Bear Creek are as high as or higher than readings from Sulphur Creek subwatershed.

Gough et al. (1989) first noted the natural occurrence of Cr(VI) in very small amounts at a thermal spring in an ultramafic area of Tehama County; previously, Cr(VI) was thought exist only as an industrial product.

Fluoride

Fluoride, the dissolved ionic form of fluorine, is present in all thermal springs in the Sulphur Creek subwatershed at concentrations up to five times greater than the fluoride MCL. Apart from water streaming from mines, concentrations of fluoride are about 30 percent more than the MCL. Few data come from Bear Creek, but they indicate that Bear Creek has fluoride concentrations well below the MCL.

Iron

Iron (chemical symbol Fe) is a not a toxic pollutant of concern but does affect color and taste of water destined for drinking water. It has a secondary MCL of 0.3 mg $liter^{-1}$. Ultramafic rocks naturally have high iron content in their minerals. Fe(II) precipitates and accumulates at discharge points from high-salinity springs in Sulphur Creek subwatershed. Elgin Mine and Jones Fountain of Life are the two springs with consistent values for iron concentrations above the MCL. The total iron in Sulphur Creek water is very high (Suchanek et al. 2002), but creeks flowing into Sulphur Creek from the Wide Awake Mine and the Cherry Hill mine have dissolved-only iron concentrations three times higher than the MCL. These concentrations are diluted to amounts well under the MCL near the mouth of Bear Creek (Department of Water Resource data, 2001-2006). Other subwatersheds north of Sulphur Creek are likely not major sources of iron.

Manganese

Manganese (chemical symbol Mn) has a secondary MCL of 0.05 mg $liter^{-1}$, a notification level of 0.50 mg $liter^{-1}$, and a response level of 5.0 mg $liter^{-1}$. Manganese is a widespread metal in ultramafic rocks in Bear Creek watershed. Measurements from Elbow Spring and the Jones Fountain of Life, the creeks originating from mines, and Sulphur Creek stream water exceeded the MCL for manganese. Concentrations for manganese in Sulphur Creek in May 1994 (Goff et al. 2001) were three to four times higher than readings taken in February 2001 (Suchanek et al. 2002). Manganese concentrations near the mouth of Bear Creek, however, are well below the MCL (California Department of Water Resources data, 2000-2006).

Non-toxic concentrations of manganese in soil range from 40 to 900 ppm (Agency for Toxic Substances and Disease Registry (ATSDR) 2008). Manganese forms cation-exchange bonds and ligand exchanges for its retention in soil, and natural accumulations (without constant inputs) occur in subsurface soil horizons. When the cation ion exchange capacity and organic matter content of soils are high, manganese concentrations are higher in the soils. Bacteria play an as yet poorly defined role in manganese toxicity; for example, bacteria may make manganese more mobile and bio-available by converting Mn(IV) to Mn(II) (Gadd 2004). Like boron, manganese is a plant micronutrient that can become toxic to plant growth when concentrations in soils become too high. Concentrations in the watershed present moderate risk to local residents. Skin contact with manganese compounds in soil is usually not toxic as soil manganese is usually somewhat inert with only about 3 to 5 percent of the soil amount in contact being absorbed internally (ATSDR 2008).

Nickel

Nickel is commonly found in large amounts in areas of ultramafic rocks and soils. Plants, notably in the cabbage family (Brassicaceae), have adapted to soils with high nickel concentrations and can accumulate nickel internally. All data for nickel concentrations in water from Sulphur Creek watershed were more than 50 percent below the nickel MCL. Nickel compounds appear not to accumulate in the food chain. In general, nickel does not accumulate to toxic levels in animals or in humans (Barceloux 2000) except in unusual situations such as in the proximity of nickel mines.

Sulfur

Ions containing sulfur, particularly sulfate and sulfide, are present in high amounts in all geothermal springs found in the Sulphur Creek subwatershed. The odor of hydrogen sulfide gas permeates the air around several springs in the subwatershed and lower Sulphur Creek itself. Churchill and Clinkenbeard (2002) estimate that between seven and sixteen metric tons of sulfate ions enter Sulphur Creek annually from abandoned mines and hot springs. An as yet unknown amount of sulphate originates as well from the cold springs in the southwest corner of Bear Valley (Slowey and Rytuba 2008). The co-occurrence of sulfur and mercury at abandoned mine sites is critical in magnifying the impact from mercury to biota and the stream ecosystems of Sulphur Creek and lower Bear Creek (Rytuba 2000). High concentrations of sulfate are important because sulfates bind readily to mercury in cinnabar to form water-soluble mercury sulfate. Solubility mobilizes the diffusion of mercury from sediments into stream water. Subsquently, bacteria are able to methylate mercury in the presence of dissolved organic matter in fluvial and wetland environments. Methylation converts mercury into methylmercury, the form of mercury most easily incorporated into human and wildlife bodily tissues, and result in mercury accumulation and sometimes to mercury toxicity. Churchhill and Clinkenbeard (2002) also point out that managing stream concentrations of sulfate is indispensible step to controlling mercury and methylmercury in Sulphur Creek and lower Bear Creek.

APPENDIX K

PROPERTIES OF HYDROTHERMAL SPRINGS IN SULPHUR CREEK SUB-WATERSHED IN REGARD TO CONTAMINANTS AND WATER PROPERTIES

The following table summarizes work undertaken by the US Department of Energy (Goff et al. 2001), a team from the US Geological Survey and the University of California - Davis (Suchanek et al. 2002), and the Central Valley Water Board (Cooke and Stanish 2007) to characterize spring waters. Concentrations in excess of primary maximum contaminant levels are highlighted in yellow; concentrations in excess of secondary maximum contaminant levels are highlighted in blue; and concentrations in excess of notification levels are highlighted in green. The largest value recorded for a particular chemical constituent or water property is in red type. Unless otherwise specified, concentrations of elements are in parts per million.

The MUN standards used here for reference apply only to watersheds or subwatersheds that have MUN as a designated beneficial use. Lower Sulphur Creek does not have MUN as a designated beneficial use. Thus, these data provide an overview about how natural spring sources in the Sulphur Creek subwatershed depart from characteristics for suitable municipal water.

Table K.1 – Characteristics of major hydrothermal springs in the Sulphur Creek subwatershed

Water Sources	Temp º C	Field pH	Mercury Raw	Aluminum	Antimony	Arsenic	Barium mg liter-1 total	Boron
Wilbur Spring Don White's	54 – 58	7.2 – 8.0	0.0064	<0.200	<0.010 – 0.021	<0.010	1.12 – 1.43	255 - 278
Wilbur Spring Main	50 – 57	6.87 – 7.9	0.0035 - 0.0073	<1.000	0.003 – 0.023	<0.010 – 1.200	1.34 – 1.39	283 - 295
Jones Fountain of Life	53 – 62	7.28 - 8.2	0.0220 – 0.0336	<1.000	<1.000	<0.010 – 1.200	1.32 – 1.53	265 – 300
Blanck Spring	36 – 45	7.0 – 7.5	0.0069	<0.100	0.003 – 0.310	0.010 – 0.063	3.21 – 3.86	158 - 196
Elbow Spring	70 – 74	8.0 - 8.5	0.0610	<0.010 – 1.800	<0.010	<0.001 – 0.010	1.16 – 1.22	315 – 355
Elgin Spring Main	67 – 70	7.4 - 8.3	0.0110	<0.010	0.010	<0.010	2.96 – 3.14	220 – 223
Elgin Spring Orange Tub	63	8.2	0.0007	<0.005	0.010	<0.010	3.44	223
Unnamed Hot Spring	52	7.0	0.0043	<0.100	<0.010	<0.010	1.11	319

Water Sources	Cadmium	Cloride	Chromium	Copper	Flouride	Iron	Lead	Manganese
Wilbur Spring Don White's	<0.010	9720 - 11080	<0.020	<0.020	2.11 – 2.36	80	<0.010	0.020
Wilbur Spring Main	<0.005	8810 - 11100	<0.010	<0.002 - 0.010	2.10 – 3.32	<0.020 – 0.265	<0.004 – 0.010	0.010 – 0.060
Jones Fountain of Life	<0.005	9130 - 11260	<0.010	<0.002 – 0.030	2.54 – 5.15	0.040 – 0.410	0.005 – 0.060	0.010 – 0.080
Blanck Spring	<0.010	7519 - 8765	<0.010	<0.010 – 0.023	2.47- 0 3,57	0.050 – 0.180	<0.020	<0.010 – 0.020

Water Sources	Cadmium	Cloride	Chromium	Copper	Flouride	Iron	Lead	Manganese
Elbow Spring	<0.010	12530 - 13390	<0.020	<0.010 – 0.030	4.36 – 5.76	0.070 – 0.09	<0.020	0.010 – 0.110
Elgin Spring Main	<0.010	11170 - 11390	<0.010	0.020	2.43 – 3.48	0.300 – 0.700	<0.020	<0.010 – 0.040
Elgin Spring Orange Tub	<0.005	11480	<0.010	0.020	2.56	0.500	<0.010	0.020
Unnamed Hot Spring	<0.010	12550	<0.010	<0.010	4.61	0.060	<0.010	<0.020

Water Sources	Nickel	Nitrate	Nitrite	Selenium	Silver	Sulfate	Thallium	Vanadium	Zinc
Wilbur Spring Don White's	<0.020	<0.200	<10.000	n.d.	<0.005	141 –420	n.d.	n.d.	<0.010 – 0.070
Wilbur Spring Main	<0.010	<2.000	<0.500	n.d.	<0.005	72.7 – 187	<0.00002	n.d.	<0.100
Jones Fountain of Life	<0.010	<0.200	<0.500	0.040	<0.005	109 - 220	<0.00020	<0.002	<0.100
Blanck Spring	<0.005 – 0.030	<0.200 – 5.96	<10.000	n.d.	<0.010	292 - 506	n.d.	n.d.	<0.050
Elbow Spring	<0.005 – 0.060	<0.200	<10.000	<0.001	<0.010	56.6 - 455	n.d.	n.d.	<0.010 – 0.070
Elgin Spring Main	<0.010	<0.200	<1.000	n.d.	<0.010	104 - 221	n.d.	n.d.	<0.050
Elgin Spring Orange Tub	<0.010	<0.200	<0.200	n.d.	<0.005	262	n.d.	n.d.	0.050
Unnamed Hot Spring	<0.010	<0.200	<0.200	n.d.	<0.005	194	n.d.	n.d.	<0.050