Final

TUOLUMNE COUNTY

Foothill Watershed Assessment

Prepared for:
Tuolumne County

February 2007

ESA

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Report Acronyms

BMPs	best management practices
CALFED	California Bay-Delta Authority
CAMMR	California's Management Measures for Polluted Runoff
CGS	California Geological Survey
CGU	Channel Geomorphic Unit
CLS	California Laboratory Services
COC	Chain of Custody forms
CT-1	Curtis Creek Monitoring Location 1
CVRWQCB	Central Valley Regional Water Quality Control Board
DEM	Digital Elevation Model
DOQQ	digital ortho quarter quadrangle
ELAP	Environmental Laboratory Accreditation Program
ESA	Environmental Science Associates
GIS	Geographic Information System
GV-1	Garrotte Creek Monitoring Location 1
HA	Hydrologic Area
HGU	Hillslope Geomorphic Unit
HU	Hydrologic Unit
MEP	maximum extent practicable
mg/L	milligram per liter
mL	milliliter
MM-1	Mormon Creek Monitoring Location 1
MPN	most probable number
MRP	Monitoring and Reporting Plan
NA	Not Applicable
NAD 83	North American Datum 1983
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTU	nephelometric turbidity unit
PSA	Primary Study Area

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QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
RL / IAL	Reporting Limit / Instrument Accuracy Level
RPD	Relative Percent Difference
SNEP	Sierra Nevada Ecosystem Project
SV-1	Sullivan Creek Monitoring Location 1
SV-2	Sullivan Creek Monitoring Location 2
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TB-1	Turnback Creek Monitoring Location 1
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TSS	total suspended solids
UCCE	University of California Cooperative Extension
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WD-1	Woods Creek Monitoring Location 1
WQC	Water Quality Committee
WQP	Water Quality Plan
µg/L	microgram per liter
µS/cm	microSiemen per centimeter

Chapter 1
Introduction

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Introduction

1.1 Overview

This Watershed Assessment (Assessment) was undertaken to evaluate current water quality conditions within the foothill region of the Upper Tuolumne and Stanislaus River watersheds.[1] In support of this objective, this Assessment provides a description of existing conditions at a reconnaissance level in an effort to identify factors influencing water quality and, more importantly, to capture the spatial extent of those influences. The findings and recommendations developed as part of this Assessment will form a scientific basis for the preparation of a Water Quality Plan (WQP) for Tuolumne County (County). In this context, this Assessment focuses on hydrologic areas within the foothill region of the County and their interactions with the larger Upper Tuolumne and Upper Stanislaus River watersheds.

1.2 Assessment Background and Context

Similar to many foothill watersheds within the Sierra Nevada, little information in terms of hydrology and surface water quality is available for smaller hydrologic areas that drain into the larger, well-known river systems (e.g., Tuolumne and Stanislaus Rivers). Until recently, much of the attention in the Upper Tuolumne and Stanislaus River watersheds has been directed toward their upper reaches due to water supply, hydroelectric, timber, and recreational interests. Consequently, much of the existing information is limited to these areas. However, as growth within the Central Valley continues to expand east, its effects are being felt in numerous foothill communities, including those within the County. This trend has prompted the need for a better understanding of foothill watershed dynamics and how continued urbanization will affect the structure and functionality of foothill watersheds in addition to corresponding implications to surface water quality.

The purpose of preparing this Assessment is to support the CALFED drinking water quality objective by assessing source water quality within the County and developing a planning framework that responds to the assessed conditions. This Assessment looks broadly at surface water resources within the County based on existing information and places specific emphasis on surface water quality within the foothill region where limited information exists and urbanization is actively occurring. For these foothill watersheds, this Assessment is supported by a surface water quality-monitoring program and a sediment characterization component developed for a smaller sub-unit that yielded data that may be extrapolated to the larger, developed foothill region (see Chapter 4, Foothill Geomorphology and Sediment Transport Dynamics).

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[1] A "watershed" is defined as the region draining into a river, river system, or other body of water above a particular point.

By virtue of the applied beneficial uses to these downstream water-bodies (e.g., drinking water and cold water habitat), the County is interested in further understanding how the various land use activities occurring within its jurisdiction affect watershed function and, more importantly water quality, in the context of each watershed. Just as important is how future water quality regulations may be applied in the County. For these reasons, this Assessment identifies and broadly evaluates those influences to downstream water impoundments to better understand the function of the foothill watershed in the context of the overall hydrologic unit (e.g., Upper Tuolumne River). Just as important is the understanding of how these functions have changed as a consequence of urbanization, agricultural practices, timber harvesting and management, and water diversions and/or impoundments in unincorporated sections of the County.

The County recognizes that there are numerous valued components and processes in a given watershed and could spend an enormous amount of time and money studying them. With this understanding, it becomes clear that it is necessary to identify and prioritize a few characteristics that are critical to evaluating relative watershed health and, most importantly, surface water quality. The constituents of most concern in water bodies that drain to the Sacramento-San Joaquin Delta with respect to drinking water include microbial pathogens, organic carbon, salinity, turbidity, and nutrients. These constituents in addition to other common urban and agricultural contaminants, as identified in Chapter 5, Surface Water Quality, were chosen as the primary water quality indicators for this Assessment. A general evaluation of ecosystem processes, local geomorphology, and land use history was necessary to link the water quality data acquired from the County water quality program in efforts to determine if and where cumulative or mass loading of pollutants is impairing surface water quality. More importantly, it is necessary to know the extent to which watershed conditions have been altered by land use within the County's jurisdiction.

1.3 Land Ownership and Jurisdictional Context

Tuolumne County is almost exclusively contained within the Upper Stanislaus and Tuolumne River watersheds in the central Sierra Nevada (see Figure 1-1). The County comprises just less than 1.5 million acres; the Stanislaus National Forest and Yosemite National Park comprise the eastern two-thirds of the land area. With federal lands comprising such a large proportion of the County, the primary geographic scope of the Assessment is focused to the foothill regions of the two watersheds where urban growth is actively occurring and where the County maintains primary land use authority.

This Assessment is driven by the need to develop a WQP that focuses on the County's concerns for surface water quality based on observed risks. At the same time, the WQP needs to assist CALFED in achieving its primary mission by protecting major sources of drinking water for the Sacramento-San Joaquin Delta and the San Francisco Bay. To this end, the objectives of this Assessment are twofold: (1) assessing foothill watershed conditions in terms of cumulative surface water quality conditions and sediment production, and (2) identifying the priorities and preliminary content of the WQP.

This Assessment was prepared with the intent of establishing a baseline for foothill watersheds within the Upper Tuolumne and Stanislaus River watersheds, specifically lands within County jurisdiction. An attempt to assess cumulative watershed effects (CWEs) was undertaken as part of this Assessment to better understand watershed processes and the impacts that result from human activities. To the extent possible, the relationship between human activities, watershed processes, sources of stress ("stressors"),[2] and the ecological endpoints are also considered.

1.4 Watershed Scale and Study Area Focus

By virtue of the expansive drainage areas within the Upper Stanislaus and Upper Tuolumne watersheds, it is not practical to provide a detailed assessment of the entire watersheds. Additionally, the County is not interested in studying land areas where it does not have discretionary authority over land use decisions. For these reasons, the Assessment only provides an evaluation of watershed conditions at two distinct, but inter-related, watershed scales. These watershed scales are based on smaller watershed units delineated in the 1999 California Interagency Watershed Map (CalWater Version 2.2.1) for portions of the Big Oak Flat, Clavey River, and Copperopolis Hydrologic Areas.

To determine the appropriate scales of analysis, a jurisdictional overlay was completed to eliminate watershed areas outside the County's jurisdiction. For those watersheds within the County's jurisdiction, focus was placed on watersheds that are experiencing development pressures, supply drinking water to downstream reservoirs, and contain waterways exhibiting water quality concerns. Five planning watershed areas were identified for the reconnaissance-level scale of the Assessment. These include the Sullivan Creek, Woods Creek, North Don Pedro, and Big Creek watersheds within the Upper Tuolumne watershed and the Rawhide Flat watershed within the Upper Stanislaus watershed. These watershed areas are contained along the foothill margin of the County and comprise the primary study area (PSA) of the Assessment. The reconnaissance-level watershed scale was chosen to assess cumulative, mass-loading conditions within local foothill watersheds in conjunction with their interactions with unit-wide watershed conditions, with emphasis placed on surface water quality.

The second and more detailed watershed scale evaluated in this Assessment correlates with the highest priority tributaries within the PSA and the County's interest in understanding the dynamics of sediment transport. Based on discussions with County staff, the public, and agency staff, the Sullivan Creek watershed, a tributary to Don Pedro Reservoir, was identified as one such priority watershed. This watershed scale was chosen to allow for stratification of the Sullivan Creek watershed into units with shared attributes for more detailed characterization of sediment production and transport through the watershed. Fluvial geomorphologic measurements generated as part of this Assessment provide insight on sediment loading to Phoenix Reservoir and Don Pedro Lake from the Sullivan Creek watershed.

[2] "Stressor" refers to anything, natural or human-induced, that could cause harm to components and processes within the watershed.

1.5 Constraints to the Assessment

Access proved to be the single, most constraining factor to the preparation of this Assessment in that the field reconnaissance conducted was generally restricted to public road right-of-ways (ROW). The level of disturbance in these locations is expected to be higher than that of other reaches, where road crossings do not exist. This factor left much of the river channels studied unobservable and limited to aerial photographs for interpretation. Another factor is the presence of engineered water imports and exports. Aqueducts, canals, penstocks, storm drains, and pipelines can interfere with the otherwise-clean delineation of a watershed and, more importantly, interpretation of water quality data.

1.6 Public Involvement

This Assessment has been conducted under the auspices of the County, with funding provided by the California State Water Resources Control Board and CALFED, through a Proposition 13 grant (Costa-Machado Water Act of 2000). This Assessment, including the scope of work, the Quality Assurance Project Plan (QAPP), Monitoring and Reporting Plan (MRP), and Project Assessment and Evaluation Plan (PAEP), have been overseen by a Water Quality Committee (WQC), who have helped to guide the study and review draft documents (see Chapter 7 for the WQC's membership).

The Upper Tuolumne (USGS Cataloging Unit No. 18040009) and Stanislaus River (Cataloging Unit No. 18040010) watersheds have been designated as Category I watersheds by the California Unified Watershed Assessment (CUWA). Watersheds with high values (e.g., water quality), high risks to maintaining those values (e.g., stresses from human population growth, wildfire hazards, and loss of habitat), and high opportunity for achieving improvements (e.g., the presence of local working groups) are considered the highest priority of the Category 1 watersheds. The Upper Tuolumne and Stanislaus watersheds generally meet the first two criteria, but are lacking in the third in terms of a working group that can manage issues at a watershed scale. For this reason, both watersheds are not identified as priority watersheds in the 1997 CUWA; however, the County is optimistic that the program developed as part of the WQP will increase public involvement and agency coordination.

Public outreach and informational exchange during the preparation of this Assessment will be accomplished in several ways. Three public scoping sessions were held in 2005 to solicit public input on current water quality problems within the County, their respective locations, and the constituents of concern (e.g., sediment). Informational exchange and stakeholder involvement continues to evolve within the County through staff coordination and a web link on the County's new website.

1.7 Previous Studies

The Upper Stanislaus and Tuolumne River watersheds have been the subject of several past studies, as well as actions and efforts by local residents to investigate and solve problems associated with the river systems, including impaired water quality. This Assessment in support of the County's WQP builds on past studies, and includes new studies, such as the hillslope and channel geomorphology assessment and a surface water quality monitoring program. This Assessment synthesizes the results of past studies that are applicable to the PSA and provides a context for regional surface water quality conditions. In support of this objective, data acquired for this Assessment consist of a combination of GIS layers, aerial photography (USGS digital ortho-quarter quadrangle [DOQQs]), and various written reports, which are referenced in Chapter 7.

1.8 Report Outline

Following the introduction provided in Chapter 1, Chapter 2 presents a synopsis of watershed conditions from both a regional and local perspective. Chapter 3 briefly summarizes the local landscape history with emphasis on those activities that led to major changes to the physical watershed environment (e.g. road development, mining, urban development, etc.). Chapter 4 describes the initial observations and findings of ESA's geomorphic assessment and sediment characterization study conducted for the Sullivan Creek sub-hydrologic area. Chapter 5 provides a synopsis of surface water quality data obtained as part of this project along with other sources. Principal findings and conclusions of the Assessment are synthesized and presented in Chapter 6. Chapter 7 provides lists of the report authors, the persons consulted, and references.

Chapter 2

Physical Watershed Characteristics

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Physical Watershed Characteristics

This chapter presents an overview of the physical watershed attributes that characterize the foothill region of the Upper Stanislaus River and Upper Tuolumne River watersheds; and more specifically, the primary study area (PSA) of the Assessment. Emphasis is placed on providing an understanding of those physical watershed features that influence, in part, the movement and fate of nonpoint source (NPS) pollutants within the foothill region of the two watersheds. This information is framed in the context of how these attributes interact within the larger San Joaquin River Hydrologic Basin to supplement other CALFED drinking-water programs.

From a classical watershed perspective, the PSA is characterized as a hydrologic sub-basin, which includes five large watershed units, comprising a total of 224.8 square miles (143,847 acres). The first portion of this chapter provides a general description of the PSA in the overall context of the Upper Stanislaus River and Upper Tuolumne River watersheds. The second portion of this chapter provides a more detailed description of the five watershed units that comprise the PSA, which include all or portions of the Sullivan Creek, Woods Creek, North Don Pedro, Big Creek, and Rawhide flat watersheds. Due to the large area involved and topographic complexity of the five watersheds in conjunction with limitations on access and available funding, the level of investigation is more variable at the sub-watershed level. This variability is further noted under the description for the individual watershed units in the later section.

2.1 Watershed Characteristics

2.1.1 Structural Geology

Tuolumne County resides within the central portion of the Sierra Nevada geomorphic province and is characterized by geology dating back to the Paleozoic Era (570 million years ago [mya]). A majority of the County's geology is composed of Mesozoic plutons[1] that are overlain by continental volcanic and sedimentary rock from the Cenozoic Era[2] (CDC, 1997). The eastern two-thirds of the County exhibit intrusive contacts and volcanic/sedimentary cover, whereas the western third is comprised of metamorphic terranes, deformed by folding and faulting. The western-most exposures of the intrusive contact occur in the Phoenix Basin and near Tuolumne City. Further west, metamorphic terranes trend generally north-northwest along fold axes that dip steeply to the east and were formed during the Mesozoic. The vertical orientation of the unit is

1 Intrusive igneous rocks dating back to 66 to 208 mya. .
2 The Cenozoic Era refers to the last 66 mya.

readily visible in horizontal road cuts, for example along Jacksonville Road near Sullivan Creek. Locally, the Calaveras and Shoo Fly complexes exhibit strikes that trend more strongly west-northwest. A general geologic map for the PSA is illustrated in **Figure 2-1**.

The Tuolumne Table Mountain geologic unit is the principal drainage divide between the Upper Tuolumne and Upper Stanislaus Rivers. This geologic feature is clearly visible from State Route (SR) 108 near Chinese Camp and resembles a tabletop from the road (See **Figure 2-2**). Table Mountain is the remnants of an ancient stream canyon cut in a broad flat sheet of volcanic ash and filled by lava that extends for 60 miles from the high Sierra Nevada to its terminus at a bluff of sedimentary andesitic beds near Knights Ferry. Over time, the soft ash was eroded away as the Sierra Nevada was raised and tilted westward. This left the resistant lava flow exposed, creating the appearance of a table. The resistant latite lava flow overlies andesitic tuffs, gravels, Eocene quartz gravels and boulders (Geologic Guidebook, 1949).

2.1.2 Soils Resources

In general terms, the distribution of soil resources across the County is mainly representative of coarse-grained materials overlaying a granitic and/or granodiorite parent material in the eastern two-thirds and finer-grained materials overlaying a metasedimentary and metabasic (or metavolcanic) parent material in the western third. In the upper reaches of the foothill region, the surface soils are highly weathered and often resemble a reddish brown, coarse-textured sandy clay loam with differing quantities of organic matter. North-facing aspects typically have higher contents of organic matter as a consequence of denser vegetation, lower evapotranspiration, and are greater in depth as compared to south-facing locations. In the upper elevations, the subsurface consists of a yellowish red, sandy clay loam that grades to weathered gabbrodiorite at depth (NRCS, 2003). At lower elevations, the soil resource consists of shallow to moderately deep materials comprised of higher fractions of clay and formed in vertically tilted material weathered from metamorphic rock (NRCS, 2002).

Throughout the PSA the depth to bedrock is typically dependent on the degree of slope, but may range from less than 10 inches along hill-slopes and ridgelines to greater than 60 inches in narrow gulches and small alluvial plains. The contact with the bedrock is generally abrupt, although some slightly weathered fracture planes are randomly scattered in many areas. Soils within the PSA are usually well-drained with medium to very rapid runoff, depending on slope angle and ground cover (NRCS, 2003). The rock fragment content ranges from <5 to 50 percent throughout the profile (NRCS, 2002); increasing along hill-slopes and ridgelines. Soil infiltration and permeability is highly variable depending on surface cover, soil depth, and slope.

Numerous medium to very large rock outcrops blanket portions of the foothill region. This rock is generally highly resistant metamorphic or granitic rock that extends to variable depths around the exposed outcrop. In some locations, the rock outcrop unit covers over an acre of land. The plant cover in these locations consists of sparse grasses and stunted trees. In isolated areas, a thin mantle of soil material may be present; however, the depth is typically less than five inches with surface runoff occurring rapidly.

Figure 2-1

Figure 2-2

Within the local stream corridors, bar units that occur in and along these channels consist of highly stratified[3] stony and/or boulder sand that is typically barren, except for isolated areas containing riparian areas, which are subject to inundation during high flows during significant rainfall events (e.g., >10 year, 24 hour). These soils are subject to frequent scouring or cutting as well as to deposition, depending on creek flow and bed load.[4] Typically the surface runoff is moderate and the drainage is variable.

2.1.3 Climate

Tuolumne County is characterized by warm, dry summers with little to no precipitation, and cold, wet winters with moderate to heavy precipitation. At elevations above 5,000 feet, this precipitation is generally in the form of snow. The majority of annual precipitation falls as rain from November through April. However, when subtropical air masses move into the Sierra Nevada in summer and early autumn, sufficient moisture is available to generate extreme rainfall. Intense convective storms occurring over a period of three or four days can generate local flooding. In the foothill region, the total annual rainfall averages approximately 35 inches. By virtue of the orographic uplift created by the presence of the Sierra Nevada, precipitation is highly influenced by elevation. General precipitation zones are illustrated in **Figure 2-3**. Within the foothill region, the 10-year, 24-hour estimated precipitation amount is approximately 5.5 inches and the 100-year, 24-hour precipitation amount is approximately 8.0 inches (WRCC, 1973).

About half the recorded precipitation in the major river basins of the west slope of the Sierra Nevada becomes stream flow (**Table 2-1**) (Kattelmann et al., 1983). Stream flow, both in absolute magnitude and as a proportion of precipitation, increases with elevation. In a 1-square-kilometer (250-acre) research basin in Sequoia National Park at 2,800 to 3,400 meters (9,200 to 11,100 feet), 75 to 90 percent of the annual precipitation became stream flow (Kattelmann and Elder, 1991).

TABLE 2-1
APPROXIMATE DISPOSITION OF PRECIPITATION IN MAJOR RIVERS

River	Gauging Station	Precipitation (Centimeters)	Stream Flow (Centimeters)	Losses (Centimeters)
Stanislaus	(New Melones Reservoir)	115	75	40
Tuolumne	(Don Pedro Reservoir)	110	55	55

SOURCE: Kattelmann et al., 1983

3 The term refers to geologic deposits or soil layers that result from processes of soil formation through layering.
4 Rock particles rolled or pushed along the bottom of a stream by moving water.

Figure 2-3

2.1.4 Regional Surface Water Hydrology

Tuolumne County is almost exclusively contained within the Upper Stanislaus and Tuolumne River watersheds (U.S. Geological Survey Catalog No. 1804009 [Upper Tuolumne River] and No. 1804010 [Upper Stanislaus River]) located in the central Sierra Nevada (see **Figure 2-4,** Hydrology). These hydrologic units span the entire western slope of the Sierra Nevada, extending approximately 90 linear miles from large dam impoundments in the lower foothills east to the crest; rising over 12,000 vertical feet. The North Fork and mainstem Stanislaus River delineate the northern boundary of the Upper Stanislaus River watershed, which defines the boundary between Tuolumne and Calaveras Counties. This drainage divide is a result of the Calaveras Table Mountain sequence situated along the southwestern boundary of Calaveras County and Summit Level Ridge further east. As indicated in Section 2.1.1, a similar Table Mountain sequence forms the division between the Upper Tuolumne and Stanislaus Rivers systems. To the south, a series of ridgelines delineate the drainage divide between the Upper Tuolumne River watershed and the Merced River watershed. These ridgelines include the Piney Ridge, Penon Blanco, Warner, Pilot Ridges, and the Cathedral Range further east.

Several dam systems regulate flows within the middle and lower reaches of both river systems. Don Pedro Reservoir along the Tuolumne River and New Melones Reservoir along the Stanislaus River are the largest impoundments within each watershed with 2,030,000 acre-feet (AF) and 2,420,000 AF of capacity, respectively (USGS, 2003). These two impoundments disconnect each waterway from its lower reaches within the Central Valley. Below each reservoir, each river flows west, southwest before converging with the San Joaquin River. Once in the San Joaquin River, flows travel northwest towards the City of Antioch where they converge with the Sacramento River prior to empting into Suisun Bay, which drains into San Pablo Bay. A schematic depicting the Upper Stanislaus and Upper Tuolumne River's connection to the Sacramento-San Joaquin Delta is depicted in **Figure 2-5**.

The PSA is situated near the base of the two watersheds and represents a small fraction of the total watershed area. Within the Upper Stanislaus River watershed, the PSA accounts for a very small fraction (approximately 3 percent) of the total watershed area. Within the Upper Tuolumne River watershed, the PSA accounts for a larger, but still relatively minor portion (approximately 11.5 percent) of the total watershed area. Numerous contributing waterways are located upstream of the PSA within both river systems (see Figure 2-4). These waterways generally traverse U.S. Forest Service or National Park Service land and, thus are outside the County's land use authority and not the focus of this study. For this reason, a brief description of these waterways is provided to the extent necessary to compare their integrity and evaluate their overall interaction with the waterways within the PSA.

Gages on these waterways are more available and comprehensive due to their importance as drinking water sources as compared to waterways within the PSA. Unregulated (often called unimpaired) streams within the PSA lack complete datasets and are generally improperly sited for use in this Assessment. Stream gaging stations in the County are operated by the U.S. Geological Survey (USGS), local utilities, irrigation districts in the Central Valley, and a few other federal agencies (e. g., U.S. Bureau of Reclamation).

Figure 2-4

Figure 2-5

Upper Tuolumne River Watershed (Hydrologic Unit)

The Upper Tuolumne River Watershed (Hydrologic Unit 18040009) is drained by the Tuolumne River, which originates in Tuolumne Meadows at the confluence of streams descending from the slopes of Mt. Lyell (13,100 feet) and Mt. Dana (13,155 feet). The Tuolumne River is the largest river flowing into the San Joaquin Valley, draining approximately 1616 square miles (1,033,947 acres), and, on average produces approximately 1.8 million AF of runoff per year. Precipitation largely influences the seasonal flow. The watershed is comprised of 1,944 miles of waterways with 80 percent of the watershed unobstructed by impoundments (ICE, 1997). Approximately 35 percent of the watershed is located on slopes in excess of 15 percent (ICE, 1997). All flows within the watershed drain into Don Pedro Reservoir. Portions of the Tuolumne River are classified as a Wild and Scenic River. This provides additional protection to the river by prohibiting improvements or additions to facilities within the one-quarter-mile corridor on each side of the river until the Wild and Scenic River Management Plan is complete. The corridor is managed by the Stanislaus National Forest Service.

From Tuolumne Meadows the river descends through the steep Yosemite wilderness, before its flow is impounded by the O'Shaughnessy Dam in Hetch Hetchy Valley (3,500 feet). At this point, a portion of the water from O'Shaughnessy Dam is diverted towards the Kirkwood Powerhouse. Above O'Shaughnessy Dam, the river drains a land area of approximately 459 square miles and is located entirely within Yosemite National Park. Just below Yosemite National Park, Cherry Creek enters the river. Further downstream, the Tuolumne River's South and North Forks, as well as the Clavey River, join the main stem above Don Pedro Reservoir.

There are three major reservoirs within the watershed above Don Pedro Reservoir: Hetch Hetchy, Lake Eleanor, and Cherry Valley Reservoirs. Their storage capacities are 360,000, 273,000, and 27,000 AF, respectively (USGS, 2003). These reservoirs are used primarily as water supplies for surrounding counties and any surplus is supplied to San Francisco. Discharge from these reservoirs flows down into the Lower Tuolumne River watershed through Don Pedro Reservoir, which is a major water source for the Cities of Turlock, Modesto and San Francisco.

The North Fork of the Tuolumne River is similar to the sub-watershed units within the PSA and converges with the main stem Tuolumne River, approximately 1 mile upstream from Don Pedro Reservoir. The North Fork is about 10 miles long and drains an area of 114 square miles between Duckwall Mountain, Murphy Peak, and Marble Mountain on the east, and SR 108 to the west. Its major tributaries include Sugarpine and Wrights Creeks, as well as Basin, Duckwall, and Hunter Creeks. The North Fork watershed is small, at a low elevation, and most of its runoff is associated with winter rainfall (FERC No. 10081-002, Turlock Irrigation District, DEIS/EIR Clavey River Project 1994). **Figure 2-6** illustrates the terrain of the North Fork.

Figure 2-6

Don Pedro Reservoir (USGS Cataloging Unit 11287500) is formed by an earthfill dam, which was completed in 1971. It is located 500 feet downstream from Mexican Gulch, and 3.4 miles northeast of La Grange. Storage began on November 3, 1970. The mutually agreed-upon minimum storage is 309,000 AF below, which occurs at an elevation of 600.0 feet. Water passes through a powerplant at the dam and then down the Tuolumne River to La Grange Dam, 2.5 miles downstream, where it is diverted into the Turlock and Modesto Canals for irrigation. The reservoir is owned and operated jointly by Turlock and Modesto Irrigation Districts. Prior to June 1971, the reservoir was formed by a concrete gravity-type dam completed in 1923 with a capacity of 290,400 AF. Extremes for the period of record (September 1923 to 2003) include maximum contents of 2,044,000 AF on January 2, 1997 at an elevation of 831.11 feet. The minimum storage since the reservoir was first filled to its current levels is 302,600 AF, which occurred on October 14 and 15, 1977, at an elevation of 598.2 feet. (USGS, 2003)

Upper Stanislaus River Watershed

The Upper Stanislaus River Watershed (USGS Cataloging Unit 18040010) is composed of 1,660 miles of waterways, with approximately 85 percent of the watershed unobstructed by impoundments (ICE, 1997). There are 32 dams within the watershed and an estimated 1,215 stream crossings (ICE, 1997). Approximately 35 percent of the watershed is situated on slopes in excess of 15 percent slope (ICE, 1997). All flows within the watershed ultimately drain into the federally owned New Melones Reservoir.

The Upper Stanislaus River drains an area of about 997 square miles (638,066 acres). In normal water years, the regulated runoff in the Stanislaus River at New Melones Dam is 1,050,000 AF of water. New Melones Reservoir was formed by an earth rockfill dam and completed in November 1978. It is located 0.1 mile downstream from the old Melones Dam, and 7.6 miles southwest of Sonora. The dam is downstream from the original concrete dam, which was completed in December 1926. When the elevation is above 808.0 feet, water is released through New Melones Powerplant to Tulloch Reservoir where it is used for irrigation. Extremes for the period of record (1926-2003) include maximum contents of 2,400,000 AF for July 8 through 10, 1983 at an elevation of 1,086.42 feet. The minimum since the reservoir was first filled in July 1983 was 83,630 AF on October 1, 1992 at an elevation of 721.15 feet (USGS, 2003).

The 39-mile North Fork Stanislaus River flows through 35 miles of the Stanislaus National Forest from Mosquito Lake to the Middle Fork Stanislaus. McKays Point Reservoir, Lake Alpine, Utica Reservoir, Union Reservoir, and New Spicer Meadows Reservoir all lay within the North Fork. The Middle Fork Stanislaus River flows southwesterly from the Emigrant Wilderness Area (elevation 9,650 feet); joining the North Fork Stanislaus River, approximately 50 miles downstream (elevation 1,230 feet); to form the main stem of the Stanislaus River. The terrain is characterized by 67.5 miles of National Forest (2 miles of the river are outside the forest) from the headwaters to the North Fork Stanislaus. The tributaries that feed into the Middle Fork Stanislaus River include Kennedy Creek in the Emigrant Wilderness Area, Summit Creek, and the Clark Forks of the Stanislaus River.

The South Fork Stanislaus River also flows southwesterly from the Emigrant Wilderness Area near Bay Meadow (elevation 8,800 feet) to the New Melones Reservoir, approximately 35 miles downstream. The only major tributary to the South Fork is Herring Creek. Three storage dams lie along the South Fork Stanislaus River, including Strawberry Dam, which impounds Pinecrest Lake, as well as the Philadelphia Diversion and Lyons Dams and are operated by Tri-Dam. The combined storage capacity for the three dams is 24, 541 AF, which is about 12 percent of the 200,000 AF estimated unimpaired runoff of the South Fork Stanislaus River in a normal water year (Tri-Dam, 2002). The Tuolumne Utilities District (TUD) delivers water supplies to much of unincorporated Tuolumne County from Lyons Reservoir, below Pinecrest Lake on the South Fork Stanislaus River.

2.1.5 Groundwater

Tuolumne County is contained within the portion of the Sierra Nevada geomorphic province where groundwater is primarily located in fractured hard rock fissures. As a result, the County contains no large, well-defined groundwater basins. The highest groundwater yields typically occur at shallow depths where fracturing is greatest. The depth and location of groundwater within the County is highly variable due to the influence of fractures, foliation, faults, or man-made structures such as wells or ponds, and groundwater gradients are likely to be shallower near perennial streams and ponds. According to Delineation of Wellhead Protection Areas in Fractured Rock (USEPA, 1991) and Groundwater Resources and Water Supply Alternatives in the Wawona Area of Yosemite National Park (Borchers, 1986), groundwater flow in fractured-rock aquifers occurs mainly through discrete fracture conduits (Tuolumne County Groundwater Protection Grant Final Report, 2000).

2.1.6 Terrestrial Vegetation

Regional natural plant communities in the PSA include those that are common to the Sierra Nevada Foothills (Upper Foothills Metamorphic Belt Ecological Unit), such as mixed oak, interior live oak woodland, mixed chaparral, and ponderosa pine. Typical elevations within this ecological subsection range from 800 to 5,000 feet above sea level. The PSA contains a diverse assemblage of plant communities and wildlife habitats, from closed canopied, multi-tiered woodlands to open grasslands, ponds, and wetlands. While native plant species dominate most plant communities in the PSA, their structure and composition has been substantially altered over time by resource extraction (including mining and logging), grazing, development, and fire suppression (see Chapter 3.0, Influences from Land Management and Population Growth). In general, these anthropogenic influences have fragmented some habitats, while fire suppression has resulted in most plant communities succeeding into later seral stages that contain high levels of biomass. For example, many of the oak woodland plant communities are both denser, and have a smaller mean polygon size, than what was likely present over 100 years ago.

Plant Communities and Wildlife Habitats

Plant communities are assemblages of plant species that occur together in the same area. They are defined by species composition and relative abundance. The plant community descriptions and nomenclature described in this section generally follows the classification system provided in Sawyer and Keeler-Wolf (1995). **Figure 2-7** illustrates the plant communities found within the PSA. In general these plant communities include:

- Black Oak Series/Montane Hardwood;
- Black Oak Series/Blue Oak Woodland;
- Interior Live Oak Series/Montane Hardwood;
- Mixed Oak Series/Montane Hardwood;
- Ponderosa Pine Series/Montane Hardwood-Conifer;
- Wedgeleaf Ceanothus Series/Montane Chaparral; and
- California Annual Grassland Series/Annual Grassland.

2.1.7 Riparian and Aquatic Ecosystems

Riparian areas are the focal point of many resource conflicts in the Sierra Nevada because they are a critical ecological link between land and water. Although scarcity of quantitative information and unaltered reference sites currently limit the development of quantitative conclusions about riparian health across the entire Sierra Nevada, a few generalities were identified as part of the Sierra Nevada Ecosystem Project (SNEP, 1996).

In the SNEP Report, the term “riparian area” refers to the transition zone between the upslope terrestrial ecosystem and the adjacent aquatic ecosystem. Similarly, the term riparian corridor refers to the land on either side of the stream and including the stream. An emerging concept of riparian (or streamside) management zones has been used by agencies as a management tool to include some upland areas that may influence or buffer the riparian corridor (SNEP, 1996).

Riparian areas are water-dependent lands along streams and lakes where transitions occur between terrestrial and aquatic parts of a watershed. They may be best described as the zone of direct interaction between land and water (Swanson et al., 1982; Gregory et al., 1991; Cummins, 1992). Riparian corridors connect the headwaters to the valley and facilitate transfer of materials (Gregory et al., 1991). Water, energy, and organic matter move downstream through a continuum of changing ecological processes along each stream (Vannote et al., 1980). The continuity of riparian areas is one of their critical characteristics, which is readily disrupted by human activities.

Riparian areas do not have precise boundaries because of temporal fluctuations of stream levels and intermixed vegetation types on the upland side. During most of the year, riparian areas are clearly separate from (though intimately connected to) their adjacent stream. However, during periods of high water, the topographically-lower sections of a riparian area that constitute a floodplain become part of the stream. Riparian communities usually contain a gradient in soil moisture from the stream through the floodplain and sometimes up into the lower terraces, depending on geomorphology and hydrology of the particular site. Typical riparian vegetation requires the high soil moisture usually found along streams, and some can even tolerate saturated soils and occasional inundation.

Figure 2-7

Riparian systems are distinct in mountain areas because they traverse broad vegetation belts that are arranged largely by elevation. At variable distances away from the stream, riparian vegetation grades into upland vegetation. In some cases, there is little obvious difference in the composition of vegetation between the streamside area and the adjacent hillslopes. Elsewhere, there are marked contrasts between deciduous species in the riparian area and conifers or chaparral on the hillsides. The thin, linear nature of riparian areas in the Sierra Nevada limits their total area to a small fraction of any watershed. Because habitat elements associated with riparian areas are relatively rare compared to the entire landscape, modification of even small areas has a proportionally greater impact in riparian areas than elsewhere in the watershed (SNEP, 1996).

In general, riparian areas are the most productive and diverse parts of the landscape (Risser, 1995). Microclimates and soil moisture regimes found along streams are highly favorable for plant growth to be sustained for longer periods of each year than in other geographic locations. The frequent disturbance by floods and variety of physical habitats promotes much greater diversity of species than on more uniform hillslopes (Odum, 1978; Gregory et al., 1991). Under natural flow regimes, frequent disturbance by various levels and durations of flooding results in riparian vegetation with a patchy distribution of species and ages (Swanson et al., 1990). The diversity of species and habitat structure may be reduced by human impacts that tend to simplify ecological processes and components. Riparian communities identified in the PSA include (Sawyer and Keeler-Wolf, 1995) the following:

- White Alder Series/Valley-Foothill Riparian;
- Creeks and Ponds/Aquatic Habitats; and
- Spikerush Series/Seasonal Wet Meadows and Swales.

2.1.8 Existing Land Use

The major population center in the PSA is the City of Sonora with a population of about 4,500. The nearest major population center outside Tuolumne County is the City of Stockton, located about 65 miles to the west. The physical distribution of the County's defined communities within the PSA is shown in **Figure 2-8**. As depicted, Groveland, Big Oak Flat, the Don Pedro Subdivision, and Pine Mountain Lake are located in the southern section of the PSA. Moccasin, owned and operated by the City and County of San Francisco, is also located at the southern end of Don Pedro Reservoir at the confluence of Moccasin Creek. Due to its physical separation from the remainder of the County, the land use patterns tend to be more rural and service needs are generally supported by the central portion of the PSA (e.g., Sonora). This portion of the PSA is commonly referred to as gateway to the Yosemite National Park and a large portion of the area's economy caters to park visitors (Tuolumne County General Plan, 1996).

Figure 2-8

The central and northern portions PSA are characterized by highly urbanized areas with agricultural operations and rural development at the edges of, and between, the individual communities. The central portion of the PSA is relatively rural, extends from Jamestown eastward to Twain Harte, and is the center to the majority of the County's population and the bulk of the County's development since the Gold Rush. This area provides the majority of the County's shopping centers, public services, and industrial facilities. Other urbanized areas in-between and to the north and south include the communities of Columbia, East Sonora, Phoenix Lake, Mono Vista, Soulsbyville, Sonora, Tuolumne City, Tuttletown, Standard, and numerous residential subdivisions located in and around these communities. The Standard Lumber Company and West Side Lumber Company left behind the communities of Standard and Tuolumne City. While few residential structures remain in Standard, a large section of the residential district in Tuolumne City remains intact (Tuolumne County General Plan, 1996).

2.2 Foothill Watershed Characteristics

This section provides a general description of the five watershed units that comprise the PSA. In certain instances, and in the interest of efficiency, particular emphasis is placed on specific sub-watershed units within each of the five watershed units based on the level of urbanization. **Figure 2-8** illustrates the PSA and the location of the five watershed units within the PSA. In addition, Figure 2-8 illustrates the local hydrologic connections of the PSA to the larger Upper Stanislaus River and Upper Tuolumne River watersheds.

To enable enhanced analysis of the five major watersheds comprising the PSA, numerous drainage catchments were delineated within each of the watersheds through surface interpolation of 10-meter Digital Elevation Models (DEM) for the USGS 7.5-minute quadrangles for New Melones Dam, Sonora, Standard, Tuolumne, Columbia, Columbia SE, Twain Hart, Keystone, Chinese Camp, Duckwall Mountain, Moccasin, Groveland, and Jawbone Ridge. The 10-meter DEM was used rather than the recently produced California Watersheds (CalWater 2.2) Geographic Information System (GIS) dataset, due to its finer detail in recognition of the topographic complexity of the PSA. The modeled drainage catchments are illustrated within each of the context of the larger five watersheds in the following sub-sections.

2.2.1 Rawhide Flat Watershed

Mormon Creek and Bear Creek are the principal drainage features within the Rawhide Flat watershed and drain some 16,287 acres (25.4 square miles). The Rawhide Flat watershed is located in the southern section of the Copperopolis Hydrologic Area (Calwater 2.2), south of New Melones Reservoir. Mormon Creek is the principal drainage feature south of the community of Columbia, west of the Tuolumne County Table Mountain divide, and extends approximately 8.1 miles (see **Figure 2-9**). Bear Creek originates to the south of Rawhide Flat and extends 3.1 miles southwesterly towards New Melones Reservoir. The lower reaches, roughly two miles, of both waterways are inundated by New Melones Reservoir.

Figure 2-9

Based on the level of urbanization within the Mormon Creek sub-watershed, this sub-watershed is the focus of this Assessment for the larger Upper Stanislaus River Watershed. Mormon Creek originates in a small alluvial fan at the eastern base of Union Hill, south of the Columbia Airport, and trends south from Columbia along the western side of Table Mountain. Mormon Creek abruptly bends to the west in response to Rawhide Flat uplands and trends towards New Melones Reservoir (see **Figure 2-9**). Above the town of Springfield, flows within Mormon Creek are intermittent and largely controlled by surface runoff from rainfall events. Below Springfield, flows within Mormon Creek are regulated by a series of small dam impoundments. The impoundments generally sustain base flows year-round. Unfortunately, no public gages are located along Mormon Creek, and therefore, no seasonal flow data are currently available.

The stream corridor itself is highly modified with rural and low-density residential development comprising much of the riparian corridor and approximately 18 major road crossings. Riparian cover ranges from <10 percent to >90 percent depending on the reach. Vegetation within the watershed is dominated by the Blue Oak-Foothill Pine plant community, which comprises over 50 percent of the land area. Other characteristic plant communities include Annual Grassland, Blue Oak Woodland, Montane Chaparral, and Ponderosa Pine. The upper section of the watershed houses a majority of the urbanized development (14 percent).

Upper reaches of Mormon Creek are characterized by a combination of step-pool and cascade alluvial-channel morphologies (Montgomery and Buffington, 1998), while lower grade channel morphologies are generally inundated by New Melones Reservoir. In the vicinity of the Columbia Airport, Mormon Creek consists of a modified channel that is more-or-less routed along the southern boundary of the airport (see **Figures 2-9** and **Figure 2-10**, Photograph M-A). In the vicinity of Springfield, Mormon Creek begins to resemble an intermediate step-pool channel morphology that continues south and west along SR 49. Photograph M-B in **Figure 2-10** illustrates the channel upstream of Mormon Creek Road.

Stream gradients with step-pool channels are such that larger bed materials (rock fragments, large organic debris, etc.) only become mobile during relatively infrequent hydrologic events. As a result, movement of larger grain sizes occurs only during large events when flows reach flood-prone widths[5] and step-pool morphology is reestablished at the tail of the hydrograph (Montgomery and Buffington, 1998). Flood-prone widths in the vicinity of Mormon Creek Road are readily distinguishable below Rawhide Road (see Photograph M-C, **Figure 2-11**). During more average discharges, finer materials are stored in pools and along banks providing some level of sediment storage. In contrast, reaches below Sheppard's Ranch Road grade to an intermediate cascade channel morphology, which is characterized as a sediment transport zone ((see Photograph M-D, **Figure 2-12)**. One of the dam impoundments along Mormon Creek is located just up-gradient of this channel reach (see Photograph M-E in **Figure 2-12)**.

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5 Flood-prone width is defined as the width of the horizontal surface at an elevation twice the "bankfull" depth. Bankfull flow corresponds to flow levels that occur at recurrence intervals of two years or less.

Figure 2-10

Figure 2-11

Figure 2-12

The geology of the Mormon Creek watershed is very complex. The most dominant geologic unit within the watershed is the Calaveras Complex and it is interspersed with small areas of marble-dominated units such as those viewable from SR 49, near the intersection of Shaws Flat Road. The Calaveras Complex usually consists of undifferentiated argillite, phyllite, fine-grained schist, and metachert, with local exposures of marble and amphibolite (CDC, 1997). These lithologies represent the metamorphosed equivalents of sedimentary rocks that were deposited by submarine slides in an ocean basin as a chaotic assemblage (sedimentary melange). The assemblage was later accreted to the North American continent during the Mesozoic (CGS, 1997). The marble may represent limestone originally deposited on a seamount, which was then tectonically emplaced into the chaotic assemblage during this accretion (CDC, 1997). Phyllite-dominant and greenschist-dominant Sullivan Creek terranes are also prominent. **Table 2-2** presents geochemical information for each of the major geologic units and percentage of the watershed coverage to provide a base context for potential surface water chemistry.

2.2.2 Woods Creek Watershed

The Woods Creek watershed encompasses some 18,588 acres (29.0 square miles) with the Upper Woods sub-watershed comprising approximately 12,403 acres and the Lower Woods sub-watershed 6,185 acres, respectively. The watershed has experienced significant land use alteration with approximately 66 major road crossings within the watershed and highly variable riparian habitat. Riparian cover ranges from non-existent to more than 90 percent. The Upper Woods Creek sub-watershed is composed of stands of Blue Oak-Foothill Pine (28 percent), Ponderosa Pine (20 percent), Montane Hardwood-Conifer (5 percent), and Montane Hardwood (21 percent). The lower section of the upper watershed is mainly composed of urban development (16 percent) and scattered patches of Annual Grassland, Blue Oak Woodland, and Blue Oak-Foothill Pine. The Lower Woods Creek sub-watershed is less urban and is composed of Annual Grassland (25 percent), Blue Oak-Foothill Pine (47 percent), Chamise-Redshank Chaparral (16 percent), and scattered areas of Cropland, Montane Hardwood, and urban development.

The headwaters of Woods Creek start at the base of the northern slopes of Yankee Hill and the southern slopes of Biewetts Point. From Yankee Hill, Woods Creek meanders to the south and traverses through the towns of Martinez, Squabbletown, and Browns Flat along the western base of Bald Mountain. At Browns Flat, Woods Creek parallels SR 49 and traverses the western edge of downtown Sonora near Sonora High School, where it is channelized before its confluence with Dragon Gulch. Base flows within Woods Creek become year-round in Sonora and are partly attributed to irrigation-return flows from the City during the summer months. Below Sonora, Woods Creek roughly parallels SR 49 to the south-southwest and along the western edge of Jamestown. South of Bell Money Road, Woods Creek traverses back to the south and into a steep gorge before emptying into Don Pedro Reservoir.

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	7 %	schist	Fine-grained sedimentary rock such as shale*	silica (SiO_2) and others dependent on type of schist

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Calaveras Complex	20%	argillite	shale, mudstone, siltstone, claystone*	SiO_2
		phyllite	foliated, metamorphosed shale or fine-grained sandstone, with muscovite (mica)*	SiO_2, SiO_4, Al, K, Fe, Mg, H_20
		fine-grained schist	fine-grained sedimentary rock such as shale*	SiO_2 and others dependent on type of schist
		metachert	fine-grained metasedimentary rock with main mineral being quartz*	SiO_2
		marble (local)	metamorphic recrystallization of limestone*	$CaCO_3$
		amphibolite (local)	amphibole, plagioclase feldspar*	Fe, Mg, Ca, Al, H_20, SiO_4, K, Na, Si
Ultramafic Rock (*mostly serpentinized*)	6 %	dunite	igneous rock with coarse-grained olivine; some with chromite, magnetite, ilmenite, pyrrhotite, pyroxene††	Cr, SiO_4, Fe, Mg, Fe_3O_4, $FeTiO_3$, FeS, Ca‡
		peridotite	olivine; may contain pyroxene‡‡	SiO_2, SiO_4 Fe, Mg
Sullivan Creek terrane	22 %	turbidite	water-driven sediment§	SiO_2 and others
		phyllite (local belt)	foliated, metamorphosed shale or fine-grained sandstone, with muscovite (mica)*	SiO_2, SiO_4, Al, K, Fe, Mg, H_20
		greenschist (local belt)	metamorphized to produce chlorite crystals with schistose foliation; also includes epidote and actinolite§§	SiO_2, SiO_4, Mg, Fe, Al, H_20, Ca*
Jurassic Melange	2 %	diverse lithology within argillite and serpentinite matrix; may contain carbonate rock (local)	exotic blocks of metamorphic and igneous rock suspended in argillaceous or serpentinitic material	SiO_2, SiO_4, Mg, H_20, $CaCO_3$ and others
Plutonic Rock *(including Granitics)*	8%	silicic or mafic igneous rock	intrusive igneous rock (cools beneath surface)*	SiO_2, Mg, Fe
Quartz-Vein Systems and Hydrothermally Altered Rock	<1 %	quartz vein	quartz	SiO_2
		calcite vein	calcite	$CaCO_3$
		ankerite	carbonate mineral‡	Ca(Fe, Mg, Mn)$(CO_3)_2$

TABLE 2-2
GEOCHEMISTRY OF MORMON CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
		sericite	fine-grained white mica[§§§]	SiO_4
		talc	fine-grained silicate mineral[*]	$Mg_3Si_4O_{10}(OH)_2$
		mariposite	chrome-bearing mica	Cr, SiO_4
Tertiary and Quaternary Volcanic Rock:		silicic composition		SiO_2
Miocene-Pliocene Mehrten Formation	4 %	intermediate composition	volcanic complex of tuff, mudflows, lava flows, volcaniclastic sediment, and shallow intrusions	intermediate
Quaternary flows and hypabyssal intrusions	7 %	mostly mafic composition		Fe, Mg
Quaternary Sedimentary Deposits	1 %	alluvium, colluvium (local, at low and high elevations)	sand, gravel, and silt deposited by rivers and streams or gravity into the valley below[*]	SiO_2 and others
	2 %	mine tailings (local, at low elevations)	diverse mineralogy	diverse chemistry

Note: 20 percent of the watershed is inundated by New Melones Reservoir and/or is unclassified.
SOURCE: CGS, 1997

Woods Creek extends approximately 8.6 miles from its headwaters to Don Pedro Reservoir (see **Figure 2-13**). Various reaches of Woods Creek exhibit a combination of cascade, step-pool, plane bed, and pool riffle alluvial channel-reach morphologies. North of Sonora, Woods Creek exhibits an intermediate step-pool channel morphology, prior to entering the City of Sonora where it becomes channelized along the eastern border of Sonora High School. To the south of the high school, Woods Creek exhibits varying levels of modification (see Photographs W-A and W-B, **Figure 2-14)**. Further south, Sonora Creek joins Woods Creek near the intersection of Stockton Street (SR 49) and Southgate Road. Sonora Creek is a major contributing drainage that runs through the heart of Sonora and extends approximately 5.7 miles from the north and is a highly modified waterway and channeled underneath portions of Sonora (Photographs S-A and S-B, **Figure 2-15**).

To the south of the City of Sonora and Jamestown, Woods Creek begins to transition into a more level terrain and exhibits intermediate plane bed channel morphology (see Photograph W-B, **Figure 2-14** and Photograph W-C, **Figure 2-16**). Plane-bed channels differ morphologically from both step-pool channels in that they are characterized by long stretches of a relatively featureless bed (Montgomery and Buffington, 1998). To the west of Bell Mooney Road, the channel gradient of Woods Creeks increases to the extent that step-pool channel morphologies dominate the lower reaches prior to encountering Don Pedro Reservoir (see Photograph W-D, **Figure 2-16**).

Figure 2-13

Figure 2-14

Figure 2-15

Figure 2-16

A 2004 drainage study prepared for the City of Sonora indicates that peak flows within Woods Creek, below the confluence with Sonora Creek (south of the Fairgrounds), can range from 379.8 cubic feet per second (cfs) for a 2-year event and up to 3,351.1 cfs during a 100-yr event (Weatherby-Reynolds Consulting Engineers, Inc., 2004).

The upper reaches in the northern sections of the Woods Creek watershed are underlain by mafic plutonic rocks with small inclusions of auriferous[6] gravels. The western edge of the watershed is lined by Table Mountain latite and undifferentiated Mehrten Formations. The central and southern portions of the watershed units are underlain by a melange of meta-volcanic, ultramafic, and/or meta-sedimentary rocks. Smaller units of the Penon Blanco (Logtown Ridge) Formation[7] are also delineated in the southern sections of the watershed. **Table 2-3** presents geochemical information for each of the major geologic units and the percentage of the watershed covered to provide a basis for potential surface water chemistry.

TABLE 2-3
GEOCHEMISTRY OF WOODS CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	8.5%	See Table 2-2		
Calaveras Complex	33 %	See Table 2-2		
Mesozoic Metasedimentary and Metavolcanic Rock	23 %	See Table 2-2		
Jurassic Melange	< 1%	See Table 2-2		
Plutonic Rock	20%	See Table 2-2		
Quartz-Vein Systems and Hydrothermally Altered Rock	< 1 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock: *Oligocene-Miocene Valley Springs Formation*	10 %	See Table 2-2		
Ultramafic Rock *(mostlyerpentinized)*	5%	See Table 2-2		
Quaternary Sedimentary Deposits	< 1 %	See Table 2-2		

SOURCE: CGS, 1997

2.2.3 Sullivan Creek Watershed

The Sullivan Creek watershed is the largest drainage area within the PSA, comprising 62.7 square miles (40,118 acres). The watershed is comprised of two major water features, Sullivan Creek and Curtis Creek (see **Figure 2-17**). This watershed is the focus of the geomorphic assessment and sediment transport study and is extensively described in Chapter 4.0, Foothill Geomorphology and Sediment Transport Dynamics.

6 Sand and gravel composed mainly of pre-Tertiary rock (CGS, 1997)
7 Mafic metavolcanic rock formed as pyroclastic deposits and flows (CGS, 1997).

Figure 2-17

The headwaters of Sullivan Creek originate just south of Sugar Pine east of Twain Harte and flow along the eastern portion of the Phoenix Basin before entering Phoenix Lake; a small water supply reservoir constructed near the turn of the 20th century (see Photographs SV-1 and SV-2, **Figure 2-18**). Several smaller waterways drain into Sullivan Creek above Phoenix Lake and are described in Chapter 4.0, Foothill Geomorphology and Sediment Transport Dynamics. Sullivan Creek drains an area of approximately 15,488 acres above Phoenix Reservoir and stretches approximately 7.7 miles (see **Figure 2-17**). Below Phoenix Reservoir Sullivan Creek drains an area of approximately 9,696 acres and extends roughly 10.8 miles before empting into Don Pedro Reservoir (see Photographs SV-3 and SV-4, **Figure 2-19**).

The Sullivan Creek watershed is a highly modified unit with approximately 113 major roadway crossings. The riparian cover is generally good with >90 percent in many rural locations. The exception occurs in more urbanized locations, where bank-side and riparian vegetation can be non-existent. Photographs SV-5 and SV-6 in **Figure 2-20** illustrate the riparian stands along Sullivan Creek above Lime Kiln Road and below Algerine Road. Vegetation stands within the Phoenix Basin are dominated by Ponderosa Pine (52 percent); intermixed with Blue Oak-Foothill Pine and Montane Hardwood depending on moisture availability. The lower sections of the watershed show marked increases in the coverage of Blue Oak-Foothill Pine (50 percent) and the addition of Annual Grassland and Chamise-Redshank Chaparral.

The section of Sullivan Creek just below Phoenix Lake is modified and serves a portion of the Phoenix Ditch. Above Phoenix Lake, the TUD's Main Ditch imports water into the watershed from three storage reservoirs along the South fork Stanislaus River, Pinecrest Lake, and Philadelphia and Lyons Reservoirs. These flows are diverted into the Phoenix Ditch, which traverses the western side of the Phoenix Basin. The regulated flows are diverted by TUD below Phoenix Lake back into the Phoenix Ditch and Shaws Flat Pipeline. No continuous flow data were available for this Assessment for Sullivan Creek above Phoenix Reservoir or above Don Pedro Reservoir.

Curtis Creek is a major contributing drainage that converges with Sullivan Creek, just north of Jacksonville Road. Curtis Creek drains an area of approximately 14,934 acres and extends roughly 11.1 miles. Photographs CT-1 and CT-2 in **Figure 2-21** provide illustrations of the channel of Curtis Creek below the Town of Standard at Algerine and Lime Kiln Roads. Upstream of Standard, Curtis Creek is highly altered as a result of the movement of timber during old logging practices with only a few stands of Valley Oak remaining within the riparian zone. A portion of the waterway is utilized as the Soulsbyville Ditch for water conveyance. Stands of Blue Oak-Foothill Pine (65 percent) dominate the landscape up-gradient of Standard with scattered patches of Annual Grassland, Blue Oak Woodland, Montane Hardwood, Ponderosa Pine, and scattered development. Below Standard, the composition is similar with higher proportions of Montane Hardwood and scattered plots of irrigated agricultural land. No flow data are available for Curtis Creek.

Figure 2-18

Figure 2-19

Figure 2-20

Figure 2-21

Plutonic rock formations dominate the upper reaches of the Sullivan Watershed. Shoo Fly Complex and Calaveras Complex reside in the northern end, while the Miocene-Pliocene Mehrten Formation lies along the northeastern edge. In the south, mafic plutonic rock is accompanied by marble-dominant Calaveras Complex, ultramafic rock, phyllite and greenschist Sullivan Creek Terranes, Tertiary sand and gravel deposits, and mine tailings. The Tertiary sand and gravel deposits are erosional remnants of ancient stream channels (CDC, 1997). **Table 2-4** presents geochemical information for each of the major geologic units and the percentage of the watershed area covered to provide a baseline for potential surface water chemistry.

2.2.4 North Don Pedro Watershed

The North Don Pedro watershed covers 63.1 square miles (40,394 acres) and includes lands that extend from the north shore of Don Pedro Reservoir up to areas just west of Twain Hart, near the intersection of SR 108 and Confidence Road. Sub-watershed units within the watershed include Turnback Creek (11,693 acres), Blanket Creek (9,332 acres), Kanaka Creek (6148 acres), Deer Creek (8,796 acres), and North of Moccasin (4425 acres). This Assessment focuses on the Turnback Creek sub-watershed due to the extensive land use alteration that has occurred within this unit and the level of future growth expected. **Figure 2-22** illustrates the location of the Turnback Creek sub-unit in the context of the North Don Pedro watershed.

The Turnback Creek sub-watershed comprises roughly 11,693 acres and flows through a long, narrow canyon for approximately 15.9 miles. Turnback Creek is a perennial stream below the mill pond on the Westside-Cherry Valley site in Tuolumne, which is impounded by a concrete dam, originally constructed to float and maneuver logs for lumber production. The dam, constructed in 1912, is a concrete gravity dam approximately 22-feet high, 450 long (including side retaining walls). The crest elevation is approximately 2556 feet above mean sea level; the storage capacity is approximately 120 AF of water at operating capacity (G.L. Gritz Engineering, 2005). No continuous flow data are available for Turnback Creek below the dam impoundment.

Currently, there are 37 major road crossings on Turback Creek, including its contributing drainages. The land use alterations along Turnback Creek are extensive; however, portions of the creek have some natural features, including almost complete riparian cover, such as areas just north of Tuolumne Road; just north of the new bypass (see Photograph T-A, **Figure 2-23**). This is in contrast to the highly altered channel forms just downstream of the dam (see Photograph T-B, **Figure 2-23**) and along Box Factory Road (see Photograph T-C**, Figure 2-24**). Below Yosemite Road, Turnback Creek begins to exhibit some natural channel features along with high densities of canopy cover (see Photograph T-D, Figure 2-24).

The upper portion of the Turnback Creek watershed is composed of stands of Ponderosa Pine, which correlates to roughly 26 percent of the watershed. The center sections contain much of the urban development, 27.6 percent of the total watershed. The vegetation within the middle and lower sections of the watershed is composed of dominantly Blue Oak-Foothill Pine (29 percent) intermixed with Montane Hardwood (11 percent). Lower and middle sections of the watershed also include patches of Annual Grassland, Blue Oak Woodland, and Cropland.

TABLE 2-4
GEOCHEMISTRY OF SULLIVAN CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Precambrian and Paleozoic Metasedimentary Rock	2%	See Table 2-2		
Shoo Fly Complex	7 %	quartzite	metamorphosed quartz sandstone and chert*	SiO_2*
		quartzofeldspathic gneiss	metamorphosed, foliated granite, diorite, or schist with minerals: quartz, feldspar, hornblende, and biotite mica**	SiO_2, K, Na, Ca, Al, Si, Fe, Mg*
		gneissic granitoids	foliated portions and porphyroclasts of quartz, feldspar, mica, amphibole, and granitic aggregates†	SiO_2, SiO_4, K, Na, Al, Fe, Mg, Ca, H_20*
Calaveras Complex	6 %	See Table 2-2		
Sullivan Creek terrane	4 %	See Table 2-2		
Mesozoic Metasedimentary and Metavolcanic Rock	<1 %	See Table 2-2		
Jurassic Melange		See Table 2-2		
Plutonic Rock *(including Granitics)*	60%	See Table 2-2		
Quartz-Vein Systems and Hydrothermally Altered Rock	< 1 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock: *Oligocene-Miocene Valley Springs Formation*	10 %	See Table 2-2		
Ultramafic Rock *(mostlyerpentinized)*	5%	See Table 2-2		
Quaternary Sedimentary Deposits		mine tailings (local, at low elevations)	sand, gravel, and silt deposited by rivers and streams or gravity into the valley below*	SiO_2 and others*
	< 1 %	schist	diverse mineralogy	diverse chemistry
		quartzite		
		quartzofeldspathic gneiss		

SOURCE: CGS, 1997

Figure 2-22

Figure 2-23

Figure 2-24

The northern section of the watershed is characterized by geologic units composed of granitic plutonic rocks and the Shoo Fly Complex and Mehrten Formation. The southern section of the watershed is composed of phyllite-dominant and greenschist-dominant Sullivan Creek terranes, as well as small amounts of melange and ultramafic rock. The Calaveras Complex is also abundant within this section of the watershed. **Table 2-5** presents geochemical information for each of the major geologic units and the percentage of the watershed area covered to provide a base context for potential surface water chemistry.

TABLE 2-5
GEOCHEMISTRY OF TURNBACK CREEK GEOLOGIC UNITS

Rock Unit	Percentage of Area	Dominant Rock Type	Derived From	Geochemistry
Shoo Fly Complex	20 %	See Table 2-4		
Calaveras Complex	13 %	See Table 2-2		
Plutonic Rock *(including Granitics)*	51 %	See Table 2-2		
Tertiary and Quaternary Volcanic Rock:	16 %	See Table 2-2		
Miocene-Pliocene Mehrten Formation	<1 %	See Table 2-2		

SOURCE: CGS, 1997

2.2.5 Groveland Watershed

The Groveland watershed is located in the southern portion of the PSA and covers roughly 44.5 square miles (28,460 acres). The watershed is located at the western end of the Clavey River Hydrologic Area (Calwater 2.2.1) and is comprised of three major watershed units: Big Humbug Creek (9,759 acres), Pine Mountain Lake (8,064 acres), and Hells Hollow Creek (10,637 acres). The Groveland Creek sub-unit of the Pine Mountain Lake sub-watershed is the focus of this Assessment since it supports much of the development in the south County and is entirely contained within the County's jurisdiction. The Groveland Creek watershed is illustrated in **Figure 2-25** in the context of the larger Big Creek watershed.

The entire Big Creek watershed includes a total of 35 major road crossing with nine of the major crossings occurring along Groveland Creek. Big Creek is approximately 15.7 miles (82,802.9 feet) with Pine Mountain Lake impounded near its mid-point. Groveland Creek, approximately 4.2 miles in length, drains into the southern end of Pine Mountain Lake. Groveland Creek parallels SR 120 and Ferretti Road down to the Pine Mountain Lake subdivision. Riparian habitat in the vicinity of Groveland is marginal, but improves downstream (see Photographs G-A and G-B, **Figure 2-26**). Ponderosa Pine is the dominant vegetation stand in the Pine Mountain Lake watershed, with small inclusions of Blue Oak-Foothill Pine, Mixed Chaparral, and Montane Hardwood.

Figure 2-25

Figure 2-26

Flow in Groveland Creek is seasonal; however, no flow data are available for the winter months. However, flows within Big Creek above Whites Gulch, 2.5 miles east of Groveland, have been recorded from May 1969 to 2003. Extremes for the period of record include a maximum discharge of 2,620 cfs on February 17, 1986, with a gage height of 7.03 feet. This measurement was based on the slope-area measurement at gage height 6.51 feet. No flow occurred for many days in most years (USGS, 2003). Typically, the flow is highest during the winter and spring months and lowest in late summer and early fall.

The geology of the Big Creek Watershed is mostly composed of Calaveras Complex (70 percent), with a small portion dominated by marble. In addition to the Calaveras Complex, exposures of the Mehrten Formation (2.5 percent), Sullivan Creek terrane, made up of a phyllite belt, (23 percent), and granitic rock (4.5 percent) underlie the remaining sections of the watershed. **Table 2-2** provides geochemical information for each of these geologic units to provide a base context for potential surface water chemistry.

Chapter 3

Land Management and Population Growth Influences

CHAPTER 3
Land Management and Population Growth Influences

3.1 Overview

In an effort to produce a comprehensive watershed assessment, the County and its consultants determined that research and discovery into the historic land uses of the PSA should be conducted. The key driver of this decision was the common knowledge that the County has a unique history on at least four fronts. First, the area was part of the gold mining industry of the region, which at the time used invasive techniques to mine gold (i.e., placer, hydraulic, sluice and dredging). Logging, which began around the turn of the 20th century and agriculture and ranching (beginning around the 1920s) led to the development of an extensive roadway and rail system, much of which exists today and forms the base of the expanded road network. With a corresponding increase in state-wide water demand following the 1940s, both watersheds have been tapped by regional water interests, resulting in an extensive network of water diversion canals, dam impoundments, and pipelines, which have significantly altered natural hydrology at a basin-wide scale. Finally, the continuing urbanization within the foothill region is expected to further alter natural drainage patterns with corresponding surface water quality implications.

The following sections provide an overview of these occurrences with emphasis placed on those actions that resulted in alterations to the physical hydrologic conditions of the foothill margin of the County.

3.1.1 Pre-1850s

Current evidence suggests that people have lived in the Sierra Nevada region for about 12,000 years (Tri-Dam Project, Beardsley/Donnells Project, 2002). Archeological research suggests that the Central Sierra Miwok were the most recent Native American occupants to inhabit portions of the range that now includes portions of Tuolumne County. The severity of winter in the upper elevations of the Sierra Nevada precluded permanent villages, with aboriginal populations generally inhabiting the foothill zones below 4,000 feet, where a more moderate winter climate prevailed (Barrett and Gifford, 1933). Due to the complexity of the foothill terrain, most villages were situated on ridges or terraces above the streams (Beardsley Hydroelectric Project, FERC Project, 2002).

Frequent mention is made in the ethnographic literature of the Miwok use of fire for environmental modification, i.e., as an aid in hunting and to increase the yield of a wide variety of edibles and encourage the growth of desirable plants. These annual fires destroyed seedlings but did not harm established trees such as valley and interior live oaks, whose scattered method of growth is attributed to this repeated annual burning.

Impacts of Native Americans on the hydrologic system appear to have been minor, largely because of the comparatively small population in the mountains and limited technology (Central Stanislaus Watershed Analysis, June 2002). Their deliberate use of fire as a vegetation-management tool would have been the primary agent in altering local hydrology. To the extent that intentional fires removed vegetation, evapotranspiration was reduced, water yields were increased, and surface erosion was increased. The geographical extent, intensity, and frequency of such fires cannot be quantified. Therefore, the conclusions that may be drawn regarding the hydrologic consequences of this activity are limited. Areas near population centers were probably impacted to a greater degree than remote areas (SNEP, 1996).

3.2 Mineral Extraction

In Tuolumne County, the first major industry that significantly modified the landscape was gold mining, which began around 1848 with the discovery of gold near the confluence of Woods and Moccasin Creeks. Since the 1848 discovery, this region of the Mother Lode has produced greater than 4 million tons of processed ore tailings (Wagner, 1970). Most of the gold deposits formed within a folded and faulted metamorphic belt often referred to as the Melones Fault Zone (MFZ). Within the Tuolumne County portion of the MFZ, many of the lode gold ores are associated with quartz veins and carbonate rocks formed by metasomatic reactions of mineralizing fluids with greenschist rocks at very high temperatures (SNEP, 1996).

Mining in the Sierra Nevada was intimately connected to the development of lumber and water resources and promoted the development of camps and towns to supply the needs of miners and loggers (SNEP, 1996). Water was necessary for gold production, and in later times it provided power for mining activities. Lumber was required to carry water in flumes, to support excavations, to provide fuel for steam engines and pumps, and to support tunnels. Lumber was also needed for housing and business structures. Camps and towns were often consumed by fires, requiring further timber harvest. Contemporary sketches and photographs of northern and central Sierran communities show barren environments around mining settlements (SNEP, 1996).

Hillsides became pockmarked from mining operations. Channels and tunnels were cut to divert water so that streambeds could be mined. Flumes were constructed of wood to divert water from streambeds, requiring the cutting of adjoining forests. This water was used and reused farther downstream. Rivers became filled with sand. Boulders were moved out of streambeds to expose placer gold and were placed elsewhere, creating new riverine environments. Flumes leaked or collapsed, creating erosion gullies. Water storage dams burst, generating great surges of water that pushed mud, stones, and trees before the flood (Ziebarth 1984; Beesley, 1994). Mercury was used to assist in the recovery of fine gold particles in placer, hydraulic, and hardrock mining during this period. Its release into stream systems stretching all the way to the San Francisco Bay was measured in tons before 1940 (Meals,1995).

At that time, diversions and flumes were also built to supply water to off-channel claims for separating gold and for ground sluicing where diverted water was used to erode ancient stream deposits. Natural channels were often totally dewatered to supply maximum flow in an artificial waterway. The erosive power of water was used with great effectiveness by containing water within pipes and hoses under high pressure and then directing it at hillslopes composed of gold-bearing gravels (SNEP, 1996). Remnant hill-slope scars, which are now vegetated, are still visible at many locations within the County. As an example of power and hydraulic water use, flumes and pipes with 120 meters (400 feet) of head could deliver about one million gallons of water per hour through a 10-inch nozzle at a speed of about 120 miles per hour (Logan, 1948; SNEP, 1996). Sediment-laden runoff from the eroded hillslopes was directed into long sluice boxes, often in tunnels, to extract the gold and then discharged into the nearest creek (SNEP, 1996).

Quartz gold mining grew in importance after 1900. Permanent communities such as Sonora reflected the relatively stable nature of this industry (Clark 1963, 1980; Sinnott, 1976). The extent of impact this industry had on water and other Sierran elements has not been completely determined. During World War II, most of these hardrock gold mining operations were closed so that the iron, fuel, and wood they consumed could be redirected into the war effort. Few reopened after 1945.

As depicted in **Figure 3-1**, many of the mines within the PSA are concentrated along the Moccasin and Sullivan Creek drainages, which are now partially inundated by the Don Pedro Reservoir on the Tuolumne River. Waste materials produced during mining operations are heterogeneous piles of rocks that have undergone varying degrees of crushing, granulation, and chemical processing. They are mineralogically complex chemical reactors that interact with the atmosphere and with the waters of Don Pedro Reservoir, which seasonally floods many of the mines and mill sites of the Tuolumne River Canyon (Savagea et al., 1999).

Many other mineral commodities have been produced in Tuolumne County, mostly in small quantities and in a sporadic manner. These include asbestos, clay, chromite, construction aggregate (crushed stone, sand and gravel), copper, decorative rock (mariposite rock, dolomite, serpentinite), diatomite, dimension stone (marble, slate granite), dolomite, graphite, lead, limestone, magnesite, manganese, platinum (placer), silver (by-product of gold mining), talc, tungsten, uranium, and zinc. Most important among these in tonnage and value have been construction aggregate, dimension stone (marble), dolomite, limestone, and silver.

Next to gold, carbonate rock (limestone and dolomite) has been the most valuable mineral commodity produced in the County. Quarrying of such rock for dimension stone began at least as early as 1860 at the Columbia Marble Quarry, northwest of Columbia. This mine was once the largest marble quarry in California; subsequently, the rock was quarried for other uses. Recently, two large operations have been quarrying in this immediate area: Blue Mountain Minerals, mainly for limestone for diverse uses, and Marine Magnesium Company, for dolomite for use in the magnesium chemicals industry. More recently, the Blue Mountain Minerals Company purchased the Marine Magnesium quarry currently operates both quarries. Other smaller quarries have been developed in carbonate rock for dimension stone and decorative rock throughout the belt of carbonate rocks of the Calaveras Complex. South of Sonora, along Lime Kiln Road, U.S. Lime Products operated one of the most important high-calcium limestone mines in northern California for many decades. Now closed, it was notable for being an underground mine rather than a quarry.

Figure 3-1

Production of crushed stone for use as construction aggregate has increased as Tuolumne County has grown over the last several decades. Currently, the two main mines in operation, Table Mountain Quarry and Sierra Rock Products Quarry, produce crushed stone from sources near the main population centers (see **Figure 3-1**). Sand and gravel have been produced at very few sites, mainly because of the scarcity of high-quality deposits of this commodity. The scarcity is a result of both geologic conditions and because two potential sources, the Tuolumne and Stanislaus Rivers, have been dammed, flooding most of their canyons at lower elevations. An important deposit along the Tuolumne River near the now-inundated Town of Jacksonville was mined for many years. Small borrow pits have been used around the County, mostly for road maintenance (CDC, 1997).

3.3 Timber Production and Grazing

By 1900, timber and agricultural grazing, which were initially support industries for the mining operations in Tuolumne County and the region, had become established local industries. The forests in the vicinity of the PSA could not be efficiently harvested until the expansion of the Sugar Pine Railway system in the mid-1920s. At this time, the system allowed the transportation of the logs from remote portions of the forest directly to the mills for processing. Produce and later beef production became important in the County's economy in the latter half of the 20th century. More recently, the production of turkeys and small viticulture operations have become important agricultural enterprises in the County (Tuolumne County, 1997).

Steam engines called steam donkeys damaged young trees and disturbed forest soils as they dragged logs to chutes or loading pads, where they were loaded on wagons or railcars for transport to the mills. Saws at the mills generated large quantities of sawdust, which was often dumped into nearby rivers, killing fish and creating health hazards and reduced water quality for those living downstream. Felled logs were frequently cut at the point where limbs began, leaving the rest behind to serve as fuel when fires started, often damaging nearby merchantable timber. Large quantities of potentially marketable trees were cut to build V flumes to transport cut lumber (SNEP, 1996). These V flumes consumed 135,000 board feet per mile (SNEP, 1996).

By 1890, some forest and scenic resource issues were addressed by the creation of two national parks (Sequoia and Grant Grove, and Yosemite) and several Sierra Nevada forest reserves (Sierra, Stanislaus, and Tahoe). While federal legislation was passed, no overall policy was developed to administer these new federal responsibilities (Runte, 1987). The Sierra Club was founded at the same time to help shape policies for these areas (Jones, 1965).

More recently, timber production is regulated on public lands by the federal government through the Stanislaus National Forest, which mainly comprises lands east of the PSA, although small in-holdings are located in the upper reaches of Sullivan, Woods, and Turnback Creeks. On State and private lands, the State Board of Forestry regulates timber harvesting through the use of Timber Harvest Plans. County staff provides limited guidance through Section 17.52.170 of the Tuolumne County Ordinance Code, which addresses local rules for commercial timber harvesting on parcels less then three acres in size (Tuolumne County, 1997). As of March 1, 1995, Tuolumne County was assessing 84,449 acres of private land zoned TPZ (Timberland Production Zone) (Tuolumne County, 1997). According to the 2004 Tuolumne County Crop and Livestock Report, the timber industry in Tuolumne County harvested 23.5 million board feet of timber worth $5,038,500 (Tuolumne County, 2005).

Rangeland use within the County started with the sheep industry, which developed in two distinct periods before 1900. The first period (1848–1860) involved driving animals from New Mexico and southern California to mining camps and towns in the western foothills for consumption. This phase did not result in much actual grazing in the Sierra Nevada. The second phase (after 1860) depended on grazing Sierran pastures. The number of sheep that foraged on Sierran meadows before the Forest Service and County regulations began can only be guessed at. There was no limit to the size or the number of bands that entered the Sierra before 1900, nor was there a limit on the length of time they could utilize a specific area.

Gradually during this same period, and through the remainder of century, cattle replaced sheep on many Sierran ranges, resulting in more soil compaction and increased effects on vegetation in riparian zones (SNEP, 1996). It has been documented that heavy grazing patterns over a short time period will reduce infiltration rates on porous soils by about 50 percent, while longer term light and moderate grazing decreased rates to about 75 percent of their original values (SNEP, 1996). However, without information regarding the frequency, duration, and quantities of animals grazed, it is difficult to determine the exact level of disturbance caused by grazing. Today, a majority of the west County agricultural land base within the PSA continues to be used for rangeland. Photos A and B in **Figure 3-2** illustrate the variability in grazing intensity that commonly occurs from one property to the next. Where more productive soils are present in combination with available irrigation water, the production of numerous other crops is feasible, including field crops, fruit and nuts, and small-scale vineyards.

3.3.1 Fire Suppression and Vegetation Conversion

Years of aggressive fire protection and timber management have dramatically changed the character of the County's forests, brush, and grassland communities, including those that characterize the upper reaches of the PSA. The California Department of Forestry and Fire Protection (CDF) utilizes a Fire Hazard Severity Classification System to assess the wildland fire potential of a site (Stanislaus Forest Service Fire Plan, 2004). The classification system is based upon factors of slope, fuel, and summer weather patterns. In general terms, the wildland fire hazard within the PSA varies from moderate, in the relatively level annual grasslands in the west County, through high to extreme, in the dense brush and tree covered slopes in the upper reaches of the watersheds.

Figure 3-2

Portions of the PSA overlap with the Stanislaus Forest Service's Fire Management Unit (FMU) No. 2, which covers low elevations with the National Forest. Approximately 992 wildfires (244,100 acres) have originated in FMU No. 2 between 1970 and 2002; 26 percent of the total fires on the Stanislaus National Forest during that time period (Stanislaus Forest Service Fire Plan, 2004). This FMU includes land not included in FMU No. 1, which is characterized by historically frequent fire (fire regimes I and II). The PSA is located at elevations below 6,000 feet in elevation and is represented by fire regime I, which is one of frequent, low severity surface fires. The majority of the fires and area burned in the PSA are caused by lightning. Of the human-caused fires, discarded cigarettes, sparks from mechanized equipment, and escaped campfires and controlled burns are generally the culprits. Following a fire, burned areas are exposed to the effects of erosion oduring rainfall events. Indirect affects of this accelerated erosion to affected water ways may include measurable increases in pH, nitrates, and phosphorus. However, the largest, most observable increase is generally in the form of increased turbidity.

Notwithstanding the alteration of the natural fire regime, the intense grazing of sheep in the latter half of the 19th century significantly impacted meadow systems in the County. Some observers attribute the reduction of some native perennials and their replacement by more aggressive annual species in upper-elevation grassy hillsides and higher-elevation meadow systems to these unregulated activities (SNEP, 1996). In the foothill region, the period between 1945 and 1975 was especially important in the development of range and forest management practices using controlled burning, herbicides, range seeding, and fertilization practices to optimize selected species. More recently, residential and commercial landscaping practices have introduced numerous plant species that are very successful at out-competing natives. Table 3-1 lists a number of documented invasive plants that have been observed within the PSA. Although the introduction and spread of non-native plants is well-documented, it is not clear how these changes have altered localized hydrology in the context of more physical alterations, such as road construction.

3.4 Development of the Transportation Network

Economic development in the mid-1850s in the central Sierra produced foothill road systems in the most accessible areas (e.g., stream terraces, intermittent channels, etc.). Access to Yosemite was well established by the 1870s through Big Oak Flat near present-day Groveland. This route includes parts of the original SR 120, which enters the Sierra foothills near Knights Ferry. Sections of SR 120 were added to the state highway system in 1899 (Sierra Nevada Photos, 2005) with the local roadway network constructed off the main route. Much of the Sierra Nevada Range further south remained isolated during this time (SNEP, 1996).

Trail alignments of what eventually became SR 49 were established by the 1860s to provide access to and from Columbia and Sonora. Sections of SR 49 were added to the state highway system in 1909, while other sections were not added until 1964 (Sierra Nevada Photos, 2005).

TABLE 3-1
OBSERVED INVASIVE PLANT SPECIES WITHIN THE PSA

Plant Species (Common/Scientific)	Habitat
Himalayan blackberry (*Rubus discolor*)	Found in riparian areas, seasonally wet areas
Yellow starthistle (*Centaurea solstitialis*)	Abundant; especially in disturbed areas in grasslands and woodland understory
Medusahead (*Taeniatherum caput-medusae*)	Found in grasslands, open fields
Perennial pepperweed (*Lepidium latifolium*)	Seasonal and permanent wetlands or low spots in grasslands
Oblong spurge (*Euphorbia oblongata*)	Disturbed areas, roadsides, fields/pastures
Rush skeletonweed (*Chondrilla juncea*)	Disturbed areas, roadsides, fields/pastures
Smooth distaff thistle (*Carthamus baeticus*)	Disturbed, open sites of grasslands and pastures
Spotted knapweed (*Centaurea maculosa*)	Fields, roadsides, disturbed open sites, grasslands, and logged area.
Scotch broom (*Cytisus scoparius*)	Disturbed areas, roadsides
Tree of heaven (*Ailanthus altissima*)	Disturbed areas, riparian areas, disturbed woodlands
Puncture vine (U*lus terrestris*)	Roadsides, vacant lots, other dry disturbed areas
Canada thistle (*Cirsium arvense*)	Roadsides, vacant lots, other dry disturbed areas
Klamathweed (*Hypericum perforatum)*	Pastures, abandoned fields, disturbed places
Vetch (*Vicia sativa*)	Disturbed areas, fields
Field hedge-parsley (*Torilis arvensis*)	Disturbed areas, grasslands, woodlands
Fennel (*Foeniculum vulgare*)	Roadsides, waste places, ditches
Periwinkle (*Vinca major*)	Riparian areas, wet woodlands
Italian thistle (*Carduus pycnocephalus*)	Roadsides, pastures, waste areas, grasslands
Bull thistle (*Cirsium vulgare*)	Disturbed areas, grasslands

Parts of the original emigrant's trail follow the current SR 108/120, which enters the Sierra foothills near Knights Ferry and passes through the south edge of Sonora (Sierra Nevada Photos, 2005). Similar to the Groveland area, much of the local roadway networks extend off SR 49 and SR 108.

Similar to the major highways, the need for railroads was generated by the logging and mining industries. More widespread use came with advancements in timber extraction, which was able to provide the ties, timbers, fuel, and planking necessary to build the railroads. In 1897, the Sierra Railway Company of California was formally incorporated, with grading beginning in Oakdale. The Sierra Railroad, completed in 1897, was constructed along a right-of-way that included alternate sections of land on either side. A year later, the railroad's terminus was moved to Sonora. Much of the lumber to build the railroad came from these adjacent lands. Extensive cut and fill was necessary in conjunction with long trestles and bridges crossings were necessary to maintain a low grade for the railroad alignment.

The combination of trail, road, and railroad development, vegetation removal, and the frequency of disturbance resulted in significant alternation of the natural drainage pattern in the PSA. The installation of large structures and parking areas, driveways, trails and horizontal road cuts between the late 1920s and 1990s has concentrated sheet wash down-gradient through engineering drainage systems and roadways ascents, modified stream channel morphology by the accumulation of sediment, and diverted natural flow to other locations.. Gullies often form where drainage is diverted onto unprotected slopes by roadside ditches and culverts, where culverts block and divert flow over roadbeds and fill slopes, or where ruts form above road cuts and driveways thereby concentrating runoff. The phenomenon is exhibited in numerous locations within the PSA (see Photographs C and D, **Figure 3-3** and Photos E and F, **Figure 3-4)**.

Other topographic modifications may divert runoff from one stream to another. Road and trail crossings obstruct and channelize small contributing drainage-ways and, in some instances, may divert runoff away from the natural drainage channels. In these cases, flow is reduced in the original channel while the new, engineered or pre-existing channels must accommodate higher flow volumes. Any change in runoff volume, its mode and timing of production, and its rate of transport through a channel system all affect both the rate of water delivery to any point and its ability to transport sediment.

3.5 Water Resource Management and Conveyance

3.5.1 Early Surface Water Conveyance

The County's extensive ditch and reservoir system, as depicted in Figure 2-8, had its origin in the Gold Rush days of the 1850s. The first canal infrastructure supplied water power to the mines and placer claims and water for domestic uses in mining camps. The Tuolumne County Water Company, incorporated in September 1852 for more than half a century, was the main entity responsible for the development of dams, reservoirs, and ditches and the delivery of water to a large part of the County (PG&E Canal History, 1947).

In 1898, the Tuolumne County Water Company was reincorporated as the Tuolumne County Water and Electric Power Company, which constructed the Phoenix Powerhouse in 1898 prior to merging into the Sierra and San Francisco Power Company in 1909 (PG&E Canal History, 1947). The properties of the Sierra and San Francisco Power Company were leased on January 1, 1920, to the Pacific Gas and Electric Company (PG&E) and were purchased in 1927 by PG&E. As a result, the reservoirs and ditches built originally to serve the mines and camps became a part of the PG&E system that today serves nearly all of the PSA. Many of the old ditches and reservoirs identified in Figure 2-8 that comprise PG&E's water system in Tuolumne County are still in existence and utilized as part of the Tuolumne Utilities District's (TUD) water distribution system (see Figure 3-5). Major dam impoundments and water conveyance features constructed within the County are listed in Tables 3-2 and 3-3. TUD is contracted with PG&E for transfers of water from the South Fork Stanislaus River, below Lyons Dam through the Main Tuolumne Canal for consumptive use in the PSA and power generation at Phoenix Powerhouse.

Figure 3-3

Figure 3-4

Figure 3-5
11x17

Back of 11x17

TABLE 3-2
PG&E RESERVOIR SYSTEM

Name	Use	Year Built	Capacity (acre-feet)
Blue Gulch (Bought in February 1876 by Tuolumne County Water Company from Tuolumne Hydraulic Mining Company.)	Irrigation	Prior to 1876	0.7
Jamestown	Domestic	Rebuilt 1932	0.55
Kincaid (Purchased in November 1896 by Tuolumne County Water Company from W.I. Morgan Estate.)	Irrigation	Prior to 1866	48.3
Lyons (Land for the Lyons Flat Reservoir was bought by Tuolumne County Water Company on March 29, 1881, from Gardner Grey. The dam was built in 1897-1898 and later reconstructed by PG&E.)	Phoenix	1930	5,508
Matelot	Irrigation	1853	12
O'Neill (Purchased by Tuolumne County Water Company in February 1856 from Allen Oliver.)	Irrigation	Prior to 1856	12
Phoenix (Purchased by Tuolumne County Water Company on February 24, 1876, from its builder, the Tuolumne Hydraulic Mining Company.)	Irrigation	1852	850
Relief	Stanislaus Powerhouse	1909	15,554
Sand Bar	Stanislaus Powerhouse	Rebuilt 1939	51
San Diego (Bought by Tuolumne County Water Company from Erwin Davis, July 7, 1860.)	Irrigation	Prior to 1860	40
Slum Dam (Rebuilt in 1900)	Irrigation	1853	0.5
Sonora	Domestic	1929	4.7
Stanislaus Forebay	Stanislaus Powerhouse	1908	320
Main Strawberry (Originally there were two Strawberry Reservoirs, Upper and Lower, both built by the Tuolumne County Water Company in 1856-1857. The present reservoir was built in 1916.)	Electric Power	1856	18,266
Tuolumne	Domestic	Rebuilt 1931	2.1
Wolfling (Purchased in May, 1878, by Tuolumne County Water Company from John Wolfling. Rebuilt by PG&E in 1930.)	Domestic	Prior to 1878	2.0

Source: PG&E Canal History, 1947

TABLE 3-3
PG&E'S CANAL SYSTEM

Name	Construction Date/Information	Diverts From	Discharges Into	Length (Miles)	Use
Algerine	Algerine Ditch was constructed about 1852 by the Tuolumne Hydraulic Mining Co.	Curtis Creek	Blue Gulch Res.	9.5	Irrigation
Columbia	The original Columbia ditch was purchased from the Columbia and Stanislaus River Water Company by the Tuolumne County Water Company in 1860. It extended from the Middle Fork of the Stanislaus above Donnell's Flat 23 miles to a 3,000-foot tunnel that emptied into the South Fork and thence to the vicinity of Columbia, a total distance of 50 miles. The ditch was completed in 1850 but was used only three or four years.	Main Canal at Big Hill Camp	Junction of Matelot and San Diego Canals	4.04	Domestic & Irrigation
Eureka	Constructed in 1888-1889 to Carter's and vicinity.	Section Four	Tuolumne Res.	8.06	Domestic & Irrigation
Jamestown	The Jamestown Ditch, built in 1896, extended from the Golden Gate Mine on Wood's Creek to Jamestown.	Sonora Canal	Jamestown Res.	4.45	Domestic
Kincaid	Constructed by the W.I. Morgan Estate about 1866.	Curtis Creek	Kincaid Res.	0.51	Irrigation
Main	Constructed in 1851-1852.	South Fork Stanislaus River below Lyons	Columbia Canal at Big Hill Camp	18.81	Phoenix Ph. Domestic & Irrigation
Matelot		Columbia Canal	Sec. 14, T. 2 N. R. 14 E.	1.52	Irrigation
Philadelphia		South Fork Stanislaus River	Spring Gap Powerhouse	4.67	Electric Power
Phoenix	Constructed by the Tuolumne Hydraulic Mining Company to serve the Standard Lumber Company at Standard City in 1852. A bypass, 1.66 miles long, extends from Sullivan Creek to Phoenix Canal.	Phoenix Res.	Curtis Creek	3.12	Domestic
Racetrack		Shaw's Flat Canal	Racetrack Res.	1.18	Irrigation
Roach's Camp	The original ditch constructed in 1900 by the Tuolumne County Water Company extended from Tuolumne to Ajax and Free Lance Mines, a distance of 7.30 miles.	Eureka Canal	Turnback Creek	2.04	Irrigation
San Diego		Columbia Canal	Byrd's Res. Site	3.74	Irrigation
Section Four		Main Canal	Eureka and Soulsbyville Canals	2.74	Domestic & Irrigation
Shaw's Flat	Shaw's Flat ditch has been known as Street's Ditch and sometimes as Phoenix Ditch. It originally took water from Phoenix Lake to Sonora and Shaw's Flat. It was built by the Tuolumne Hydraulic Mining Company about 1852.	Phoenix Canal	Slum Dam Res.	10.50	Irrigation

TABLE 3-3
PG&E'S CANAL SYSTEM

Name	Construction Date/Information	Diverts From	Discharges Into	Length (Miles)	Use
Soulsbyville	Constructed in 1888-1889 by Tuolumne County Water Company from Eureka Camp to head of Black Oak mine.	Section Four Canal	Jamestown Canal	4.73	Irrigation
Sonora	Constructed about 1855 by the Tuolumne Hydraulic Mining Company.	Shaw's Flat Canal	Jamestown Canal	3.81	Domestic & Irrigation
Stanislaus	Stanislaus Powerhouse was built in 1908 by the Stanislaus Electric Power Co., which soon afterward transferred the property to the Sierra and San Francisco Power Co. Water to operate the plant was diverted from the Middle Fork of the Stanislaus River at Sand Bar Dam and transported 16 miles to the forebay above the powerhouse through a wooden flume built along the precipitous wall of the canyon. In 1941, the flume was replaced by a tunnel that now carries the flow through solid rock through most of its 11-mile length. The flow diverted from the Middle Fork comes from storage in Relief Reservoir and from Lake Strawberry on the South Fork, from which it is carried by ditch over the divide to Spring Gap Power House and thence into the Middle Fork.	Middle Fork of the Stanislaus River	Stanislaus Forebay	11.20	Power
Table Mountain	Constructed by the Tuolumne County Water Company in 1851-1852 from Springfield Weir to O'Neill Reservoir, a distance of 5.55 miles.	Slum Dam	O'Neill Res.	5.45	Irrigation

SOURCE: PG&E Canal History, 1947

Due to the linear nature of the diversions and earthen canal features, the alterations to the localized drainage patterns and stream hydrology within the PSA is similar to those associated with the early roadway system. In contrast, however, while the canal system has remained relatively unchanged from its early days, the roadway system has and continues to expand in response to continued population growth. Another significant alteration to the hydrologic system resulted from the installation of smaller dam impoundments that still exist today and have acted as sediment traps for much of the coarser sediment generated by previously-mentioned topographic alterations. Although these features are capable of capturing coarse sediment (e.g., sands), finer materials such as silts and clays are likely to pass through these smaller impoundments due to the settling time required to remove these materials from suspension. Today reservoir sedimentation is receiving increased attention due to the associated reductions in reservoir capacity, thereby necessitating costly dredging practices, and the accumulation of certain contaminants and heavy metals that bind readily to sediments.

3.5.2 Regional Water Conveyance Facilities

In 1926, the Oakdale and South San Joaquin Irrigation Districts built the Melones Dam and Powerplant. The peak of construction by irrigation districts came in the 1950s with construction of the Tri-Dam Project, which consists of the Donnells and Beardsley Dams on the upper Stanislaus River, Tulloch Dam on the lower Stanislaus River, and the enlargement of Goodwin Dam, also on the lower river (Reclamation, 2005). In 1978, New Melones Reservoir was formed by an earth and rockfill dam, downstream from the old Melones Dam, 7.6 miles southwest of Sonora. The New Melones Unit was officially transferred to the U.S. Bureau of Reclamation in November 1979 for integrated operation with the Central Valley Project.

The Don Pedro Reservoir is formed by an earthfill dam, which was completed in 1971. It is located 500 feet downstream from Mexican Gulch, and 3.4 miles northeast of La Grange. Storage began November 3, 1970. Water passes through a powerplant at the dam and then down the Tuolumne River to La Grange Dam, 2.5 miles downstream, where it is diverted into the Turlock and Modesto Canals for irrigation. The reservoir is operated jointly by the Turlock and Modesto Irrigation Districts. Prior to June 1971, the reservoir was formed by a concrete gravity-type dam completed in 1923 with a capacity of 290,400 AF (USGS, 2003).

Under state law, the Turlock and Modesto Irrigation Districts hold "senior" water-rights to base flows within the Tuolumne River. The San Francisco Public Utilities Commission (SFPUC) holds "junior" rights, in which the exact distribution is determined daily by a calculated estimate of what the flow would be at La Grange (located just below Don Pedro Reservoir), absent any dams on the river. Most of the year, all of the river's flows below 2,416 cfs belong to the two districts. Over the 60-day period from mid-April to mid-June, typically the period of highest river flow due to melting snow, that threshold is raised to 4,066 cfs.

The SFPUC does not divert water directly from Don Pedro Reservoir, but owns the right to store up to 740,000 AF in Don Pedro Reservoir (more than twice the total volume of Hetch Hetchy Reservoir (SFPUC, 2004)). The SFPUC uses its storage in Don Pedro Reservoir as a water bank and is still able to divert river flows upstream by using its bank in three "upcountry" reservoirs, Hetch Hetchy, Lake

Eleanor, and Cherry Valley Reservoir. In accordance with State law, the SFPUC spills a portion of the river flow as it impounds the upstream flow or diverts it to the San Francisco Bay Area. Water storage in Don Pedro Reservoir is also managed to prevent the Tuolumne from flooding Modesto and the surrounding areas. Consequently, neither San Francisco nor the irrigation districts are allowed to fill their portions of the reservoir until the end of the spring snowmelt.

3.5.3 Groundwater Management

Currently, approximately 30 percent (16,500) of Tuolumne County's 55,000 residents depend on groundwater either from private wells or one of the small or large public water systems. As the primary non-public water source, wells continue to be drilled for new development, particularly for rural residents (an average of 114 wells per year during the past five years). Since the adoption of the Tuolumne County Water Well Ordinance in 1986 (Chapter 13.16 Tuolumne County Ordinance Code [TCOC]), the Environmental Health Division had issued approximately 1,900 water well drilling permits as of 1999 (Tuolumne County, 1999).

Public water systems with more than 200 service connections are regulated by the State Department of Health Services (DHS). There are 16 such systems in Tuolumne County. The largest water provider in Tuolumne County is TUD, with the majority of its customers served by surface water (e.g., the Stanislaus River and associated impoundments) and only about 5 percent served with well water (300 connections with about 720 users). TUD maintains 45 wells, some of which are used to supply make-up water during droughts and ditch outages (Tuolumne County, 1999).

Other large water providers, such as the Groveland Community Services District and Twain Harte Community Services District also use surface sources. However, several others such as Mi Wuk Mutual, Cold Springs and Odd Fellows Sierra Park, and many of the smaller public water systems in the County depend on a groundwater for at least part of their water supply. There are 106 small water systems regulated by the County's Environmental Health Division (EHD). Eighty-two of these systems rely exclusively on groundwater (Tuolumne County, 1999).

3.5.4 Wastewater Treatment

Historically, Tuolumne County communities from Jamestown to Twain Harte have discharged sewage effluent directly to Woods or Sullivan Creeks (Tuolumne County, 1997). With the adoption of the Clean Water Act in 1972 and, shortly thereafter, the establishment of the State Water Resources Control Board and Regional Water Quality Control Boards, these practices were ended. At that time, a Regional Wastewater Plan was developed, and treatment plants at Sonora and Jamestown were upgraded to treat the wastewater to a level of quality suitable for discharge to surface waters. Interceptor lines were constructed to bring primary treated sewage from Twain Harte and untreated sewage from other communities throughout the area to the Sonora treatment plant. The upgraded regional collection and treatment system has been in operation since April 1976 (Tuolumne County, 1997). TUD is the major provider of wastewater service within northern sections of the PSA; with other smaller providers servicing more isolated urban cores within the central and southern portions of the PSA. Table 3-4 lists the major wastewater service providers within the PSA.

TABLE 3-4
PRIMARY SEWAGE DISPOSAL – TUOLUMNE COUNTY

Agency	Location of Treatment Collection Facilities	Capacity (Gallons per Day)	Average Throughput (Gallons per Day)	Maximum Possible Connections (Number)	Disposition of Effluent
Tuolumne Utilities District (TUD)	End of Southgate Drive, Sonora	5,200,000 [1]	2,800,000–3,000,000 [1]	20,800 – 24,186 [1]	Storage at Quartz Reservoir, and used for agricultural irrigation
Groveland Community Services District (GCSD)	At the main GCSD Office, Ferretti Road, Groveland.	400,000	188,000	1,300	Complex of spray fields and ponds for evaporation and a portion is used at the Pine Mountain Lake gold course for irrigation, although salt concentrations are reducing this use.
Tuolumne Sanitary District	Near Box Factory Road, North of Turnback Creek and south of RR, Tuolumne City.	360,000 gpd (dry weather)	65,000 (dry weather)	850	Spray evaporation ponds downstream from Tuolumne along Turnback Creek
Jamestown Sanitary District	Plant alongside Wood's Creek, Jamestown	280,000 gpd (dry weather)	180,000	1,250	Effluent pumped to Quartz treated-wastewater reservoir and used for agricultural irrigation
Grand Total		**6,240,000**	**3,233,000–3,433,000**	**24,200–27,586**	

[1] Facility is currently built to handle 2,600,000 gallons per day, but the facility is designed to begin expansion to 5,200,000 gallons per day once the facility hits 80 percent capacity. The facility currently serves between 10,400 and 12,093 connections based on TUD's guidelines of 215 to 250 gallons per day residential household. Current average throughput is 1.4 to 1.5 million gallons per day. Source: Gary Egger, TUD, August 1, 1986.

SOURCE: Tuolumne County General Plan EIR, 1996

Today, TUD's Sonora Regional wastewater treatment plant (WWTP) and Jamestown Sanitary District's (JSD) WWTP treat wastewater to a disinfected secondary standard. The TUD plant is regulated by Waste Discharge Requirements (WDR) Order No. 94-192; the JSD plant is regulated by WDR Order No. 5-01-062. These WDRs are regulated by the Central Valley Regional Water Quality Control Board (CVRWQCB). In addition to centralized wastewater treatment facilities, it is estimated that approximately 40 percent of Tuolumne County residents (about 22,000 people) do not have available sewer service and therefore must use on-site sewage treatment and disposal systems (Tuolumne County, 1999). This has resulted in the installation of an estimated 7,500 septic tank-leachfield systems county-wide (Tuolumne County, 1999). Of this total, it is not clear how many of these septic tank-leachfield systems reside within the PSA; however, given that the PSA includes a large fraction of the development within the County it is presumed that it includes a large proportion of the total systems. Many of these operate without problems, but others suffer from poor design or increased use.

The EHD regulates underground disposal using individual or common tank and leach field systems. Because the volume of wastewater introduced to a septic tank system from a typical household unit ranges from 40 to 45 gallons per day per person (Canter and Knox, 1985), it is estimated that about 880,000 gallons of sewage are discharged into the ground per day in the

County (Tuolumne County, 1999). The most problematic systems are generally located in older communities with high septic system densities and lots with inadequate leachfield area. Some of these subdivisions were developed primarily for use as vacation cabins but now have a high rate of year-round occupancy.

Most of the septic systems were installed prior to the adoption of Chapters 13.04 and 13.08 of the Tuolumne County Ordinance Code (TCOC) (in 1975 and 1981, respectively), which now require a health review and soil investigations to demonstrate feasibility and long-term operation prior to approval (Tuolumne County, 1999). Additionally, the County notes that some of these systems were installed in fractured rock and are potentially a threat to groundwater quality and local water wells. Those wells of most concern are generally associated with older residences drilled prior to the adoption of the local well construction ordinance in 1986 (Chapter 13.16 TCOC), which mandates minimum separation between leachfields and other sources of pollution (Tuolumne County, 1999). In other instances if local bedrock fractures are oriented laterally, problematic septic systems may pose a potential hazard to surface water.

3.6 Population Growth

3.6.1 Demographic Trends

Prior to 1900, the County's population varied from 16,229 in 1860 to 6,082 in 1890 in response to the decades marked by California's Gold Rush. Only since 1930 has Tuolumne County experienced a steady growth rate (Tuolumne County, 1997). From the 1950s to the 1960s, the growth rate of the unincorporated area of Tuolumne County increased from 1.5 to 6.3 percent per year and remained at a high level through 1990 (Table 3-5). The population of the unincorporated area of Tuolumne County grew by 44.4 percent during the 1980s and slowed to 13.0 percent during the 1990s (Tuolumne County, 1997). The State Department of Finance projects the County to reach a population of about 65,452 by 2020 and 70,537 by 2040 (Department of Finance, 2000).

In 2000, the per capita income in the County was $20,910; approximately 70 percent of the State average and ranking 45th in the State (Department of Finance, 2000). In March 2003, the County had a civilian labor force of 22,360 persons. Of these, 20,920 persons were employed.

TABLE 3-5
HISTORICAL POPULATION GROWTH, 1900-2000

		Change from Preceding Year/Census		
Year	**Population**	**No. of Persons**	**Percentage (10 Year)**	**% Average Annual Change**
1900	9,244			
1910	7,950	-1,294	-14.0%	-1.4%
1920	6,084	-1,866	-23.5%	-2.3%
1930	6,993	909	14.9%	1.5%
1940	8,630	1,637	23.4%	2.3%
1950	10,136	1,506	17.5%	1.7%
1960	11,679	1,543	15.2%	1.5%
1970	19,069	7,390	63.3%	6.3%
1980	30,681	11,612	60.9%	6.1%
1990	44,303	13,622	44.4%	4.4%
2000	50,078	5,775	13.0%	1.3%

Source: Tuolumne County General Plan, (Source: U.S. Census, City of Sonora 2001-2008 Housing Element)

This corresponds with an unemployment rate in of 6.5 percent; slightly higher than the national average, which is currently around 5 percent. The major employment sectors are government (28.5 percent), retail trade (26.7 percent) and services (25.2 percent). The 2000 Census indicates those employed within the County were employed in the following industries:

- Agriculture, Forestry, Fishing, and Hunting
- Mining
- Construction
- Manufacturing
- Wholesale trade
- Retail trade
- Transportation and Warehousing
- Utilities
- Information
- Finance and Insurance
- Real Estate, Rental and Leasing
- Professional, Scientific, and Technical Services
- Administrative, Support and Waste Management
- Educational Services
- Health Care and Socia1 Assistance
- Arts, Entertainment and Recreation
- Accommodation and Food Services
- Public Administration
- Other Services

Current employment trends suggest that the economy of the County is changing from the historic industries of agriculture, mining, and timber to more of a service based economy. Current growth trends indicate that continued residential growth threatens oak woodland habitats in the County, since these habitats are where much of the growth is occurring. The current housing boom is fueled by the County's proximity to the rapidly growing cities in the Central Valley, which are generally within commuting distance. Based on current population projections, the lower reaches of the PSA are expected to experience additional growth through 2040, especially above the shoreline of Don Pedro Reservoir.

Chapter 4

Foothill Geomorphology and Sediment Transport Dynamics

ESA

CHAPTER 4

Foothill Geomorphology and Sediment Transport Dynamics

4.1 Purpose, Scope, and Methods

ESA conducted a Hillslope and Channel Geomorphic Assessment to provide an indication of total sediment volume within the Sullivan Creek Hydrologic Area and to produce a preliminary sediment budget to identify the portion of the existing sediment load that may be potentially controllable.

4.2 Approach to Quantifying Sediment Sources

ESA's work focused on broadly quantifying the volume and extent of hillslope and streamside erosion and the associated ratios of sediment delivery occurring in the watershed. This information is then used in estimating the relative proportion of sediment delivery from erosion, which is potentially controllable or preventable.

Data collection methods for this task primarily consist of (1) unit-wide, aerial photographic interpretation; (2) field mapping, data collection and analyses on selected portions of the hillslopes and stream channels in the Sullivan Creek Hydrologic Area; (3) GIS analysis of the area; and (4) preparing a simple sediment budget for the Sullivan Creek watershed. All of these elements rely on sound professional judgment in identifying, measuring, and quantifying erosional features and sediment sources, in determining whether the erosion is natural or associated with past land use activities in the watershed, and applying field observations and literature information to the analysis.

4.2.1 General Limitations

Any form of estimate is generally complicated by the difficulties of predicting the amount of sediment eroded, the delivery of eroded sediment into the stream network, and the downstream transport of the introduced sediment, sediment storage in stream channels or flood areas, and the potential secondary effects that result from the initial introduction of sediment into a stream channel. The small scale of the aerial photographs in conjunction with an extensive canopy cover limited the amount of erosional features that could be identified remotely. Minimal access to private property also limited ESA's ability to identify or measure erosional features on the hillslopes or make stream observations beyond public ROW stream crossings. Further, estimates of erodability are based on published literature for similar geologic units and do not have the benefit of site-specific erosion measurements. Sediment transport measurements could not be verified by virtue of a of lack continuous flow data to enable correlation for the quantities of sediment believed to be held in storage and the transport potential based on specific rainfall or flow intensities (e.g. 5-year, 24-hour; 50-year, 24 hour; etc.).

4.3 Hillslope Geomorphology

4.3.1 Physical Setting

The Sierra Nevada mountain range is generally described as a westward-tilted mountain block (Bateman and Wahrhaftig, 1966). The uplift is greatest along the eastern mountain front where the elevations are highest and elevations generally decline toward the Central Valley. Various episodes of uplift and river incision have occurred over its long history. The most important episodes to consider here are those since the deposition of the early Tertiary gold-bearing (auriferous) gravels. These Eocene age deposits relate to a regional uplift, the development of major river systems, and the deposition of the alluvial (river-deposited) gold-bearing gravels. The next major event was the inundation and burial of the landscape by volcanic mudflows, volcanic lava flows, and volcanic ash flows in Miocene-Pliocene time (Huber, 1990; Higgins, 1997). In the central to northern Sierra Nevada these materials completely buried the pre-existing river landscape forming a broad plateau surface; afterwards a new drainage system developed by incising into that plateau. These volcanic materials are assigned to the Mehrten Formation (predominantly volcanic debris flows) and other distinctive lava flows such as the Table Mountain Latite along the former path of the Stanislaus River.

Central and southern Tuolumne County is the zone in which the plateau-forming Mehrten Formation and other flows become substantially less dominant. Huber (1990, p. 102) notes that the Tuolumne River, which lies immediately south of the Sullivan Creek watershed, "is the northernmost of the major rivers draining the west slope of the Sierra Nevada whose course is not totally disrupted by the voluminous lahars[1] that buried most of the northern Sierra." The Tertiary Stanislaus River to the north of the Sullivan Creek watershed was inundated by the Table Mountain Latite (see Section 2.1.1 Structural Geology). The current course of the Stanislaus River was incised into the adjacent non-volcanic rocks leaving the Tuolumne Table Mountain as a remnant marking the Tertiary course of the river.

The Sullivan Creek drainage is an interfluve[2] area between the Tuolumne River to the south and the Stanislaus River to the north. Whereas the Tuolumne and Stanislaus rivers have large watersheds which extend long distances into the high Sierra, the Sullivan Creek watershed drains a much smaller area in the western foothills. It has a watershed area of approximately 40,100 acres and has a watershed length of approximately 17 miles. Although its location is in the western foothills the maximum relief in the watershed is 4,100 feet (between Elizabeth Peak on the northern rim

1 Volcanic debris flows
2 An interfluve is the ridge line separating two drainages. In the case of Sullivan Creek this "ridge line" is sufficiently large to have its own drainage system.

and the surface of Don Pedro Reservoir). This northern ridge is above the elevation of the Mehrten Formation and was not buried by it. Despite the substantial overall relief in the watershed there is only a small area with slopes greater than 50 percent.

The watershed geology is described in Section 2.1.3 Sullivan Creek Hydrologic Area. It consists of the 16 geologic mapping units shown in Table 4-1:

TABLE 4-1
GEOLOGIC UNITS IN THE SULLIVAN WATERSHED

Mapping Unit	Name	Age	Rock Types
Qal	Alluvium	Quaternary	Sand and gravel, also includes colluvium, landslide debris, and tailings locally
Qt	Tailings	Quaternary (modern)	Various rock debris, formed from mining operations
Tm	Mehrten Formation (undifferentiated)	Miocene-Pliocene	Volcanic flows, mudflows, plugs, and sediment of andesite composition, includes some mafic and silicic rock
Tvs	Valley Springs Formation	Oligocene-Miocene	Volcanic and sedimentary rock (mainly silicic tuff)
Tg	Auriferous (gold-bearing) gravel	Eocene	Sand and gravel composed mostly of pre-Tertiary rock
Js	Metasedimentary rocks	Jurassic	Slate with subordinate metagraywacke, minor metaconglomerate and tuff, formed as turbidites
Jm	Melange	Jurassic or older	Complex of incoherent lithologies including metavolcanic rock, chert, serpentine, schist, and marble
Jsp	Sullivan Creek terrane (phyllite belt)	Jurassic (?)	Mainly phyllite and stretched conglomerate derived from argillaceous and coarser-grained sediment
Jsg	Sullivan Creek terrane (greenschist belt)	Jurassic (?)	Metavolcanic rock including pyroclastic deposits and pillow basalt
Jv	Metavolcanic rocks (undifferentiated)	Jurassic	Metavolcanic rock, generally andesitic to basaltic composition
Mzg	Granitic rocks (undifferentiated)	Mesozoic	Granite to quartz diorite, includes main Sierran batholith and isolated plutons
Mzpm	Mafic plutonic rocks (undifferentiated)	Mesozoic	Diorite to gabbro, includes pyoxenite and hornblendite locally
Pzc	Calaveras Complex (undifferentiated)	Paleozoic-Triassic	Marine metasedimentary rock with minor metavolcanic rock, mainly chaotic argillite and subordinate chert
Pzcm	Calaveras Complex (marble)	Paleozoic-Triassic	Marine limestone and dolomite metamorphosed to marble
Pzs	Shoo Fly Complex (undifferentiated)	Paleozoic	Marine metasedimentary rock, mainly quartzite with minor schist and marble, may include masses of gneiss locally
um	Ultramafic rock	Paleozoic-Mesozoic	Dunite and peridotite partially or completely altered to serpentine

SOURCE: CGS, 1997

The detailed geology can be generalized into three broad lithologic (rock) groups. The first lithologic group is the volcanic plateau formed by the Mehrten Formation with a very small exposure of the underlying Valley Springs Formation. This plateau-forming deposit may have originally extended over most of the Sullivan Creek watershed but has since been eroded away. It now underlies only a very small area to the northeast and south of Twain Harte and to the southeast of Soulsbyville. Indications of the former extent of the Mehrten plateau in the area are shown by the elongated narrow ridges that separate the upper Sullivan Creek drainage from the Curtis Creek drainage to the southeast. These elongated ridges suggest that the Mehrten Formation formerly extended at least this far and formed a continuous surface at least from southeast of Soulsbyville to these ridges. It is likely that the Mehten Formation also continued to the north through the upper Sullivan Creek watershed. Virtually all of this former extent has been eroded away exposing the second, and underlying, lithologic group.

The second lithologic group is the area underlain by intrusive igneous rocks (granitic and mafic in composition) which are referred to as granitic in this section and some of the metamorphic rocks. This is the dominant rock type in the Sullivan Creek watershed. This rock underlies the upper two-thirds of the watershed as well as some area in the southwestern-most part of the watershed. In the upper watershed these granitic rocks underwent a relatively deep weathering which produced a moderately-deep to deep weathering zone. This weathering zone is shown throughout much of the watershed by reddish surface soil horizons underlain by more pale materials. In places these pale weathering zones can be observed to transition into the underlying granitic bedrock with boulders (corestones) weathering out between the bedrock joints (see **Figure 4-1**). Throughout the upper two-thirds of the watershed remnant granitic boulders up to approximately 10 feet in longest dimension are exposed in stream beds, stream banks, hillsides, and road cuts. These granitic boulders are found at all elevations in the upper watershed underlain by the granitic rocks. They occur at the highest elevations immediately beneath the Mehrten Formation in Twain Harte (see **Figure 4-2**), on hillslopes on upper Phoenix Lake Road and along Middle Camp Road (see **Figure 4-3**), on low elevation surfaces in Standard (see **Figure 4.4**), and in valley bottoms along Curtis Creek in Standard and in Twain Harte Creek where it crosses Crystal Falls Drive. In addition, there are two areas where well-developed exfoliation sheets formed in the granitic rocks occur. One is along Phoenix Lake Road (see **Figure 4-4**) and the other is along Sullivan Creek above Crystal Falls Drive (see **Figure 4-5**).

As noted in Section 2.1.2 Soil Resources the upper soil horizons in this area tend to be sandy clay loams. Below the soil profile these deeply weathered granitic rock materials produce predominantly sand-size material (called grus). The less weathered granite also produces gravel-sized sediment. When exposed in natural stream cuts, road cuts, or other disturbed areas this range of fine-grained to sandy to gravel sediment is very erodible. The sandy grus forms a substantial portion of the sediment contribution in the watershed.

Figure 4-1

Figure 4-2

Figure 4-3

Figure 4-4

Figure 4-5

The third lithologic group is the metamorphic rocks, which are dominated by metamorphic sedimentary and volcanic rocks. These rocks outcrop in a narrow zone at the upper rim of the northern watershed and in the lower one-third of the watershed. These metamorphic rocks tend to be dense and hard and have a shallower weathering zone and soil column as compared to the granitic rocks (see **Figure 4-6**). They do not contribute substantial amounts of sediment from soil erosion except in areas immediately adjacent to streams (see **Figure 4-6**). These metamorphic rocks also form a northwest-southeast trending zone of bedded rocks in the lower portion of the watershed. Sullivan Creek and Curtis Creek have eroded steep canyons where they pass through them. In these sites coarse rock materials produced predominantly by physical weathering on the canyon walls can be contributed directly to the streams by slope processes (see **Figure 4-6**).

4.3.2 Geomorphic Terrains

Hillslope Geomorphic Units (HGUs) are the basic unit for analysis of rates of erosion and sediment production rates to stream channels. The concept of HGUs assumes that hillslopes with similar characteristics will be dominated by similar erosional processes and similar mechanisms by which eroded material is delivered to stream channels. The development of HGUs serves as the basis for a sampling of hillslopes, to measure (through use of aerial photographs and field mapping) erosion and sediment production rates. Once determined, these rates can then be extrapolated to all areas in the larger watershed that fall within the same HGU. Development of the HGUs for the Sullivan Creek watershed was accomplished primarily through the use of existing GIS data.

Because each HGU type is defined as possessing a unique combination of attributes, it was necessary to limit the number of layers that would be used in the definition. In addition, some “lumping” of attributes within a layer was necessary to reduce the number of possible combinations. In the end, three primary layers were used to characterize natural HGUS and include a 10-meter DEM, geology,[3] and vegetation. To model alterations in the natural HGUs, the County’s roads GIS layer was utilized since local observation suggest these features in conjunction with contributing driveways constitute the largest fracture of hillslope alteration. The following describes how each of these layers were used in the analysis.

A 10-meter DEM was used to calculate slope angles, expressed in terms of percent slope. The slope categories were then generalized into areas of steeper and less steep terrain through the use of a “nearest neighbor” function of the GIS. With this function, the region (or “neighborhood”) around each point on a 10-meter grid in the watershed was examined to determine the steepness of all points in the neighborhood. The slope steepness categories used included 0 to 15 percent, 15 to 50 percent, and greater than 50 percent based on Ellen and Wentworth (1995). These slope categories relate to both the potential for erosion and slope alteration for development purposes (Ellen and Wentworth, 1995).

[3] Soil/vegetation maps for Tuolumne County were produced by the Soil Conservation Service in 1968; and have been digitized and attributed for use in a GIS by the Tuolumne County’s Farm Advisor’s Office. The mapping, however, does not extend to the developed areas. Consequently, the geologic mapping of Curtis (1999) was used in placed of the soil coverage because it provides completed coverage of the entire Sullivan Creek watershed.

Figure 4-6

Slopes in the first category are gentle and present little to no constraint to road alignment and require minimal grading for development. Slopes in the 15 to 50 percent category are steep enough to require grading for flat space but sufficiently gentle to allow grading by standard means. Slopes greater than 50 percent are steeper than the standard 2:1 (horizontal:vertical) cut and fill slopes and they cannot support development requiring flat surfaces unless fills steeper than 2:1 can be sustained. In the Sullivan Creek watershed slopes are generally in the first two categories and slopes greater than 50 percent only occur in areas within canyons or small-localized areas.

Several dozen geologic units are shown as polygons in geologic maps prepared by the CGS for Tuolumne County (Higgins, 1997) and 16 of these geologic units occur in the Sullivan Creek watershed (**Table 4-1**). These units were combined into generalized categories with shared characteristics of resistance to erosion based on field observations and comparisons to work in the Yuba River watershed (Curtis et al., 2005) as described in Section 4.3.1 Physical Setting. Elsewhere in the Sierra Nevada the Mehrten Formation is notable for the occurrence of landslides, which often originate at the interface between the base of the formation and the underlying bedrock (Curtis et al., 2005). It is also considered an erosive unit along its margins (Curtis et al., 2005). However, field observations in the Sullivan Creek watershed did not identify significant landslides, and the surface erosion seen along exposed margins of the Mehrten Formation (**Figure 4-7**) was not more than that observed in the weathered granitic material. Consequently, the geologic units were grouped into two broad groups: granitic and Mehrten (moderately erodible) and metamorphics (low erodibility).

The vegetation layer includes many vegetation types converted into a grid file. These were combined into similar categories based on cover protection to reduce the number of possible HGUs. The two vegetative types used were forest (including conifer and oak woodland) and grassland.

The final HGUs were therefore defined by the combination of the three slopes classes, the two geologic erodibility classes, and the two vegetation classes or 12 separate HGUs. These HGUs are presented in **Figure 4-8**.

4.3.3 Deviations from Sampling Protocol

All aerial photograph interpretation was limited to stitched-digital ortho-photographs provided by the County. To the extent feasible, ESA utilized this aerial coverage (ten-meter resolution) to identify larger sediment sources throughout the entire Sullivan Creek watershed. Because this imagery is not available in stereo, its use in identifying small- to medium-sized features was limited due to the ten-meter resolution and further complicated by the uniform canopy cover that characterized much of the watershed. These two factors made the determination of a feature's certainty[4] minimal, even for larger features. As a consequence, ESA was unable to determine the average length, width, and depth of larger features on the aerial photo. Further, features that were identified were unable to be field-checked due to access restrictions. These limitations made transferring individual features into an ArcGIS shape file format impractical. (1:24,000 scale).

[4] This is the certainty of the analyst's interpretation of the feature type and provides information necessary for field checking of sites.

Figure 4-7

4.4 Sediment Source Assessment Results

The sediment source assessment involved roadside evaluation of the different HGUs. The 12 terrains defined by the three slope gradient classes, the two geologic erodibility classes, and the two vegetation classes were examined by observing their characteristics along the Sullivan Creek Hydrologic Area road system. While access to the actual hillslopes was very limited, numerous useful observations could be made from the roadside with respect to overall vegetative cover, the general character and amount of natural and human disturbance, and estimates of the scale of sediment production and delivery from the road systems themselves. The road system traverse included all areas within the Sullivan Creek watershed including:

- Approximate northwest to southeast transects in the lower watershed for the Lower Sullivan Creek and Curtis Creek subwatersheds including Jacksonville Road, Algerine Road, Lime Kiln Road, Wards Ferry Road, and Outback Trail.
- The upper Curtis Creek and Soulsbyville subwatersheds along Tuolumne Road, Curtis Drive, Black Oak Road, and Soulsbyville Road.
- The Lower Sullivan Creek subwatershed in Sonora Hills and along Campo Seco Road, and Avenida Bonita.
- The Upper Sullivan Creek subwatershed along Phoenix Lake Road, Old Phoenix Lake Road, Potatoe Ranch Road, Montgomery Road, El Lobo Center, Creekside Drive, American River Drive, Crystal Falls Drive, Kewin Mill Road, Longway Middle Camp Road, Road N5602, Hunts Road, Bald Mountain Road, and Big Hill Road.
- A number of the road-stream crossing evaluated for the Channel Morphology and Sediment Transport Assessment (Section 4.4) were also observed to provide context for the HGUs.

A portion of the lower watershed that is being developed as rural residential home sites was not traversed because access is by private roads. Similarly, the larger rural land ownership of grazing land could only be observed at some distance. In the northern portion of the Upper Sullivan subwatershed north of Phoenix Lake rural residential development was not directly observed because access is also by private road. In this area some general observations could be made at a distance from Big Hill Road. Overall the coverage was sufficient to be able to generally characterize, or extrapolate, the condition of the sediment sources in the watershed.

Although some locations exhibited features associated with extreme soil erosion (e.g., extensive gully systems), their extent was limited and/or unobservable due to access limitations. Observed erosion was primarily associated with human disturbance and the two primary disturbances identified were associated with roads (road cuts, road side ditches, road embankments, native or gravel surface roads) and home sites (unpaved driveways, pastures, correls, and unvegetated portions of the lot).

Figure 4-8
11x17

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To simplify the sediment budget analysis, the HGUs were also combined in the GIS into three erodibility rankings. The HGUs were combined using procedures in ArcGIS spatial analyst (ESRI, 2004). That is, the derived datasets (slope, geologic erodibility, vegetation) were first reclassified into a common scale. The three slope classes were scaled at 3 (0 to 15 percent), 5 (15 to 50 percent), and 8 (greater than 50 percent). The geologic erodibility categories were scaled at 2 for low erodibility and 6 for moderate erodibility. Vegetation was scaled at 7 for forest and 10 for grassland. The next step was to weight and combine the datasets. Because field observations indicate that natural vegetation does not have a substantial differentiating effect on erodibility it was weighted at 0.1. Geologic erodibility was considered next in importance and it was weighted at 0.4. Slope was considered the most important and weighted at 0.5. These weighting factors were applied within spatial analyst and generated three erodibility classes based on the defined parameters. The three general erodibility classes were low erodibility (1), moderate erodibility (2), and high erodibility (3). The distribution of these erodibility classes in the Sullivan Creek Watershed Area are shown in Figure 4-9(A) Erodibility.

Figure 4-9 also shows the other analysis layers used in the Sediment Budget, which is described in detail in the following section. These layers include a stream layer generated in the ArcHydro component of ArcGIS (Figure 4-9(B) Streams); a road layer (Figure 4-9(C) Roads) and a simplified developed area (i.e., areas of concentrated development; Figure 4-9(D) Developed Area), which was developed by applying a buffer to the road layer. Using the HGUs as a base, the sediment budget estimated sediment production for natural conditions and developed conditions. The developed conditions individually accounted for the roads and “Developed Area.” The process is described in detail in the following section.

4.4.1 Sediment Budget

A simplified sediment budgeting approach was developed to evaluate the sediment source and delivery to the stream channel systems in the Sullivan Creek watershed. Sediment budgets evaluate the sediment production from a variety of sources and their delivery to the stream system. Detailed sediment budgets consider hillslope surface erosion, road erosion, mass wasting (e.g., landslides), and streambank erosion among other items. The simplified sediment budgeting approach used here includes hillslope surface erosion (under natural and developed conditions) and road erosion. Mass wasting contributions are not included because of the limitations of the available aerial photography to recognize landslide scars and general absence of landslide units identified in available geologic maps. Streambank erosion is not included because of the limitations of the aerial photography to allow identification of streamside erosion and the lack of access to conduct erosion transects along streams.

Figure 4-9

The sediment budget methodology was simplified from that done by McGurk et al. (1996) in the Camp and Clear Creek watersheds in El Dorado County; tributary to the Cosumnes River. The Sullivan Creek watershed sediment budget considered the potential for sediment production and delivery from hillslopes to the stream channels for each of the four subwatersheds. In brief, the methodology created buffer zones around the stream system subdivided by the erodibility category; assigned erosion values (tons per acre per year) from the literature for each of the erodibility categories and condition categories (i.e., natural, developed, roads); and then reduced the total tons of sediment produced by an estimate of how much of the eroded sediment would be trapped on the hillslope rather than actually being delivered to a stream. The latter approach is based on the observation that the further away from a stream that sediment is produced, the less likely that sediment is to actually reach, i.e., be delivered to, a stream. The values are totaled for each of the four subwatersheds considered, i.e., Upper Sullivan Creek (all the drainage contributing to Phoenix Lake), Lower Sullivan Creek, Soulsbyville, and Curtis Creek. The process is described in more detail below.

First, the ArcHydro component of ArcGIS was used to generate a detailed stream layer [see Figure 4-9(B)]. This stream layer was compared to the U.S. Geological Survey 7.5 minute topographic quadrangle and seen to be in reasonable agreement with the contour crenulations on the maps that denote the location of streams or drainages. Then these streams were buffered by distance producing four separate buffer zones around the streams. The buffer distances used are 0 to 164 feet, 164 to 328 feet, 329 to 492 feet, and greater than 493 feet (i.e., 50-meter intervals). The assumption here is the closer a hillside segment is to a stream channel the more likely it is that any eroded sediment is to reach a stream channel (see the discussion of sediment delivery below). These buffer zones were then overlain onto the hillslope erodibility layer. This analysis generated a database that showed the acreage in each of the three erodibility categories for each of the four buffer zones for each of the four subwatersheds. That is, the analysis quantifies how the erodibility categories are spatially arranged around the stream system.

The next step was to provide estimates for the amount of erosion that would occur in the individual erodibility categories and condition categories. These values were derived from a literature review with selections made based on the field observations within the watershed and on professional judgment. The erodibility values used were in tons per acre per year of sediment that would be produced under the given conditions. The sources used for estimating the erodibility values included those from natural and disturbed conditions in the Sierra Nevada (Euphrat, 1992; Kattleman, 1996; McGurk et al., 1996; Snyder et al., 2004; Curtis et al., 2005) and from granitic terrains in the Klamath Mountains of California (Sommarstrom et al., 1990) and the Idaho batholith (Rice et al., 1972). The erodibility values are multiplied by the acres in each erodibility category for each stream buffer zone to generate a value for the total tons of sediment eroded within each of the buffer zones per year. The values are then added to provide a value for the entire subwatershed. These values are the amount of sediment movement on the hillslopes. The potential for this eroded sediment to actually reach, i.e., be delivered to, a stream is evaluated by considering the distance of each buffer zone from the stream and then applying a sediment delivery ratio.

A sediment delivery ratio is the ratio of sediment delivered from a point to the total erosion that could occur upslope of the delivery point. For example, if 7 tons of sediment is delivered to a stream when 10 tons of sediment was produced from a specific source area, the sediment delivery ratio for that site is 7 divided by 10 or equivalently 70 percent. Sediment delivery ratios reflect the fact that some portion of eroded sediment is stored on the hillslope. Sediment eroded at a great distance from a stream (e.g., from a ridge top) may not be delivered at all, thereby having a sediment delivery ratio of 0 percent. The sediment delivery ratios used for natural conditions were 25 percent for the 0 to 164-foot buffer zone, 15 percent for the 164 to 328-foot zone, 10 percent for the 329 to 492-foot zone, and 0 percent for the greater than 493-foot zone. These values are similar to those used by McGurk et al. (1996).

To evaluate the changes in sediment production and delivery that have occurred in association with existing development, two other subsets of the Sullivan Creek watershed were also developed: a simplified development area and a roads area. The intent of the development area was to identify a reasonable spatial representation of the area that has undergone substantial development thereby resulting is significant alterations to the geomorphic terrain. It was produced by buffering the existing road system and visually comparing the result with the maps and field observations of the area. Initially roads were buffered at 500 feet. Then the buffers on roads that transect less developed areas were reduced to 50 or 100 feet to generally represent the amount of development associated with them and/or road cuts that extend off the actual road alignment. This produced an area of approximately 17,000 acres of developed land within the 40,100 acre watershed. Another alteration was made within the sediment budget spreadsheet to address the fact that certain areas are more urbanized than others. Specifically, an area correction factor was applied to address the degree of development in Twain Harte and Sonora Hills. The acreage covered by these two areas was estimated from land use maps. Twain Harte was assumed to have 70 percent impermeability and Sonora Hills was assumed to have 100 percent impermeability. These values were used as sediment delivery ratios to reduce the amount of potential sediment delivered from these sites. Sediment delivery ratios were assumed to be higher for the developed areas than natural areas. The sediment delivery ratios used were 60 percent for the first buffer zone, 40 percent for the second buffer zone, 20 percent for the third buffer zone, and 0 percent for the fourth buffer zone. This developed area was assumed to have an overall impermeable area of 16 percent (Minor and Cablk, 2001) and the sediment delivery ratios were reduced as a means of estimating the area that does not produce sediment.

Next the acres of road were identified by buffering the road system by 11 feet on each side of the centerline. This generated an area of approximately 800 acres in roads. Roads are considered separately because they often produce a large amount of sediment (McGurk et al., 1996). The sediment delivery ratios used for the roads were 80 percent for the first buffer zone, 50 percent for the second buffer zone, 20 percent for the third buffer zone, and 0 percent for the fourth buffer zone. The final area under current conditions is approximately 22,350 acres in relatively undeveloped conditions, i.e., forest or grassland. Some of the grasslands are used for grazing but the areas are still similar to natural conditions and are evaluated as such in the sediment budget.

Table 4-2 summarizes the results of the sediment budget. The sediment values, in tons and tons per acre per year, are shown for sediment produced and sediment delivered. The values are also shown for completely natural conditions and then for developed conditions. The developed condition values are derived from three datasets: the current area under “natural” conditions, the developed area, and the roads area. Natural conditions are considered to have very low sediment production and sediment delivery rates based on data from the Klamath Mountains (Sommarstrom et al., 1990) and the Idaho batholith (Rice et al., 1972). Sediment production rates for developed conditions in low erodibility are taken from values from Euphrat (1992); the moderate erodibility values are taken from a Sierra-wide value reported in Kattleman (1996); and the high erodibility value is simply scaled up from the moderate value. The sediment production rate for roads is taken from McGurk et al. (1996) and scaled up for moderate and high erodibility.

TABLE 4-2
SEDIMENT BUDGET FOR THE SULLIVAN CREEK WATERSHED

Watershed Condition	Sediment Produced	Sediment Delivered	Sediment Delivery Ratio
Natural Conditions			
Upper Sullivan (tons)	421	81	0.19
Upper Sullivan tons per acre	0.027	0.005	
Lower Sullivan (tons)	229	43	0.19
Lower Sullivan tons per acre	0.024	0.004	
Soulsbyville (tons)	181	33	0.18
Soulbyville tons per acre	0.026	0.005	
Curtis Creek (tons)	195	36.5	0.19
Curtis Creek tons per acre	0.025	0.005	
Entire Watershed (tons)	1,025	193	**0.19**
Entire Watershed tons per acre	0.026	0.005	
Developed Conditions - Entire Watershed			
Undeveloped Area (tons)	564	109	0.19
Developed Area (tons)	8,655	3,417	0.39
Roads (tons)	736	462	0.63
Subtotal (tons)	9,955	3,987	0.40
Tons per acre	0.248	0.099	
Times > natural, tons/ac	9.7	20.6	
Developed Conditions - Upper Sullivan Creek			
Undeveloped Area (tons)	202	40	0.20
Developed Area (tons)	4,210	1,695	0.40
Roads (tons)	345	212	0.61
Subtotal (tons)	4,758	1,947	0.41
Tons per acre	0.307	0.126	
Times > natural, tons/ac	11.3	**24.0**	
Developed Conditions - Lower Sullivan Creek			
Undeveloped Area (tons)	138.2	26.6	0.19
Developed Area (tons)	1710.7	641.1	0.37
Roads (tons)	163.0	100.8	0.62
Subtotal (tons)	2011.9	768.5	0.38
Tons per acre	0.2	0.1	
Times > natural, tons/ac	**8.8**	**18.0**	
Developed Conditions - Soulsbyville Creek			
Undeveloped Area (tons)	72.7	13.6	0.19
Developed Area (tons)	1997.9	788.3	0.39
Roads (tons)	162.8	106.3	0.65
Subtotal (tons)	2233.4	908.3	0.41
Tons per acre	0.3	0.1	
Times > natural, tons/ac	**12.4**	**27.4**	
Developed Conditions - Curtis Creek			
Undeveloped Area (tons)	151.2	28.8	0.19
Developed Area (tons)	769.9	304.4	0.40
Roads (tons)	65.4	42.5	0.65
Subtotal (tons)	986.5	375.8	0.38
Tons per acre	0.1	0.05	
Times > natural, tons/ac	**5.1**	**10.3**	

See Appendix A for detailed calculations
SOURCE: ESA, 2006

Under natural conditions the values for sediment production and delivery are very low reflecting the low erodibility (Table 4-2). The subwatershed wide sediment delivery ratios are 0.18 or 0.19, which is in line with values reported for watersheds of this size in Walling (1994) and similar to the value 0.21 from Sommarstrom et al. (1990).

Under developed conditions both sediment production and sediment delivery increase. These values reflect the connectivity of the predominantly paved road system to streams and the connectivity of home sites, namely driveways, to roads which are connected to streams. Overall deliverability increases to 0.4 and there is an increase of 20 times in the tons per acre delivered for the entire watershed compared to natural conditions. The increase in tons per acre delivered to Phoenix Lake (i.e., the Upper Sullivan Creek Watershed) is 23 times that of natural conditions. McGurk et al. (1996) report an average annual increase of 53 times the natural rate of erosion compared to natural conditions in the residentially-influenced Clear Creek basin in El Dorado County.

Based on information provided in a newspaper article on Phoenix Lake (Wolfson, 2005), during the period from 1890 to 2005, 227 acre-feet of sediment were deposited over 115 years (including an assumption that an additional 20 acre-feet of sediment was removed by dredging in the 1980s). For comparison purposes, the acre-feet values were converted to tons based on the density of the sediment taken from reservoir cores in Englebright Lake on the Yuba River (Snyder et al., 2004). The total tons were converted to tons per acre per year. Finally, a correction factor was applied for the sediment trapping efficiency of Phoenix Lake. That is, reservoirs do not trap all the sediment that is delivered to them; specifically some amount of the fine-grained suspended sediment (e.g. clays and silts) passes through the reservoir and are transported downstream. A simple sediment trapping efficiency of 75 percent was calculated for Phoenix Lake based on the capacity-watershed ratio method (Verstraeten and Poesen, 2000). Using the above values a maximum average sediment amount of about 0.3 tons per acre per year has been delivered to Phoenix Lake. If the reported values for the acre-feet of sedimentation in Phoenix Lake are reasonably accurate then the estimated sediment delivery to the lake from the reported sedimentation is greater than the estimate from the sediment budget. However, the sediment budget does not include estimates of delivery from mass wasting, stream bank erosion, or changes in storage of sediment in the stream channel itself.

Although these are preliminary values, the simple sediment budget indicates that a large amount of controllable sediment is associated with developed conditions in the watershed including unpaved driveways, road side ditches, road embankments, pastures, corrals, and unvegetated, bare ground portions of home lots.

4.5 Channel Morphology and Sediment Transport

The amount of sediment yielded to a particular point is largely dependant upon the ability of the channels within the watershed to transport sediment. At any given instant, channels are typically transporting sediment from two distinct sources: (1) sediment delivered directly from the surrounding hillslopes and (2) sediment that is stored within the channel network itself.

In the latter case, transport is generally manifest in bed and bank erosion.[5] The ability of a channel to move sediment is termed the sediment transport capacity, which depends mainly on channel slope and discharge; the actual rate of transport, given similar slope and discharge, depends upon a third factor: the size distribution of mobile sediments. In general, sediment transport is a function of slope, discharge (flow velocity and depth) and the size distribution of mobile sediments. Further, the general morphology of a channel is usually a good indicator of transport capacity and efficiency. A planning-level analysis of channel slope and morphology, and their relation to sediment transport capacity and rate, is presented below.

4.5.1 General Approach

As noted earlier (**Section 4.3.1**), the Sullivan Creek watershed is an interfluve area between the much larger and deeper basins of the Tuolumne River (to the south) and the Stanislaus River (to the north). Soils within this watershed are generally shallow, underlain by plutonic and metamorphic bedrock, and runoff processes in response to rainfall are generally rapid. Based on 118 years of record, Goodridge (2005) calculated the average annual rainfall for the Sonora Ranger Station to be 32.4 inches. The Sullivan Creek watershed receives little to no snowmelt runoff. The hydrologic and geologic characteristics of the Sullivan Creek watershed are described in further detail in **Section 2.2.3.**

The Sullivan Creek system generally functions as more of a headwater-type system as opposed to a meandering, lowland alluvial system. Within this system, valley (or channel) segment slope and morphology is useful for distinguishing dominant sediment transport processes (fluvial versus mass wasting), inferring general long-term sediment flux characteristics (transport- versus supply-limited), and providing insight into the spatial linkages that govern watershed response to disturbance (this concept is summarized by Montgomery and Buffington [1998]). However, depending on the extent of alluvial material, segments that appear functionally similar at the valley-scale may respond differently at the reach-scale to similar perturbations in sediment loading and discharge. Thus, to the extent possible, reach-scale morphology should be used to verify or augment the description and characteristics of representative valley or channel segments.

A planning-level Channel Geomorphic Assessment was conducted to assess general sediment transport characteristics within the Sullivan Creek watershed and to supplement the sediment budget presented in **Section 4.4.** The general approach to this assessment involved Geographic Information System (GIS) analysis and a rapid field survey and inventory. Slope delineations made using ArcGIS and channel characteristics observed at the reach-scale, by means of the channel system survey of the Sullivan Creek Hydrologic Area, were used to classify channel segments into six general categories and qualitatively evaluate sediment transport capacity and characteristics. The methodologies and results of this assessment are presented below.

[5] For our conceptual purposes, bank erosion is considered to be an in-channel sediment source, though in many cases it can be considered a hillslope input (i.e., soil creep).

4.5.2 Channel Segment Slope Delineation

Channel slopes were delineated using ArcGIS and various data layers. USGS blueline stream delineations were taken from the National Hydrograph Dataset (NHD) (USGS, 2005) and are shown in **Figure 4-10**. Manmade conveyance structures moving local or imported water from the Sullivan Creek watershed were excluded from the set of streams (i.e., the Phoenix Ditch). The stream layer was superimposed onto a 10-meter DEM and slope values were generated for each channel reach. For the most part, channel reaches comprised the entire length of a particular channel between an upstream and downstream confluence with another channel. In some cases the channel reaches were segmented further; modification of the segment delineation was based upon observations made during field reconnaissance (below) and generation of a denser, artificial stream network based exclusively upon drainage area.[6] For example, if a portion of a channel transitions dramatically from a moderate gradient to plunging down through a bedrock exposure, and this segment is not bracketed by a confluence at either extreme, then the segmentation of this channel would be modified to reflect this feature.

Once the channel reaches and their associated slope values were delineated, the reaches were grouped into classes according to slope. Channel slope is a principal determinant of both morphology and sediment transport capacity. Slope classes were delineated according to channel classifications presented by Montgomery and Buffington (1997, 1998) and further summarized by Kondolf et al (2003). The three slope classes are: < 0.02, 0.02 to 0.04, and 0.041 to 0.30; herein referred to as Slope Class 1, Slope Class 2, and Slope Class 3, respectively (**Figure 4-10**). Generally, no slopes over 30 percent were observed for the principal tributaries and channels. These slope classes are also associated with, and used to generalize, a probable channel form, which was verified and expanded upon through the field reconnaissance (below).

4.5.3 Stream Channel Morphology and Observations

In order to characterize channel morphology, a general survey of the channel system was conducted for the Sullivan Creek watershed. The channel survey was essentially a road-system traverse, generally limited to stream crossings and reaches that were in close proximity to the roads. A series of observations and, in some cases, quantified measurements were made and noted at each station for a consistent set of parameters; a number of photographs were also taken for each station. For each station, all observations and measurements are summarized in **Table 4-3,** and a representative set of photographs and accompanying descriptions are presented in **Appendix B**.

[6] The artificial stream network was generated using the 10-meter DEM and the HEC-GeoHMS program for watershed and stream delineation. Delineations were made using a contributing area threshold of 20 acres. The HEC-GeoHMS program is described in detail by USACE (2000).

Figure 4-10
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Table 4-3. Summary Notes for Channel System Survey.

Station ID	Channel Segment Slope [3] (ft/ft)	Confinement [4]	M&B (1997) Classification [5]	Bankfull Dimensions (ft) width	depth	Entrenchment [6]	Riparian/Bank Vegetation	Erosion	Deposition	Bedrock Exposure
SCR-6	0.043	UC	NA	NA	NA	LOW	grassland	NA	NA	No
TWH-1	0.050	MC	ALT	9.0	2.0	MODERATE	sparse forest/blackberries	bank undercut	much sand	No
SCR-5	0.190	WC	CA	6.0	1.5	MODERATE	dense blackberries	none	pool/obstruction accumulaition	No
SCR-7	0.078	UC	SP	10.5	3.0	HIGH	sparse forest (young trees)	severe, highly incised	none	No
SCR-3	0.030	MC	PB/PR	10.0	2.5	LOW	dense forest/shrubs	none	minor clay/silt	No
SCR-2 [1]	0.014	MC	PR	12.0	2.5	LOW	sparse forest/shrubs	minor bank erosion	normal bars	No
SCR-1 [1,2]	0.006	UC	PR/PB	15.0	3.0	LOW	sparse forest/dense shrubs	bank erosion	sands over armor bed	No
SCR-18	0.146	WC	CA	3.0	0.5	MODERATE	dense shrubs	none	pool/obstruction accumulaition	No
SCR-9	0.024	UC	PB	NA	NA	LOW	sparse forest	near large culvert	none	No
SCR-10	0.086	WC	SP/CA	6.0	1.5	MODERATE	sparse forest/dense shrubs	none	pool/obstruction accumulaition	Yes
SCR-11	0.031	UC	SP/PB/PR	25.0	2.5	LOW	forest/dense shrubs/blackberries	none	none	Yes
SCR-12	0.030	WC	SP/BDRK	NA	NA	NA	sparse forest/shrubs	none	pool deposition	Yes
SCR-15	0.030	UC	PB	6.0	1.0	LOW	sparse forest/grassland	bank erosion	accumulation near road	No
SCR-16	0.038	UC	PB	4.0	1.5	LOW	grassland	none	none	No
SCR-13	0.008	UC	PB/PR	35.0	4.0	LOW	sparse forest/shrubs	none	none	No
SCR-14	0.025	UC	NA	NA	NA	LOW	grassland/pasture	none	aggraded channel	No
SCR-19	0.026	WC	SP/BDRK	NA	NA	NA	forest/dense shrubs	none	none	Yes
CCR-4	0.050	UC	CA	8.0	1.0	LOW	shrubs/blackberries	none	none	No
CCR-3	0.013	UC	PB	NA	NA	LOW	sparse forest/grassland	none	aggraded channel	No
CCR-2	0.008	UC	PB/PR	21.0	3.0	MODERATE	sparse forest/dense shrubs/blackberries	minor bank erosion	aggraded channel	Yes
CCR-1	0.024	MC	SP/PB/PR	25.0	2.5	MODERATE	dense forest/dense shrubs	none	none	No
CCR-6	0.035	UC	PB	NA	NA	LOW	forest/grassland	none	eddy downstream of bridge	No
CCR-7	0.021	UC	PB/ALT	5.0	1.5	MODERATE	grassland	channel incision	none	No
CCR-5	0.024	UC	NA	6.0	0.5	LOW	grassland/pasture	none	aggraded channel	No
CCR-9	0.027	UC	PB/PR	NA	NA	LOW	sparse forest/shrubs	none	none	No
CCR-10	0.015	UC	PB/PR	30.0	3.5	LOW	grassland/pasture	minor bank erosion downstream	aggraded channel	No

NOTES:

1 A pebble-count was conducted at this station.

2 A cross-section was surveyed at this station.

3 Slope derived from 10-meter DEM in ArcGIS.

4 UC = unconfined (valley width is generally > 4 times the channel width), MC = moderately confined (valley width is generally 2-4 times the channel width), WC = well confined (valley width is generally < 2 times the channel width). Note: confinement is characterizing the valley width compared to the channel, whereas entrenchment is comparing floodprone width to the channel. These two parameters are typically related but not always (i.e., a highly entrenched channel can occur within an unconfined valley).

5 Morphology classfied according to concepts presented by Montgomery and Buffington (1997).

6 Visual estimate of floodprone width vs. bankfull channel width. Generally, if floodprone width/bankfull width < 1.4 (highly entrenched), between 1.4 and 1.6 (moderately entrenched), and > 1.6 (low, not entrenched). After Rosgen (1994).

Confinement

Channel confinement strongly influences channel response (Montgomery and Buffington, 1998) and largely determines if, during large flows, sediment will be transported through the valley or stored within the floodplain. Confinement (as opposed to entrenchment) typically refers to the geometry of the channel above the bankfull stage (i.e., the valley width compared to the channel width) and is a measure of the space available for the channel to move laterally. Unconfined channels possess extensive floodplains across which over-bank flows spread, which limits the effect of peak discharges on channel morphology. In contrast, confined channels efficiently translate high flows into increased basal shear stress (Montgomery and Buffington, 1998). Channel confinement was qualitatively assessed for each station and, in the context of the CGU categories, is discussed further below.

Sediment Size and Storage Characteristics

Given a discharge and slope, sediment size distribution and channel confinement generally determine how the channel will respond in terms of sediment transport and form adjustment.[7] Of the two, sediment size distribution is generally more important because it is relevant for a wide range of flow conditions (confinement becomes more important only during flood events). Under similar flow conditions, a channel bed comprised of larger particles (e.g., cobbles) will remain more stable and transport less sediment compared to a channel bed comprised of small particles (e.g., sands). Further, the gradation (or sorting) of the bed material is also important; in other words, are the size classes evenly distributed or is the distribution bi-modal (e.g., lots of fine sand and lots of small boulders, with nothing in between). Hassan et al. (2005) summarized multiple studies that showed distinct phases of transport of bed material depending on the sediment size. Further, Wilcock and McArdell (1997) demonstrate that the presence of sand-sized material can enhance the transport of the larger particles on the channel bed. Significant sand deposits were noted at or near stations SCR-1, SCR-10, TWH-1, and CCR-2.

In order to obtain some quantitative sense of sediment size distribution within the Sullivan Creek watershed, pebble counts following the methodology described by Wolman (1954) were conducted at stations SCR-1, SCR-2, and CCR-2 (**Figure 4-11**). A heel-to-toe method was used to traverse the bed or bar and randomly select particles. An effort was made to avoid distinct sand deposits and only capture the separate gravel/cobble population; however, this was not practical at station SCR-1 due to the layer of sand that had been rather uniformly deposited over the bed (the bed material was more embedded and less armored at SCR-1 as a result). Regardless, the largest grain size (65mm) actively transported is similar among the three stations. The sand layer at SCR-1 is notable and becomes fully mobilized under much smaller flows compared to the underlying large gravels and cobbles. Considering the three pebble-counts and bankfull dimension estimates at the same stations, and using the stream power vs. bedload transport relation illustrated by Dunne and Leopold (1978; Figure 17-4), Sullivan Creek is likely more competent at transporting its available bedload. This conclusion is supported by field observations of notable accumulations of bed and bar sediments as provided in photos of CCR-2, CCR-3, and CCR-10. Curtis Creek tends to be wider at these locations.

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[7] Large woody-debris (LWD) also plays an important role in this respect (i.e., considered together with sediment size distribution and confinement). However, LWD was not prevalent among the channel stations surveyed, and a comprehensive inventory was beyond the scope of this report and would likely be inhibited by property-access issues.

Figure 4-11

Channel and floodplain sediment storage is another important characteristic of fluvial sediments and can have important implications regarding the calculation and interpretation of sediment budgets. Periods of significant sediment transport in small to medium channels are interspersed with much longer periods of low transport, during which most of the transportable sediment is held in temporary storage in the channel bed, bars, and floodplains (Hicks and Gomez, 2003). Sediment accumulates in, and is released from, channels and valley floors over periods that range from days to millennia (Reid and Dunne, 1996). This follows the principle of active sediment (i.e., moving once every few years), semi-active sediment (i.e., moved every 5-20 years), and inactive sediment, which only mobilizes during extreme events (Kelsey et al. (1987, *cited in* Curtis et al., 2005).

In terms of sediment yield to a particular location, the channel itself is often times the greatest source of sediment. For example, studies conducted in the Lake Tahoe basin by Nolan and Hill (1991) showed that in-stream sediment sources constituted approximately 95 percent of the suspended load delivered to Lake Tahoe from the study basins. The volume of sediment being stored within the channel network, at any given time, typically is far greater than the volume yielded at the mouth of a basin. Short-term storage typically is manifested in gravel bar formations or local accumulations behind channel obstructions such as logs or boulders. In contrast, long-term storage usually occurs within aggrading or active floodplains. Sediment characteristics and storage elements were noted for each station and, in the context of the CGU categories, which are discussed further below.

Montgomery and Buffington (1997) Classification

One of the main objectives of the channel system survey was to classify the reach at each station according to the classification scheme described by Montgomery and Buffington (1997). The slope classes were derived using this classification and with an understanding of the probable channel form that the slope classes imply. It was important to verify this relationship in the field, note any significant deviations, and expand upon the general characteristics, if necessary.

Montgomery and Buffington (1997) recognize three primary channel-reach substrates: bedrock, alluvium, and colluvium. Bedrock reaches lack a contiguous alluvial bed and reflect high transport capacities relative to sediment supply; they are typically confined by valley walls and have steep slopes (Montgomery and Buffington, 1997). Alluvial channels, on the other hand, exhibit a wide variety of morphologies that vary with slope and position within the watershed, and they may have a well-established floodplain or little to no associated floodplain features. The five alluvial reach morphologies are: cascade, step-pool, plane-bed, pool-riffle, and dune-ripple (or regime). The Sullivan Creek watershed generally lacks the last morphology (regime) all together, as this is more characteristics of larger, lowland alluvial systems. Colluvial channels are normally small headwater streams that pass over a colluvial valley and exhibit weak or ephemeral fluvial transport; identification and assessment of colluvial channels within the Sullivan Creek Hydrologic Area was not within the scope of this report.

Table 4-4 presents a brief description of the channel morphologies applicable to this assessment and their relevant Slope Class.

Other Field Observations and Measurements

In addition to the morphology classification and the sediment and confinement characteristics, the following channel characteristics were measured (where feasible) or described: bankfull dimensions (width and depth), floodprone width, entrenchment ratio, bank vegetation, bed and bank erosion, sedimentation and disturbance, and bedrock exposure. The following is a brief description of the measurement or estimate of each parameter (recorded measurements and observations for all parameters, when applicable, are presented in **Table 4-3** for each station):

TABLE 4-4
CHANNEL REACH MORPHOLOGIES

Channel Type	Description	CGU Slope Class
Cascade	**.30 > s > .10** – Tumbling flow. Energy dissipation is dominated by continuous, tumbling flow over and around individual large clasts. Generally occur on steep slopes, are confined, and exhibit disorganized bed material typically consisting of cobbles and boulders. Large particle size relative to flow depth. Low sediment supply relative to transport capacity.	3
Step-pool	**.10 > s > .04** – Characterized by longitudinal steps formed by large clasts spanning the channel width and separating pools containing finer material. Pool spacing roughly one to four channel widths. Steep gradients, small width to depth ratios, and pronounced valley confinement. Low sediment supply relative to transport capacity.	3
Plane-bed	**.04 > s > .02** – Usually refers to planar gravel and cobble-bed channels. Lack discrete bars. Moderate to high slopes and confinement varies. Moderate to Low sediment supply relative to transport capacity.	2
Pool-riffle	**.02 > s > .001** – Undulating bed that defines sequence of bars, pools, and riffles. Pool spacing roughly five to seven channel widths in self-formed channels. Moderate to low gradients and generally unconfined. Bar formation in natural channels typically limited to slopes < 0.02. Moderate to High sediment supply relative to transport capacity.	1
Bedrock	Variable slopes – Exposed rock. Lack a continuous alluvial bed and there is little, if any, valley fill. Generally confined. Low sediment supply relative to transport capacity.	Varies

SOURCE: Montgomery and Buffington (1997), ESA; s = slope

<u>Bankfull Dimensions</u>. The bankfull discharge is considered to be the maximum discharge that can be contained within the channel without overtopping the banks and is commonly accepted to represent the flow that occurs, on average, once every 1 to 2.5 years. The bankfull width, usually defined by high-water marks indicated by strand lines, fluvial sediment deposits, and the boundary formed by vegetation at the channel margin, was measured or visually estimated for most stations. Similarly, the bankfull depth, the average depth corresponding to the bankfull width, was measured or visually estimated for each station. The top of the bankfull channel is normally lower than the obvious top of bank observed in the field, which is often the elevation of a low terrace.

<u>Flood-Prone Width</u>. Unless the delineation was obvious (i.e., drift-line, debris), the flood-prone width was measured or estimated as the width of the floodplain at an elevation that was approximately twice the bankfull depth.

Entrenchment Ratio. Entrenchment is a good indicator of the channel's shear stress sensitivity, and the entrenchment ratio is a measure of how much the channel is entrenched into the valley floor. The entrenchment ratio for each station was estimated using the approach developed by Rosgen (1994), where the flood-prone width is divided by the bankfull width. Thus, the lower the ratio the more entrenched the channel.

Bank Vegetation. Description of bank vegetation provides an estimate of the resistance to lateral erosion (i.e., more heavily vegetated banks are usually less likely to erode). Bank vegetation for each station was classified in the field according to generalized vegetation categories (i.e., grassland, shrubs, dense riparian, bare, etc.).

Bank and Bed Erosion. Active bed or bank erosion is usually an indicator of vulnerability to future erosion and may indicate channel instability. Indications of active bank erosion or channel incision include: exposed bare soil, recently scoured gullies, prevalence of slumps or slides along the banks, or recently scoured bed or banks. This parameter was qualitatively assessed as being low (i.e., no evidence), moderate (i.e., patches of exposed soil; limited areas of recent erosion), or high (i.e., extensive areas of exposed soil; evidence of chronic sediment input from bank failures; evidence of active channel incision).

Sedimentation and Disturbance. Active sedimentation or disturbance (e.g., landslide) provides an approximation of the amount of sediment supplied to the channel and may be an indication of channel instability. Indications of active sedimentation within the channel include: multiple channel threads, poorly defined channel margins, sediment deposits that have not been re-worked into bar formations, or evidence of recent sediment input from bank failures. Sedimentation was qualitatively assessed as being low, moderate, or high.

The nature and extent of any observed disturbance and/or obvious sediment input processes was recorded and, where possible, quantified to the extent practical. Sediment input to channels occurs either through discrete (episodic) processes, chronic processes, or the general process of soil creep (which may manifest in either a discrete or chronic manner). Significant anthropogenic disturbances could include channel modification (i.e., rip-rap or levees), grading and excavation, vegetation modification, and road construction. Fire, naturally or artificially induced, can also have a significant effect on sediment input and overall hillslope and channel condition. Such disturbances can significantly affect, or exacerbate, either discrete or chronic sediment input processes. Evidence of discrete sediment input processes (e.g., mass wasting) includes: landslide scars, debris flows, gullies, tree-throw, and bank erosion (driven primarily by gravitational forces); evidence of chronic sediment input processes includes: sheet erosion from hillslopes, ravel/road-cut erosion, and bank erosion (driven primarily by the shearing force of flow).

Bedrock Exposure. Because most of the Sullivan Creek watershed is underlain by relatively shallow plutonic (mostly granite) or metamorphic bedrock, exposures and remnant boulders of these structures can exert much control on channel morphology. Channels flowing over bedrock typically have a high sediment transport capacity relative to the sediment supply. Bedrock exposures or prominent features (i.e., boulders) were noted at each station if present.

SCR-1 Survey

A cross-section and longitudinal profile was surveyed for Sullivan Creek at station SCR-1 using an auto-level and stadia rod (**Figure 4-12**). This station was chosen because of its relative accessibility, general morphology, and location within the Sullivan Creek watershed. Pool-riffle morphology dominates at this station and, as a result, this station is likely to exhibit a measurable change in form in response to a significant shift in sediment input or flow characteristics. Further, this station is about 3,000 feet upstream of Phoenix Lake, with no significant tributaries in between, making this location an ideal candidate for monitoring future sediment supply to the lake. Because of access restrictions, all other channel measurements were made using a stadia rod and tape measures or were visually estimated.

4.5.4 Deviations from Sampling Protocol

ESA deviated from the sampling protocol concerning calculation of the Unit Stream Power Index (SPI) and the quantitative survey of gravel bars. The Unit SPI can be approximated as the product of the cross section-averaged bankfull depth and the channel slope. As only two variables are used for this value, the Unit SPI is highly sensitive to both variables used. Access and mere magnitude of area under consideration did not permit a cross-section survey at each station accurate enough to estimate the *cross section-averaged* bankfull depth. Estimates of the absolute bankfull depth were made at most stations but this parameter is not sufficient for calculating the Unit SPI (i.e., a wide shallow channel, a wide entrenched channel, and a narrow entrenched channel may all have the same absolute bankfull depth but dramatically different *cross section-averaged* bankfull depths). Further, access restrictions prevented an accurate clinometer reading of slope for some stations. As such, the Unit SPI was not calculated for the CGU stations.

4.6 Sediment Transport Implications

Based upon the channel segment slope delineation and stream channel morphology observations, six CGU classifications were derived with regards to sediment transport characteristics and implications. Three primary classifications (Slope Class), based mainly on channel segment slope, were created for all channel segments; and three secondary classifications were derived, only for particular segments, to supplement the information provided by the primary classifications. The secondary classifications were derived for the instances where observed confinement, sediment characteristics, and/or morphology were notably different than that associated with the given Slope Class or were notable features of an expected morphology. Channel segments and CGU classifications are presented in **Figure 4-10**.

Figure 4-12

Channel Geomorphic Units (CGU)

Primary Classification

Slope Class 1 (Response)

For this CGU (Slope Class 1), channel segment slopes range from 0.1 to 2 percent. Channel segments described by this unit tend to be moderately confined to unconfined and generally exhibit a pool-riffle (with some plane-bed) morphology. Expanding on confinement, channels within this unit tend to be in valleys that are greater than two times the width of the bankfull channel. Sediment supply is greater than the sediment transport capacity for these channels and thus, on average, they are usually experiencing a net storage of sediment. Within the channel, storage is manifested in bar formations which, based on field observations, are likely in equilibrium in the Sullivan Creek watershed; but are thought to be accumulating in areas within the Curtis Creek watershed [see below]). Based upon measurements made at stations SCR-1 and SCR-2, the volume of *active* sediment (i.e., sand and gravel bars) currently stored within these segments (for the Upper Sullivan Creek watershed) is approximately 2.0 cubic meters per meter of channel. Yet, segments within the lower portion of the Sullivan Creek Hydrologic Area and within the Curtis Creek watershed were undoubtedly storing more total sediment, though it was not clear what fraction of this sediment could be considered active and comparable to the estimates made for the Upper Sullivan Creek watershed.

Longer-term storage occurs within the floodplains of these channel segments. However, floodplain development was not significant within many of these segments; those segments that had well developed, more classic floodplain features are singled out in the secondary classification below (Floodplain Storage). Segments within this CGU are considered response segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is likely to change given a moderate change in sediment supply or discharge. **Figure 4-13** is a photograph from a representative station for this CGU.

Slope Class 2 (Transport and Response)

For this CGU (Slope Class 2), channel segment slopes range from 2 to 4 percent. Channel segments described by this unit tend to be moderately confined and generally exhibit a plane-bed (with some step-pool and pool-riffle) morphology. Expanding on confinement, channels within this unit tend to be in valleys that are two to four times the width of the bankfull channel. Sediment supply is generally less than the sediment transport capacity for these channels and thus, on average, they are usually transporting most of the sediment supply. However, some of the pool-riffle segments within this CGU do not transport all of the available sediment; but this is generally the exception to the rule for this CGU. There is some degree of storage within these segments, typically in localized pools, backwater areas, or sporadic bar formations.

Figure 4-13

Based upon observations made amongst the stations within this CGU, the volume of *active* sediment (i.e., sand and gravel) currently stored within these segments (for the Upper Sullivan Creek watershed) is approximately 1.0 cubic meter per meter of channel. Longer-term storage occurs within the floodplains of these channel segments. There was generally no floodplain development within these segments. Those few segments that had well developed, more classic floodplain features are singled out in the secondary classification below (Floodplain Storage). Segments within this CGU are considered both transport and response segments, in that the morphology of most stations could be considered a transitional form between transport and response reaches. In a given year, whether a particular reach is accumulating or transporting sediment is largely dependent upon the magnitude and duration of peak discharges for that year. **Figure 4-14** is a photograph from a representative station for this CGU.

Slope Class 3 (Transport and Source)

For this CGU (Slope Class 3), channel segment slopes ranged from 4 to 30 percent. Channel segments described by this unit tend to be highly to moderately confined and exhibit a cascade and step-pool morphology. Expanding on confinement, channels within this unit tend to be in valleys that are less than four times the width of the bankfull channel. Sediment supply is typically far less than the sediment transport capacity for these channels and thus, on average, they are usually actively transporting all of their sediment supply. Storage is not a factor for many of these channels; however, those segments in which notable accumulation of sediment were observed are singled out in the secondary classification below (Obstruction Storage). Further, in the upper headwaters, where the channels in this unit become colluvial (vs. alluvial), they serve as continuous sources of sediment by means of gullying or debris flows; these are a natural functions.

Segments within this CGU are considered transport segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is only possible or unlikely to change given a moderate change in sediment supply or discharge. Most of the segments within this CGU occur in the northern section of the Upper Sullivan Creek watershed. The channel network is relatively more dense in this area and the soils tend to be more deeply weathered (i.e., along Big Hill Road) and subject to incision by the channel network. **Figure 4-15** is a photograph from a representative station for this CGU.

Secondary Classification

As stated above, the secondary classifications were derived for the instances where observed confinement, sediment characteristics, and/or morphology were notably different than that associated with the given Slope Class or were notable features of an expected morphology. These classifications were derived, only for particular segments, to supplement the information provided by the primary classifications.

Figure 4-14

Figure 4-15

Floodplain Storage and Channel Aggradation (Unconfined)

Classic floodplain development was not present in many of the Slope Class 1 segments. However, floodplain development and, in some cases, channel aggradation was noted in some of the lower reaches of the Sullivan Creek Hydrologic Unit and these segments comprise this CGU. Aggradation, as it applies to this CGU, refers to a long-term process, based upon field observations, where storage occurs within the floodplains and channels of these segments and, in some cases, the channels have almost been completely filled-in (see **Figure 4-16**). Dietrich and Dunne (1978) describe the residence time of valley floor and floodplain sediments as being on the order of thousands of years.

Channels described by this CGU tend to be wide and shallow and generally incompetent at transporting their bed material load; these segments likely serve as sediment sinks during moderate to large flood events. However, along these same lines, during an extreme flood these segments may be susceptible to significant scour of channel or valley fill. Further, the process of channel incision would be readily apparent in these segments and likely signal a longer-term shift in discharge or sediment loads. In some cases, such as the *downstream* side of Curtis Creek at the Algerine Road bridge, a slight degree of incision is currently evident, in which case the channel may be shifting to one side serving as a net source of sediment rather than a net sink. **Figure 4-17** is a photograph from a representative station for this CGU (the *upstream* side of Curtis Creek at the Algerine Road bridge). Segments within this CGU are considered response segments, in that, according to Montgomery and Buffington (1998), reach-level morphology is likely to change given a change in sediment supply or discharge. Yet, compared to the other units in Slope Class 1, segments within this CGU would likely require a larger change in sediment supply or discharge in order to illicit a measurable response.

Obstruction (Boulder) Storage

This CGU is intended, specifically, to supplement the Slope Class 3 channels in the northern half of the Upper Sullivan Creek watershed. Though segments within this CGU are still supply-limited over time, much more accumulation (typically behind in-stream boulders) of fine to sandy sediments were noted for these segments compared to the other Slope Class 3 channels. Local storage of gravel and finer material is not uncommon to this general type (i.e., all Slope Class 3 channels), but it was more pronounced for segments singled-out for this CGU. Yet, compared to the Floodplain Storage CGU, the sediments held in storage within these channel segments are flushed much more frequently. Montgomery and Buffington (1997) point to a study that showed material in such depositional sites was completely mobilized during a seven-year flood event, whereas no movement was observed during flows of less than the annual recurrence interval. Megahan (1982), in studies within basins draining the granitic bedrock of the Idaho batholith, found the change in sediment stored behind obstructions was highly variable from year to year and a function (on an inter-annual basis) of annual instantaneous peak flows.

Figure 4-16

Figure 4-17

In most local storage sites, the sediment was reddish-brown in color and comprised mainly of silt and silty-sands (see right photo in **Figure 4-18**). Thus, the source of much of the stored sediment within this unit was the deeply weathered granite on the northern slopes of the Upper Sullivan Creek watershed. A number of road-cuts and road-side ditches observed on Big Hill Road (particularly in the vicinity of stations SCR-17 and SCR-18) were obvious candidates for generation of the sediment supply to these segments. Based upon measurements made at various stations, the volume of *active* sediment currently stored behind these obstructions is approximately 0.5 cubic meters per meter of channel.

Bedrock Reach (Transport and Confined)

This CGU is intended, primarily, to supplement two Slope Class 2 segments within the lower reaches of Sullivan Creek. In these two areas, the channel has incised down to the bedrock (metamorphic rock units) and scoured-out much of the valley fill or historic channel deposits. Unlike the typical Slope Class 2 channel segments, the bedrock reaches identified by this CGU are highly confined, generally supply-limited, and very efficient at transporting their sediment loads (i.e., they are solely transport reaches). These channel segments are the most stable of all the CGUs, and reach-level morphology is unlikely to change given a moderate change in sediment supply or discharge. **Figure 4-19** is a photograph from a representative station for this CGU

4.7 Preliminary Conclusions

The 62 square mile Sullivan Creek watershed is estimated to have produced an average of 0.248 tons/acre/year with 0.099 tons/acre/year delivered to the stream network (see **Table 4-2**). This rate of erosion is 9.7 times greater than natural conditions. Including our estimate of chronic road surface erosion, the average quantity of eroded sediment delivered to the stream network is 20.6 times greater as opposed to natural conditions. These findings suggest that there is a large fraction of controllable sediment within the watershed. The relative amounts of both erosion and sediment delivery from the various terrain types in the watershed quantified in this study are in line with expectations, with more highly erodible geologic units, distributed areas, and steeper areas generally producing the largest quantities of sediment.

Erosional features associated with land management account for by far the greatest sediment delivery volumes from the watershed. In order of importance, roads, property ground coverage, and unpaved driveways account for the largest percentage of the total sediment delivery. Intensive land use practices have contributed to accelerated, human-caused erosion throughout the watershed, resulting in increased sediment loading of the streams. Over the past 90 years, subsequent sediment transport within the upland stream channels has, in all likelihood, contributed to downstream, lowland aggradation and sedimentation issues. Field observations indicate that there may be substantial quantities of sediment stored in smaller streams in areas inaccessible to filed investigators. Consequently, the granitic and Mehrten (moderately erodible) HGUs that underlie much of the forested area in the upper sections of the watershed may continue to produce relatively large quantities of sediment for some time.

Figure 4-18

Figure 4-19

In terms of sediment sources derived from the channels, the *Slope Class 1* CGU is likely the most important is terms of a chronic source of sediment to the basin outlets (particularly in terms of sand). To some degree this process is natural and expected for these channel types; however, the fraction of sand being actively stored and mobilized (annually) appears to be high. For the Upper Sullivan Creek watershed, the *Obstruction Storage* CGU is likely the second most important in-channel sediment source; though the movement of sediment is more episodic (i.e., just during large events, or once every year or two at most). This process is likely controllable to some degree, in that some of the sediment stored within this CGU is probably derived from road-cuts and ditches found on the northern slopes of the Upper Sullivan Creek watershed. For the Lower Sullivan Creek and Curtis Creek watersheds, the *Floodplain Storage* CGU is the second most important in-channel sediment source. However, this unit is highly variable in terms of its supply potential (i.e., some channels are almost completely filled and not incising, whereas others have incised slightly into the valley). The significance of these units in terms of supply could increase dramatically under a catastrophic flood or a regional shift in the flow regime. The *Slope Class* 2, *Slope Class 3*, and *Bedrock Reach* CGUs generally seem to be efficient at transporting the available sediment supply and likely do not serve as in-channel sediment sources in any significant manner.

The aerial photo analysis of these areas was performed at a scale that did not allow for a specific attribution of erosion to land management activities other than to observe a broad land use category. Further, the lack of a sequential set of historic air photographs did not allow for ESA to assess changes in land use practices over time, which was further limited by inaccessibility (e.g. private property restrictions) and time limitations.

In general, discussions with County staff and local landowners indicate that land use practices have been steadily improving in the Sullivan Creek watershed. Timber harvest practices within the watershed are generally small in scale (e.g. < three acres). Farmers and ranchers in the lower sections of the watershed have been working with the Natural Resources Conservation Service and the Farm Bureau to prevent erosion and improve both water quality protection measures and road maintenance practices in cultivated, rangeland and forest settings. While erosion and sediment delivery resulting from past management will likely continue for some time, there should be an overall decrease in sediment delivery to stream channels as land use practices continue to improve and as degraded lands recover both naturally and through proactive treatments. This trend coupled with road system improvements and landowner education, mainly in terms of groundcover reestablishment, will help to further improve conditions.

4.7.1 Recommendations for Future Study

Specific recommendations can be made with regard to improving the sediment budget in terms of the sediment transport component by performing watershed-scale drainage modeling. This form of modeling would be necessary to establish a realistic SPI for varying rainfall intensities. Site-specific erosion plots should be established to verify the erodibility rates used in the sediment budget. In particular, such plots should be established along road cuts in grus soil materials, natural areas (as a control), below culvert outfalls, and on disturbed bare ground. A more detailed classification of the road system and percent distribution of the various erosion sources based on a road sampling scheme combined with more detailed estimates of sediment deliverability should also be established to refine the sediment production and the sediment delivery values.

Chapter 5
Surface Water Quality

CHAPTER 5
Surface Water Quality

5.1 Overview

Chapter 5.0 presents the results for Phase 1 of the County's Surface Water Monitoring and Reporting Program (MRP) and compares that data with other available data within the PSA and for the larger Upper Stanislaus and Upper Tuolumne River watersheds. Much of the preexisting data are limited to watershed sanitary surveys for water diversions and compliance monitoring for point-source discharges. As a consequence, there is a well-established dataset for the main waterways within each watershed; however, minimal data exists for many sections of the PSA. Existing datasets were reviewed and are summarized to the extent possible to assess and characterize the interactions between the smaller foothill watersheds that comprise the PSA and the larger river system as a whole.

To understand how current regulatory goals and standards apply to this Assessment, it is critical to understand the basic premise of water resources, which as a public trust resource is subject to an extensive legislative and regulatory history within California. Today, the basis for water quality regulation within the United States is the Federal Pollution Control Act Amendments of 1972 and 1986, known as the Clean Water Act (CWA)(33 USC 1251-1376). The objective of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." California's Porter-Cologne Water Quality Control Act (Porter-Cologne Act, California Water Code Section 13000 et seq.) in conjunction with the CWA provides the basis for water quality regulation within California. The Porter Cologne Act requires a "Report of Waste Discharge" for any point discharge of waste (liquid, solid, or otherwise) to land or surface waters that may impair a beneficial use of surface or groundwater of the state. In practice, these requirements are typically integrated with the CWA Section 402 National Pollutant Discharge Elimination System (NPDES) permitting process[1] and implemented at the regional level by Regional Water Quality Control Boards (RWQCB) and overseen by the State Water Resources Control Board (SWRCB) and U.S. Environmental Protection Agency (USEPA) Tuolumne County is located in the east-central portion of California and lies within the jurisdiction of the Central Valley RWQCB (Region 5).

1 Section 402 establishes the National Pollutant Discharge Elimination System (NPDES), a permitting system for the discharge of any pollutant (except for dredge or fill material) into waters of the United States. This permit program is administered by the U.S. Environmental Protection Agency (USEPA) in most states (not in California) and on Native American lands.

The SWRCB carries out water quality protection authority through the adoption of specific Water Quality Control Plans[2] (Basin Plans). The Central Valley RWQCB is responsible for the Water Quality Control Plan covering the west slope of the Sierra Nevada (RWQCB, 1998). The RWQCB implements management plans to modify and adopt standards under provisions set forth in Section 303(c) of the CWA and California Water Code (Division 7, Section 13240). Under Section 303(d) of the 1972 CWA, the State is required to develop a list of waters with segments that do not meet water quality standards. The law requires the RWQCB to establish priority rankings for waters on the lists and develop action plans and/or establish Total Maximum Daily Loads (TMDL) to improve water quality.

Except for Don Pedro Reservoir, no waterbodies within the Upper Stanislaus River and Upper Tuolumne River hydrologic units are identified as impaired on the 303(d) List and TMDL (SWRCB, 2003). Don Pedro Reservoir is listed on the 2002 California Section 303(d) list and TMDL Priority Schedule for mercury contamination associated with historic mining activities with many of the mines now inundated by Don Pedro Reservoir. In addition to mercury other heavy metals, such as arsenic, may also be present; however, no data were collected for Don Pedro Reservoir as part of the County's MRP to confirm this possibility. The lower reaches of the Stanislaus and Tuolumne Rivers are also listed under the federal CWA as impaired water bodies for diazinon, Group A pesticides (aldrin, dieldrin, endrin, chlordane, heptachlor expoxid, hexachlorocyclohexane, endosulfan, and toxaphene), and unknown toxicity. The Lower Stanislaus River is also listed for mercury.

The SWRCB also adopted the Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California (SWRCB, 2000). This policy provides implementation measures for numerical criteria contained in the California Toxics Rule (CTR), promulgated in May 2000 by the USEPA. When combined with the beneficial use designations in the Basin Plan, these documents establish statewide standards for surface and groundwater quality.

Beneficial Uses and Water Quality Objectives

Existing beneficial uses applied to the Upper Stanislaus and Upper Tuolumne Rivers include agricultural supply, cold freshwater habitat, municipal and domestic supply, hydropower generation, water contact recreation, non-water contact recreation, warm freshwater habitat, and wildlife habitat (RWQCB, 1998). By virtue that many of the waterways within the Upper Stanislaus and Upper Tuolumne watersheds are not specifically prescribed beneficial uses in the Basin Plan, the Basin Plan requires the application of the "Tributary Rule" in regulating point-discharges; whereby beneficial uses identified for major waterways (e.g., Tuolumne River) apply to all contributing drainages (e.g., Sullivan Creek). In evaluating the data acquired during the Phase 1 of the MRP, those beneficial uses with the lowest numerical limits, based on Basin Plan objectives include:

2 Basin Plans establish water quality standards for particular bodies of water. California water quality standards are composed of three parts: the designation of beneficial uses of water, water quality objectives to protect those uses, and implementation programs designed to achieve and maintain compliance with the water quality objectives.

- **Cold Freshwater Habitat.** Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
- **Municipal and Domestic Supply.** Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
- **Water Contact Recreation.** Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, white-water activities, or fishing.
- **Warm Freshwater Habitat.** Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Based on the applied beneficial use, the RWQCB has set water quality objectives for all surface waters in the Central Valley. These water quality objectives include bacteria, biostimulatory substances, chemical constituents, color, dissolved oxygen, floating material, oil and grease, pH, pesticides, radioactivity, salinity, sediment, settleable material, suspended material, sulfide, tastes and odors, temperature, toxicity, and turbidity (RWQCB, 1998). In addition, objectives for specific chemical constituents have been set depending on the beneficial uses designated for each waterbody (RWQCB, 1998). Constituent limits identified in the Basin Plan in conjunction with CTR criteria were used to determine the magnitude of any water quality impairment within each of the monitored waterways (RWQCB 1998).

The CWA Section 303(d) list identifies water bodies with impaired beneficial uses, the parameters of concern within each water body that are thought to be responsible for the impairment, and the likely sources of the parameters of concern. The Section 303(d) list contains only parameters of concern for which there are water quality objectives for surface waters. Much of the regulation for drinking water applies to the treated water available for consumption and does not apply to the surface water source. Therefore, the Section 303(d) list does not contain all parameters of concern for drinking water. **Table 5-1** identifies additional parameters of concern to CALFED in terms of drinking water supplies.

5.2 Regional Watershed Water Quality

The Upper Stanislaus River and Upper Tuolumne River Watersheds are generally regarded as producing surface water of excellent quality, meaning the water is suitable for almost any use and contains low concentrations of contaminants (at least below state and federal standards). Most of the literature reviewed for this Assessment Report suggests that runoff generated from the upper reaches of the two watersheds is suitable for human consumption except for the risk of pathogens, which is generally associated with livestock grazing and wildlife. Sediment is also considered a pervasive pollutant because its production may be increased above natural background levels by almost any human or animal activity that disturbs the soil or reduces vegetation cover.

TABLE 5-1
WATER QUALITY PARAMETERS OF CONCERN TO BENEFICIAL USES

Metals	Organics/Pesticides	Disinfection By-Product Precursors	Other
Cadmium	Carbofuran	Bromide	Dissolved Oxygen
Copper	Chlordane[a]	Total Organic Carbon	Salinity (TDS, EC)
Mercury	Chlorpyrifos	Chloride	Temperature
Selenium	DDT[a]		Turbidity
Zinc	Diazinon		Toxicity of unknown origin[b]
	PCBs[a]		Pathogens
	Toxaphene[a]		Nutrients[c]
	Dioxins[d]		pH (Alkalinity)
	Dioxin-like compounds[d]		Boron
			Sodium adsorption ratio

Notes: EC = Electrical conductivity; TDS = Total dissolved solids; TOC = Total organic carbon
[a] These compounds are no longer used in California. Toxicity from these compounds is remnant, from past use.
[b] Toxicity of unknown origin refers to observed aquatic toxicity, the source of which is unknown.
[c] Nutrients includes nitrate, nitrite, ammonia, organic nitrogen, total phosphorus, and soluble reactive phosphorus.
[d] These compounds may be added after review by an appropriate group of stakeholders.

SOURCE: CALFED, 2000

Upper Tuolumne River

No water quality monitoring stations are located at the confluence of the North Fork and mainstem of the Tuolumne River, which in theory, would provide the best representation of surface water quality from the entire watershed above the PSA. In general, the vast majority of water entering Don Pedro Reservoir is thought to be well oxygenated, high quality cold water. As water flows through the Don Pedro Reservoir, it may be impacted by various sources of contaminants, similar to those thought to affect contributing waterways within the PSA. Primary water quality problems include excessive sediment inflow from development in local runoff, nutrient inflow, mercury from abandoned mining tailings, and bacterial contamination from septic systems. Additionally, seasonal temperature stratification processes in Don Pedro Reservoir are also thought to play an important role in water quality conditions. Sections of Don Pedro Reservoir are deep enough to be subject to seasonal temperature stratification; whereby, the Reservoir becomes thermally stratified each spring through fall and maintains a separation between the warmer waters of the top layer and the cold water below.

The most comprehensive water quality data for the upper reaches of the Tuolumne River available for comparison purposes come from the San Francisco Public Utilities Commission (SFPUC). The SFPUC conducts extensive microbiological and chemical monitoring throughout the upper watershed and its transmission system, including daily sampling for coliform bacteria (total and fecal coliform bacteria and *E. coli*) at its Tesla Portal and three other supplemental locations (Priest Reservoir, West Portal, and Moccasin Reservoir). The SFPUC also conducts periodic monitoring for inorganic chemicals (e.g., metals), volatile organic compounds (VOCs) (e.g., methyl tertiary butyl ether [MTBE]), synthetic organic chemicals (e.g., atrazine, 2,4-D, etc.), and water quality parameters such as pH, hardness, and nutrients (e.g., nitrate) (SFPUC, 2004).

The SFPUC's source water quality assessment for 2004 indicates that its unfiltered water supply meets all federal and state filtration avoidance criteria, including watershed protection, disinfection treatment, bacteriological quality, and operational standards; thereby providing an exceptionally high quality drinking water source (SFPUC, 2004). The SFPUC has identified pollutants sources of high concern, which include those that have the potential to contribute fecal contamination to the current water supply (livestock corrals, grazing, and small wastewater systems). From January 1 through December 31, 2004, there were 2 fecal coliform and 276 total coliform measurements that exceeded 20 and 100 MPN/100mL, respectively, at SFPUC's four monitoring sites (SFPUC, 2004). Of the 276 total coliform occurrences, 51 of them occurred at Tesla Portal. For the same period, all fecal coliform measurements taken at Tesla Portal were below 20 MPN/100mL (SFPUC, 2004).

In addition to the high concern category, the SFPUC has identified a medium concern category that includes those potential contaminants that may contribute other contaminants to the current water supply, such as sediment, ash, organic material, or groundwater discharges from leaking underground fuel tanks (USTs). The potential contaminant sources of medium concern are indicative of localized erosion and sedimentation, previous wildfires (e.g., the 2,310-acre Hetch Hetchy fire near Tiltill and Rancheria Creeks in October 2004), and a groundwater remediation project at Tuolumne Meadows Service Station (SFPUC, 2004).

Upper Stanislaus River

The most recent evaluation of the overall water quality in the upper reaches of the Stanislaus River, has been conducted by Brown and Caldwell (1995) and Tetra Tech EM, Inc. (2001) (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). These studies were undertaken to satisfy the requirements of the California Surface Water Treatment Rule. Although limited, the data collected by entities including the U. S. Geological Survey (USGS), Pacific Gas & Electric (PG&E), and the California Department of Fish and Game (CDFG) suggest that water quality within the Upper Stanislaus River is good to excellent. In general, water temperatures are generally low, dissolved oxygen (DO) readings are usually 7.0 milligrams per liter (mg/L) or greater, concentrations of organic chemicals such as nitrate and phosphate are low, and most metals occur at undetectable levels (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005).

Based on an extensive review of available water quality data, Brown and Caldwell (1995) reached the conclusion that the water in the Stanislaus River is low in nitrogen. The maximum nitrate concentration recorded was 0.27 mg/L, which is well below the 1.0 mg/L nitrate standard used to characterize source waters that can stimulate algae growth (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). Stanislaus River water is soft, with hardness readings ranging from 3 to 65 mg/L as calcium carbonate; alkalinity levels indicate a very high buffer capacity. The water is basic to slightly alkaline with pH readings ranging from about 7 to 8 units (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005). Brown and Caldwell also concluded that, based on expected land use changes in the watershed, it was unlikely that water quality would significantly change in the next 20 years (Tri-Dam, Beardsley/Donnells Project, FERC Project No. 2005).

Brown and Caldwell (1995) and Tetra Tech (2001) concluded that grazing, recreation (body contact recreation), and wildfires pose a low to moderate threat to water quality similar to the upper Tuolumne River, and that all other contaminant sources pose a low threat to water quality. However, this report noted that lower sections of the watershed may be susceptible to increases in nutrient levels, bacteria, pesticides, herbicides, surfactants, solids, and turbidity. The literature review conducted in support of this Assessment suggests that water quality within the upper reaches of the watershed more than likely meets or exceeds all water quality objectives stated in the Basin Plan.

5.3 Foothill Surface Water Quality

5.3.1 Methods

Within the PSA, the vast majority of water quality data available prior to the initiation of this project are associated with compliance monitoring for point-source discharges, such as the Tuolumne Utilities District's (TUD) wastewater treatment plants (WWTP). In addition, TUD's 2002 watershed sanitary survey (2002) to assess the source quality of drinking water supplies and a 1999 groundwater study prepared by the County's Environmental Health Department provide information relevant to the Assessment. In addition, a review of the USEPA's STORNET database was also performed; however, the most recent data for the PSA date back to the early 1970s and were not considered appropriate for comparison purposes. These reports are integrated to the extent necessary to augment the water quality data collected as part of the Assessment.

Due to the expansive area contained within the PSA and the range of possible contaminants that could be present in foothill waterways, the County developed a MRP that consists of a two-phased approach to monitoring implementation. Phase 1 involved the establishment of a water quality baseline for the five watersheds that comprise the PSA. The monitoring locations in Phase 1 were selected to assess cumulative or mass loadings within each of the five watersheds and provide an indication of total pollutant loadings into downstream water supply reservoirs (i.e., New Melones and Don Pedro Reservoirs). These monitoring locations are depicted in **Figure 5-1** and described in **Table 5-2**. Phase 2 of the MRP has yet to be initiated and will consist of a more focused monitoring effort that will largely be driven by the findings in this Assessment.

Phase 1 of the MRP included the collection of grab samples at seven monitoring locations. The parameters sampled include: flow, pH, total suspended solids (TSS), specific conductance, oil and grease, temperature, priority pollutant metals, DO , turbidity, and nitrate + nitrite as N. Other analytical tests included EPA 8151A for herbicides, EPA 8260B for volatile organics compounds (VOCs), and total and fecal coliform bacteria. **Table 5-3** presents the analytical parameters sampled at each of the seven monitoring locations and the laboratory methods employed as part of the MRP. Concurrent with collection of the above grab samples, visual observations for the presence of floating and suspended materials, films or sheens, discoloration, turbidity, potential nuisance conditions (e.g., odor), and aquatic life were also recorded and photo-documented. Due to funding limitations, no formal bioassessment or acute and/or chronic toxicity monitoring were conducted in support of this monitoring effort. Phase 2 of the MRP may include this form of monitoring at specific locations if funding becomes available.

Figure 5-1

11x17

Back of 11x17

Surface Water Monitoring Results

Monitoring was conducted on November 8, 2005, December 1, 2005, and January 18, 2006 according to methods outlined in the County's MRP. Samples requiring analytical analysis were submitted to the appropriate analytical laboratory within the required holding times. Each monitoring event was characterized by a 24-hour rainfall of differing intensities with the November 8, 2005 event totaling 0.08 inches, the December 1, 2005 event totaling 0.66 inches, and the January 18, 2006 event totaling 0.56 inches as measured at the Sonora Weather Station (elevation 1,749 feet) (CDEC, 2006). The 24-hour precipitation amounts that occurred over this three month sampling period are graphically depicted in **Figure 5-2** and provide further indication of the rainfall events leading up to or preceding each of the three events. Creek flows, measured in velocity, were recorded to provide additional correlation with the water quality data (e.g., turbidity, TSS, etc.).

TABLE 5-2
DESCRIPTIONS OF SAMPLING LOCATIONS

Sample Site Designation[a]	Sample Site Location (Latitude/Longitude)	General Land Uses Assessed[b] (Percent of Watershed Area)
Turnback Creek (TB-1)	37 deg 57' 0.0 "	Rural, Estate, and Low-Density Residential; General Commercial; Timber Production; Light Industrial
Lower Sullivan Creek (SV-1)	37 deg 55' 12.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Grazing; Heavy and Light Industrial; Business Park
Upper Sullivan Creek (SV-2)	38 deg 0' 36.0"	Rural, Estate and High and Low-Density Residential; General Commercial; Grazing; Timber Production
Mormon Creek (MM-1)	37 deg 59' 24.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Light Industrial ; Airport (Mixed Use)
Groveland Creek (GV-1)	37 deg 51' 0.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Mixed Use
Woods Creek (WD-1)	37 deg 56' 24.0"	Rural, Estate and High and Low-Density Residential; General and Heavy Commercial; Grazing; Light Industrial; Business Park
Curtis Creek (CT-1)	37 deg 57' 0.0"	Rural, Estate, High and Low-Density Residential; General and Heavy Commercial; Grazing; Heavy and Light Industrial; Business Park

[a] Ambient Surface Water Sampling Sites – Water samples were collected and analyzed for constituents list in Table 5-3.
[b] Upstream land uses were determined based on interpretation of the County's zoning coverage.

SOURCE: ESA, 2006

Figure 5-2

TABLE 5-3
SURFACE WATER SAMPLING PARAMETERS AND CONSTITUENTS

				Monitoring Location						
Analysis	**Method**	**Units**	**RL/IAL**	**SV-1**	**SV-2**	**GV-1**	**MM-1**	**TB-1**	**CT-1**	**WD-1**
Flow	Field	Cubic feet per second	--	x	x	x	x	x	x	x
pH	Field	Standard Unit	pH Unit	x	x	x	x	x	x	x
Specific Conductance	Field	μS/cm	± 0.5%	x	x	x	x	x	x	x
Temperature	Field	deg. F	± 0.5	x	x	x	x	x	x	x
Dissolved Oxygen	Field	mg/L	± 2%	x	x	x	x	x	x	x
Turbidity	Field	NTU	± 2%	x	x	x	x	x	x	x
Oil and Grease	EPA 1664	mg/L	5.0	x	x	x	x	x	x	x
Total Suspended Solids	EPA 160.2	mg/L	5.0	x	x	x	x	x	x	x
Priority Pollutant Metals	EPA 200.8[(A)]	μg/L	variable	x	x	x	x	x	x	x
Low-Level Mercury	EPA 1631	ng/L	0.5	x			x	x	x	x
Total & Fecal Coliform	STDM 9221	MPN/100 mL	N/A	x	x	x	x	x	x	x
Nitrate/Nitrite as N	EPA 300.0	mg/L	0.500	x	x	x	x	x	x	x
Volatile Organics	EPA 8260B	ug/L	variable	x		x	x	x	x	x
Herbicides	EPA 8151A	ug/L	variable	x	x	x	x	x	x	x

Notes: SV-1 (Lower Sullivan Creek); SV-2 (Upper Sullivan Creek); GV-1 (Groveland Creek); MM-1 (Mormon Creek); TB-1 (Turnback Creek); CT-1 (Curtis Creek); WD-1 (Woods Creek).
uS/cm – microsiemens per centimeter; mg/L – milligrams per liter; RL/IAL – Reporting Limit/Instrument Accuracy Level; μg/L – micrograms per liter
EPA Method 200.8 is designed to obtain analytical results for numerous metals with differing detection limits.

Because the County did not to receive formal approval of its Quality Assurance Project Plan (QAPP) until early November, the first rainfall event was not collected. The first rainfall, commonly referred to as the "first flush" event, occurred on September 21, 2005 (CDEC, 2006). This rainfall event was associated with a monsoonal weather pattern, whereby a moisture-rich air mass moved into the southern Sierra from the south; producing nearly an inch (0.99) of rainfall in the vicinity of the PSA. With the approval of the QAPP in early November, the next rainfall event that occurred on November 8, 2005 was sampled, but produced less than forecasted. This event did not produce rainfall sufficient to generate surface flow within Groveland Creek and, therefore, GV-1 was not sampled on November 8, 2005. The next measurable precipitation fell on December 1, 2005, and was collected at all seven sampling locations. This event best-characterizes an early winter second major flush rainfall event. The next significant rainfall occurred on January 18, 2006, and was sampled to characterize mid-winter conditions.

Figures 5-3 through **5-9** illustrate a more localized vantage point for each of the monitoring locations depicted in **Figure 5-1** to provide additional context for the monitoring data. Site MM-1 is located downstream of Columbia along SR 49 and just upstream of the Mormon Creek Road Bridge (see **Figure 5-3**). As shown in **Figure 5-4**, site WD-1 is located southwest of Jamestown along SR 108 and upstream of the Bell Money Road crossing. Site SV-1 is located at the Algerine Road Bridge crossing where samples were grabbed downstream of the bridge due to poor access upstream (see **Figure 5-5**). As shown in **Figure 5-6**, site SV-2 is located just east of Phoenix Lake on Potato Ranch Road. Sampling at SV-2 occurred upstream of the bridge at the western end of the Phoenix Lake Country Club. Site CT-1 is located upstream of the Lime Kiln Road Bridge to the west of Standard (see **Figure 5-7**). As shown in **Figure 5-8**, site TB-1 is located at the end of Box Factory Road and west of the Tuolumne WWTP. Site GV-1 is located downstream of the town of Groveland, along Ferretti Road, and upstream of the Groveland CSD access road bridge (see **Figure 5-9**).

Table 5-4 provides the minimum and maximum values acquired for the constituents sampled at each of the seven monitoring locations. The discussion that follows presents an evaluation of the constituents sampled in the context of the results summarized in **Table 5-4** and other available local datasets.

TABLE 5-4
SUMMARY OF MONITORING RESULTS FOR GENERAL WATER QUALITY CONSTITUENTS

Analysis	Units	RL/IAL	SV-1		SV-2		WD-1		CT-1		TB-1		MM-1		GV-1	
			Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
pH	units	+/- 0.2	5.2	6.9	5.3	6.5	5.9	7.2	6.0	6.7	4.9	6.2	6.4	7.8	4.8	5.9
Temperature	deg. F	+/- 0.27	45.9	54.9	44.8	52.5	46.9	54.4	45.2	54.2	44.7	53.1	45.4	54.8	45.3	49.8
Dissolved Oxygen	mg/L	+/- 2%	8.6	10.4	9.2	10.9	9.3	10.9	9.4	11.3	7.7	10.3	9.3	10.4	9.7	10.7
Specific Conductance	uS/cm	+/- 0.5%	84	239	89	112	207	380	116	269	98	137	373	408	102	127
Turbidity	NTU	+/- 2%	0.80	25.90	2.34	85.40	1.48	29.50	2.06	70.70	2.68	70.40	4.45	13.60	30.20	30.30
TSS	mg/L	5.0	20.0	53.0	20.0	110.0	18.0	25.0	ND	44.0	17.0	42.0	6.2	8.0	6.2	56.0
Hardness	mg/L	1.0	38.0	120.0	35.0	44.0	91.0	210.0	49.0	120.0	43.0	61.0	200.0	240.0	47.0	68.0
Oil and Grease	mg/L	5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1	ND	ND	ND	ND
Nitrate and Nitrite (as N)	mg/L	0.500	ND	0.46	ND	0.41	ND	0.50	ND	0.41	ND	ND	ND	0.61	ND	ND
Fecal Coliform	MPN/100 mL	2	27	500	600	1600	170	1700	130	1100	17	1600	240	500	70	1600
Total Coliform	MPN/100 mL	2	240	1600.	1600	16000	1600	9000	300	16000	1600	16000	900	1600	1400	1600

Note: Complete dataset is included in Appendix C.

mg/L milligrams per liter; uS/cm microsiemens per centimeter; MPN most probable number; NTU = nephelometric turbidity units

Source: ESA, 2006

Figure 5-3

Figure 5-4

Figure 5-5

Figure 5-6

Figure 5-7

Figure 5-8

Figure 5-9

Temperature

Water temperature is an important influence on water chemistry as rates of chemical reactions generally increase with increasing temperature. For example, temperature helps to regulate of the solubility of gases and minerals (solids); thereby determining how much of these materials can be dissolved in water. The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases. Inversely the solubility of most minerals increases as the water temperature increases.

During the period of monitoring, water temperature exhibited a downward trend at all monitoring locations, which coincided with decreasing air temperatures. Surface water temperatures were in the mid to low 50s in late fall at all monitoring locations and trended downward through January into the mid 40s. Of all the monitoring locations sampled, Groveland Creek was the only one to go dry during the summer of 2005. This trend suggests that the other waterways would be subject to warming in the summer when flows are lower. In shallower reaches of Mormon, Sullivan, Curtis, and Turnback Creeks, there is insufficient natural slope to keep the mainstem flowing rapidly. Therefore, these creeks are subject to warming by high summer temperatures. This occurrence is intensified along unvegetated stream banks and below small storage reservoirs.

Dissolved Oxygen

Dissolved oxygen (DO) is gaseous oxygen dissolved in water. It is generated by diffusion from the surrounding air, as a byproduct of photosynthesis and from turbulence in the water column. Dissolved oxygen is largely controlled by biotic processes, mainly photosynthesis and plant respiration. The difference in these two processes alone can account for the large daily variations in dissolved oxygen concentrations, especially during the summer months. However, diurnal variations were not the focuses of this analysis and, therefore, additional sampling would be required to establish trends for diurnal fluctuations.

During the period of sampling, DO levels experienced an upward trend coinciding with colder water temperatures. The relatively high DO levels suggest that the contributions of oxygen-demanding substances (e.g., organics) are not depleting the oxygen levels, at least during the period of monitoring. The Basin Plan standard for DO is based on the application of the cold water habitat beneficial use, which is 7.0 milligrams per liter (mg/L). The values measured at all the sampling locations, during the period of sampling, exceeded this standard. However, future monitoring under Phase 2 of the MRP will be critical to augment the current dataset to support this conclusion, especially during the summer. Continued monitoring at CT-1 during the summer should be emphasized, as large algal blooms were noted during the summer of 2005. It is well-documented that if a sufficient nutrient supply is available during the summer months to stimulate algal blooms, DO levels can be depleted leading to anoxic conditions.

pH

The pH is a conventional parameter used to express the acid or alkaline condition of a water sample. The pH of natural waters tends to range between 6 and 9. The RWQCB uses a range from 6.5 to 8.5 in regulating discharges to local receiving waters. This standard provides a buffer to lower and higher pH levels that may adversely affect the ability of aquatic organisms to complete life cycles, especially as the pH becomes >9.0 or <5.0.

As water flows, it dissolves mineral substances it contacts, picks up aerosols and dust from the air, receives inputs of man-made substances, and supports photosynthetic organisms, all of which affect pH. As noted in **Table 5-4**, several of the sampling locations recorded pH levels that were well below 6.5. During the sampling period, sites SV-1, TB-1, and GV-1 all exhibited pH values below 6.5; whereby sites TB-1 and GV-1 recorded pH measurements of 4.9 and 4.8, respectively, on December 1, 2005. In light of the limited sampling duration, the exact reasons for these low pH values are not well understood. Potential influences could include the local geology [iron (Fe) and aluminum (Al) oxides], the addition of organic materials which tend to be acidic, and potentially acid rain influences. All sites measured on January 18, 2006 exhibited a gradual increase in pH suggesting that the above influences may all be contributing to this phenomenon. However, given that pH values in the upper reaches of the Upper Stanislaus and Upper Tuolumne River watersheds tend to be more neutral (e.g., 7.0) compared to data for this Assessment, continued monitoring is warranted to establish long-term trends.

Specific Conductance

Electrical conductivity is a measure of the ability of water to conduct electricity, and therefore, a measure of the water's ionic activity and content. In general terms, with an increase in the concentration of ionic (dissolved) constituents in solution, there is a corresponding increase in the solution's electrical conductivity. Specific conductance (SC) is simply the conductivity normalized to a temperature of 25º C. SC is generally found to be a good measure of the concentration of total dissolved solids (TDS)[3] and salinity. Elements whose ionic forms contribute the most to these measures include: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), sulfate (SO_4^{2-}), and chloride (Cl^{-}).

SC within the Sierra Nevada is generally low as a consequence of the associated lithology; which is composed dominantly of plutoic rocks [silicon dioxide (SiO_2), Mg, Fe}. A more diverse geology within the foothill region contains exposures of marble and amphibolite (CDC, 1997), especially in the Woods Creek and Mormon Creek watersheds, which contain differing quantities of Ca, Mg, Cl, and Na. Both Mormon Creek and Woods Creek had the highest SC measurements. WD-1 had a maximum reading of 380 µS/m; while MM-1 recorded a maximum of 408 µS/m. The readings recorded at Woods Creek are likely associated with the presence of two wastewater treatment facilities upstream of WD-1. For example, TUD has measured TDS readings of 340 mg/L at its Sonora WWTP and 260 mg/L at the Jamestown WWTP (RWQCB Monitoring and Reporting Program No. R5-2002-0202). Additionally, reclaimed water produced consistent with Title 22 California Code of Regulations (CCR) Section 60301 et seq., (Title 22) by TUD is used for irrigation proposes within the Woods Creek watershed and stored in Quartz Reservoir, downstream of site WD-1. This activity also represents a possible contribution of TDS to the Woods Creek watershed.

The readings in Mormon Creek are less obvious, but could be associated with improperly functioning septic systems. Additionally, the presence of the Roll-In Mobilehome Park wastewater treatment facility upstream of MM-1, which consists of two 1,500-gallon septic tanks that are pumped into a series of six ponds, may contribute to the elevated conductivity (RWQCB

3 For comparison purposes, TDS is generally equal to 0.68 multiplied by SC.

Order R5-2002-0069). However, as no monitoring plan has been submitted, there are no data available to support this. Nonetheless, the owners of the Mobilehome Park have submitted a proposal to connect the facility's wastewater collection system to TUD's sewer system. Once connected, the six existing wastewater ponds would be closed, thereby eliminating any potential subsurface discharge to Mormon Creek.

The remaining sites recorded a SC of less than 140 μS/m, except at SV-1 (239 μS/m) and CT-1 (269 μS/m). The higher SC values at these locations are thought to be attributed to the numerous intermittent contributing drainages that traverse through grazing lands, horse corrals, and feed lots. The data suggest that flows from upstream locations contribute some level of dilution in terms of SC. The California secondary maximum contaminant level (MCL) for SC is 900 μS/m; none of the sites sampled encroach near this limit (see Appendix C).

Turbidity

Turbidity is a measure of the degree of suspended particles, including organic matter (e.g. algae) and inorganic particles (e.g. silt and clay) that scatter light passing through a water column. Light scattering increases with increasing sediment load. Turbidity is commonly measured in nephelometric turbidity units (NTU) and is simply stated as the measure of relative clarity of a liquid. The most frequent causes of turbidity in rivers are soil and bank erosion and contributions of organic materials. The predominant contributing factor to seasonal turbidity in the PSA appears to be peak flows in the winter, when bare soils are eroded and are carried downstream as suspended load, which also may be measured as total suspended solids (TSS). The RWQCB standard for turbidity is based on comparing upstream to downstream NTU levels (see **Appendix C**). Therefore, since this Assessment focuses only on receiving waters, the compliance standard is not applicable. The RWQCB generally sets standards for TSS, which range from 50 to 100 mg/L; depending on the discharge.

As provided in **Table 5-4**, the maximum NTU values were substantially higher than the minimum values collected; with the exception of site MM-1, which is believed to be affected by a series of small storage reservoirs that act as sediment traps. The increased NTU values, along with the correlating increases in TSS values, are mainly attributed to higher rainfall intensities and associated flow velocities recorded on December 1, 2005 and January 18, 2006. Higher rainfall intensities are more erosive on bare soils, while higher flow velocities are more erosive to un-protected banks. The highest recorded values were obtained at SV-2, TB-1, and CT-1. Sites CT-1 and TB-1 are located below areas where new development, and hence construction, is occurring in the County. However, in the case of site CT-1, measurements were taken considerably downstream from developing areas. For this reason, the NTU values acquired at CT-1 should be taken in the context of the probable dilution effect from less-developed areas. Similarly, NTU values obtained at TB-1 were taken below the Westside Pond, which acts as a sediment basin or trap. In this context, contributions of sediment to Turnback and Curtis Creeks at upstream locations could have considerably higher NTU values than those provided in **Table 5-4** and Appendix C.

In contrast, the measurements recorded at SV-2 are believed to be associated with pre-existing development for reasons discussed in Chapter 4.0. Site SV-2 is located at the base of Upper Sullivan Creek, just east of Phoenix Lake, and provides a sample of all drainage flows that originate from the central and eastern section of the Phoenix Basin. Prior land use activities in the Phoenix Basin have modified natural hillslope drainage by altering topography and removing ground cover. Road cuts, water delivery features, and other excavated faces have increased overland flow by intercepting subsurface flow, concentrating it, and redirecting it downslope and efficiently routing it into natural waterways. Further, compacted surfaces[4], including road embankments, unpaved driveways, and housing pads, lead to a loss in aggregate stability, which in turn, results in decreased surface infiltration of water and increased runoff. Increasing slope steepness and length further intensifies this effect. Compacted surfaces not only affect the susceptibility of soil surfaces to erosion, but also limit the reestablishment of protective groundcover by inhibiting root penetration and decreasing the amount of aeration and available water. These chronic conditions are suspected to be the major cause of turbidity at SV-2.

In interpreting the turbidity data, it is important to note that the available dataset includes only three discrete samples and does not include data from larger storm events. For example, as depicted in **Figure 5-2**, a significant rainfall event occurred over the 2005/2006 New Years Day weekend, but was not collected. However, local observations during this period indicated that bankfull flows occurred and, in some instances, flows extended beyond the banks and into low-lying floodplains. High turbidity levels were more than likely associated with this event, but are not reflected in the data presented in **Table 5-4** and Appendix C.

Further, TUD staff have stated that NTU readings in the Phoenix Ditch, above Phoenix Lake, which drains western portions of the Phoenix Basin, have been recorded at much higher levels than those measured as part of this study (see **Table 5-4**). For example, TUD has recorded turbidity levels of 160 NTU at its Scenic View Water Treatment Plant (WTP) and 300 NTU at its Sonora WTP, which both are below Phoenix Lake (TUD, 2002). It is assumed that the NTU readings upstream of Phoenix Lake would be even higher due to the settling of large particles (e.g., sand) in Phoenix Lake. In addition, TUD has noted that its raw water turbidity tends to increase as water flows through its ditch systems away from Lyons Reservoir (TUD, 2002).

Synthetic Compounds

For the purposes of this Assessment, synthetic compounds represent a potential range of urban pollutants chosen for sampling under the MRP and include oil and grease, VOCs, and chlorinated herbicides. The following discussion provides an evaluation of the data collected as part of the MRP and, where available, provides an expanded discussion based on other data sources reviewed as part of this Assessment.

Oil and grease measurements were included in the MRP to provide an indication of the level of petroleum and associated by-products entering local waterways from roadways, fueling stations, etc. During the three sampling events, no oily sheens were observed at the seven monitoring

4 Soil compaction occurs when soil particles are pressed together, thereby reducing pore space between them. This increases the weight of the solids per unit volume of soil (bulk density). Soil compaction occurs in response to pressure (weight per unit area) exerted by humans, off-highway vehicles, etc.

locations. As provided in **Table 5-4**, oil and grease was not detected at any of the sampling sites, except at TB-1 on December 1, 2005. The California public health goal for drinking water for oil and grease is 2.0 mg/L. However, the California primary MCL is 15.0 mg/L. The concentration of oil and grease at TB-1 was just above the method detection limit at 5.1 mg/L. Given that TB-1 is in close proximity to Tuolumne City and oils tend to float at the surface, thereby not being removed by the Westside Pond, it is reasonable to conclude that small quantities of oil and grease are being discharged into foothill waterways from urbanized areas. However, given that a majority of the monitoring sites were located a substantial distance downstream of urbanized areas, the dilution factor provided by undeveloped lands generally maintains concentrations of oil and grease at undetectable levels. An expanded dataset would be desirable to support this conclusion.

VOCs are chemicals of an organic nature, which readily volatilize or travel from the water into the air. Most of these substances are industrial chemicals and solvents. They include light alcohols, acetone, trichloroethylene, dichloroethylene, benzene, vinyl chloride, xylenes, and MTBE. These potentially toxic chemicals are used as solvents, degreasers, paints, thinners, and fuels. Because of their volatile nature, they readily evaporate into the air, increasing the potential exposure to humans. Due to their low water solubility, environmental persistence, and widespread industrial use, they are commonly found in soil and water.

Table 5-5 provides the water quality standards and method detection limits for all VOCs sampled on November 8, 2005. None of the constituents listed in **Table 5-5** were detected in samples collected for using EPA Method 8260B. This result includes duplicate samples taken on the same day.

TABLE 5-5
LABORATORY ANALYTICAL METHODS AND WATER QUALITY STANDARDS FOR VOLATILE ORGANIC COMPOUNDS AND CHLORINATED HERBICIDES

Analyte	Matrix	Reporting Units	Analytical Method	Method Reporting Limit	Water Quality Standards
Volatile Organic Compounds (VOCs)					
1,1-Dichloroethane	water	µg/L	*EPA 8260B*	1.0	5 (a)
1,1-Dichloroethylene	water	µg/L	*EPA 8260B*	0.5	6 (a)
1,1,1-Trichloroethane	water	µg/L	*EPA 8260B*	2.0	200 (a)
1,1,2-Trichloroethane	water	µg/L	*EPA 8260B*	0.5	5 (a)
1,1,2,2-Tetrachloroethane	water	µg/L	*EPA 8260B*	0.5	1 (a)
1,2-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	600 (a)
1,2-Dichloroethane	water	µg/L	*EPA 8260B*	0.5	0.5 (a)
cis-1,2-Dichloroethene	water	µg/L	*EPA 8260B*	0.5	6 (a)
1,2-Dichloropropane	water	µg/L	*EPA 8260B*	0.5	5 (a)
1,2,4-Trichlorobenzene	water	µg/L	*EPA 8260B*	5.0	5 (a)
1,3-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	600 (e)
1,3-Dichloropropene	water	µg/L	*EPA 8260B*	0.5	0.5 (a)
1,4-Dichlorobenzene	water	µg/L	*EPA 8260B*	2.0	5 (a)
Benzene	water	µg/L	*EPA 8260B*	0.5	1.0 (a), 0.15 (c)
Bromoform	water	µg/L	*EPA 8260B*	2.0	100 (a), 80 (b)
Bromomethane	water	µg/L	*EPA 8260B*	2.0	510 (d)
Carbon tetrachloride	water	µg/L	*EPA 8260B*	0.5	0.5 (a), 0.1 (c)
Chlorobenzene (mono chlorobenzene)	water	µg/L	*EPA 8260B*	2.0	--
Chloroethane	water	µg/L	*EPA 8260B*	2.0	16 (d)
Chloroform	water	µg/L	*EPA 8260B*	0.5	100 (a), 80 (b)
Chloromethane	water	µg/L	*EPA 8260B*	2.0	2400 (d)
Dibromochloromethane	water	µg/L	*EPA 8260B*	0.5	10 (a), 80 (b)
Dichlorobromomethane	water	µg/L	*EPA 8260B*	0.5	--

TABLE 5-5
LABORATORY ANALYTICAL METHODS AND WATER QUALITY STANDARDS
FOR VOLATILE ORGANIC COMPOUNDS AND CHLORINATED HERBICIDES

Analyte	Matrix	Reporting Units	Analytical Method	Method Reporting Limit	Water Quality Standards
Dichloromethane	water	µg/L	*EPA 8260B*	2.0	5 (a)
Ethylbenzene	water	µg/L	*EPA 8260B*	2.0	300 (a), 300 (c)
Hexachlorobutadiene	water	µg/L	*EPA 8260B*	1.0	--
Naphthalene	water	µg/L	*EPA 8260B*	10.0	170 (e)
Tetrachloroethene	water	µg/L	*EPA 8260B*	0.5	5 (a), 0.06 (c)
Toluene	water	µg/L	*EPA 8260B*	2.0	150 (a)
trans-1,2-Dichloroethylene	water	µg/L	*EPA 8260B*	1.0	10 (a)
Trichloroethene	water	µg/L	*EPA 8260B*	2.0	5 (a)
Vinyl chloride	water	µg/L	*EPA 8260B*	0.5	0.5 (a), 0.05 (c)
Methyl-tert-butyl ether (MTBE)	water	µg/L	*EPA 8260B*	3.0	13 (a)
Trichlorofluoromethane	water	µg/L	*EPA 8260B*	5.0	150 (a)
1,1,2-Trichloro-1,2,2-Trifluoroethane	water	µg/L	*EPA 8260B*	10.0	1,200 (a)
Styrene	water	µg/L	*EPA 8260B*	0.5	100 (a)
Xylenes	water	µg/L	*EPA 8260B*	0.5	1,750 (a)
Chlorinated Herbicides					
Bentazon	water	µg/L	*EPA 8151A*	2.0	18.0 (a)
2,4-D	water	µg/L	*EPA 8151A*	10.0	70 (a)
Dalapon	water	µg/L	*EPA 8151A*	10.0	200 (a)(b)
Dinoseb	water	µg/L	*EPA 8151A*	2.0	7 (a)
Picloram	water	µg/L	*EPA 8151A*	1.0	500 (a)(c)
2,4,5-TP (Silvex)	water	µg/L	*EPA 8151A*	1.0	50 (a), 25 (c)
Pentachlorophenol	water	µg/L	*EPA 8151A*	1.0	1 (a), 0.4 (c)

(a) California primary MCL
(b) USEPA primary MCL
(c) California public health goal for drinking water
(d) California Secondary MCL
(e) DHS Action Level for Drinking Water

mg/L = milligram per liter; µg/L = microgram per liter; mL = milliliter; MPN = most probable number; ng/L = nanograms per liter; ppt = parts per trillion

Source: RWQCB Water Quality Goals, 2003; Tuolumne County Quality Assurance Project Plan, 2005.

Leaking USTs are documented as having caused localized soil and water contamination in Tuolumne County (Tuolumne County, 1999). As of 1999, there were 46 sites where groundwater contamination has been attributed to hazardous waste spills or leaking tanks. Because no agency database searches were conducted as part of this Assessment, it is assumed that an undetermined number of sites have been added since that time. Compounds associated with gasoline, such as benzene, toluene and xylene and additives such as MTBE, are considered the most problematic and have been detected in close proximity to USTs. However, none of these contaminants were detected during Phase 1 of the MRP at the method reporting limits, which are below regulatory standards provided in **Table 5-5**. This finding is attributed to the considerable dilution that is thought to occur at the cumulative monitoring sites as a result of runoff from undeveloped lands.

In addition to the VOCs associated with USTs, the dry cleaning solvents such as tetrachloroethene (TCE), perchloroethene (PCE) and their decay products cis 1,2-dichloroethene (cis 1,2-DCE) and vinyl chloride are mobile in groundwater, and were detected in monitoring wells at Sierra Launderers and Cleaners. The monitoring wells, originally drilled as part of an UST investigation, obtained samples that contained up to 12,000 µg/L of PCE, 1,700 µg/L of TCE, 4,500 µg/L of cis

1,2-DCE and 300 µg/L of vinyl chloride (RWQCB Resolution No. R5-2002-0109). The source area is immediately adjacent to Woods Creek and about 600 feet from Sonora Union High School (RWQCB Resolution No. R5-2002-0109). To date, the extent of pollution is undefined. TUD and the RWQCB are currently requesting funds from the State Water Pollution Cleanup and Abatement Account to assist in responding to this water quality problem.

The results of the analytical analysis completed as part of this Assessment indicates that the constituents covered by EPA Method 8260B were not detectable at the cumulative loadings sites identified in **Figure 5-1**. As these compounds were not detected at the method reporting limit, it may be concluded that sufficient dilution is occurring from the remainder of the watershed, to the extent, that downstream water supply reservoirs are not at significant risk. Further discussion on these constituents is provided in Chapter 6.0. It is expected that these constituents may be detectable at more site specific locations within the PSA. In addition, an expanded dataset would be appropriate to further support this conclusion. Further discussion is provided in Chapter 6.0.

In addition to VOCs, chlorinated herbicides have been used wide-spread in the past decades for landscaping, agriculture, forestry, and vegetation control applications. These compounds have high to very high acidity, low to high water solubility, and very low to moderate volatility. Both water solubility and soil retention are dependent on soil pH. Overall soil retention is generally low. Breakdown of these herbicides is typically associated with microbial decomposition. As an example, the average active half life of 2,4-D is approximately 11 years. In contrast, chlorinated pesticides, such as DDT, which were not sampled during Phase 1 of the MRP, are more persistent for many years after application.

As provided in **Table 5-5**, samples collected for chlorinated herbicides analyzed under EPA Method 8151A had undetectable concentrations for all constituents. These results suggest that chlorinated herbicides are not present at detectable levels in major waterways draining from the PSA. However, this conclusion should be taken in the context of the limited datasets available for this Assessment and the cumulative loading sites sampled. Further, the County acknowledges that Phase 1 of the MRP did not include analysis of other herbicides that may be used within the PSA. For example, following the preparation of the MRP, additional discussions with staff from the Central Sierra Environmental Resource Center (CSERC) and Tuolumne County have indicated that other herbicides are commonly used within the County, depending on the target plant species and include Pronone and Velpar, Round Up Pro, Aqua Master, Garlon, Gallery, and pre-emegents, such as Telar and Payload.

The active ingredient in Pronone and Velpar is hexazinone, which is water-soluble and readily mobilized due to adsorption to soil particles (Weed Control Methods Handbook, 2001). Round Up Pro and Aqua Master are contact herbicides, containing the active ingredient glyphosate, and are generally non-selective. Round Up Pro is used in the control annual weeds, woody brush and trees, while Aqua Master is used to control emergent vegetation in and around bodies of water. The active ingredient in Garlon is triclopyr, which is used to control of woody vegetation and broadleaf weeds (Weed Control Methods Handbook, 2001). Gallery is chiefly composed of isoxaben and is used as a selective pre-emergence herbicide that prevents the growth of broadleaf weeds, such as poison oak and Himalayan blackberry. The active ingredient in Telar is a chlorosulfuron, which is mainly used along railroads, highway rights of way, and around power distribution poles. Payload is composed on flumioxazin, which is used to maintain bareground and control invasive plants, such as Russian and Canada thistle, crabgrass, Bromus species, ryegrass and foxtails.

These herbicides were not sampled for as part of Phase 1 of the MRP and, thus additional sampling would be required under Phase 2 of the MRP to verify their relative absence or presence in the water column at the cumulative sampling locations. Chapter 6.0 provides additional discussion on this issue in terms of additional forms of investigation that should be considered in future planning.

Trace Metals

Sources of trace metals in waterways are influenced by various factors including industrial processes occurring in upstream locations, corroding metal surfaces, combustion processes, natural deposits (e.g., mining), etc. Trace metals (especially copper, lead, and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. For this reason, trace metals were sampled at each of the seven monitoring locations to determine if County land uses are contributing significant concentrations of trace metals to downstream water supply reservoirs. Additionally, influxes of metals, including arsenic, mercury, copper, etc, from abandoned and/or inactive mines are also thought to contaminate local surface waters.

As previously indicated, the focus of this Assessment was to assess potential impacts to water supply reservoirs, namely in terms of drinking water. For this reason, trace metals were analyzed using EPA Method 200.8, due to its cost-effectiveness and ability to detect trace metal concentrations below drinking water standards for arsenic, cadmium, chromium (total), copper, lead, mercury, nickel, selenium, silver, and zinc. This approach is important to note given that other analytical methods are available to detect trace metals at lower concentrations based on their effects on aquatic organisms. However, these methods are generally much more expensive both in terms of the analytical equipment required and staff resources needed to acquire the sample.

Under Phase 1 of the MRP three sampling events were conducted for each of the seven sites, except at GV-1, using EPA Method 200.8 for trace metals analysis. The results indicated that trace metals were at undetectable levels at the method reporting limits provided in **Table 5-6**. The exception to this finding occurred at sites MM-1 and GV-1, where selenium was detected at concentrations of 5.5 µg/L and 7.3 µg/L, respectively; just above the method reporting limit. The presence of selenium is thought to be attributed to the associated geology and/or aerial deposition. In addition to those constituents identified in **Table 5-6**, TUD makes mention in its 2002 Watershed Sanitary Survey that raw water periodically exhibits elevated concentrations of iron at levels substantially lower than the secondary MCL for iron (5000 µg/L) (TUD, 2002). Iron was not sampled during Phase 1 of the MRP, since it is not identified as a priority pollutant and is associated with the local geology.

Based on the historic mining activity that occurred within the PSA, the County included one additional round of sampling for mercury using EPA Method 1631, which provides a low detection limit, down to 0.5 nanograms per liter (ng/L). The results show that very low levels of mercury were detected at sites SV-1, WD-1, MM-1, CT-1, and TB-1. Site TB-1 recorded the highest concentration of 3.43 ng/L. These concentrations are very low and likely represent background levels. Additionally, with the presence of the former Jamestown Mine upstream of WD-1, the values obtained under both EPA Method 200.8 and 1631 would suggest that onsite stormwater controls at the mine are functioning properly and providing the necessary containment. Based on the water quality standards provided in **Table 5-6** in conjunction with the method report limits for metals analyzed using EPA Methods 200.8, it is reasonable to conclude that contributions of trace metals do not represent a significant hazard to downstream water supply reservoirs. Further, the existing mercury TMDL for Don Pedro Reservoir is thought to be attributable to the heterogeneous piles of rocks that are frequently inundated by Don Pedro Reservoir.

Nutrients

Nutrients are generally identified as a water quality concern due to their association with the biostimulation of algal growth. Nutrients are typically introduced into the watershed through agricultural and residential land uses, which use soluble forms of phosphorus and nitrogen, as fertilizer. Algal growth is largely limited due to the availability of phosphorus and nitrogen. In the absence of a controlling or limiting growth factor, algal blooms will eventually cloud the water and block the sunlight exhibited in reaches of Curtis Creek below Lime Kiln Road (see **Figure 5-10**).

TABLE 5-6
ANALYTICAL METHODS AND WATER QUALITY STANDARDS FOR TRACE METALS

Analyte	Matrix	Reporting Units	Analytical Method	Reporting Limit	Basin Plan Standard or CA Toxics Rule
Arsenic	water (salinity <0.5 ‰)	µg/L	EPA 200.8	1.0	10 (a), 0.004 (b)
Cadmium	water	µg/L	EPA 200.8	0.25	5.0 (c), 0.07 (b)
Chromium	water	µg/L	*EPA 200.8*	2.0	50 (c)
Copper	water	µg/L	EPA 200.8,	0.5	1300 (c), 170 (b)
Lead	water	µg/L	EPA 200.8	0.5	12.0 (b), 100 (c)
Mercury (inorganic0	water (low level, parts per trillion)	ng/L (ppt)	EPA 1631	0.5	2.0 µg/L (a,c), 1.2 µg/L (b)
Nickel	water	µg/L	EPA 200.8	5.0	10 (a)
Selenium	water (salinity >0.5 ‰)	µg/L	EPA 200.8	5.0	50.0 (e)
Silver	Water	µg/L	EPA 200.8	1.0	100 (d)
Zinc	Water	µg/L	EPA 200.8	10.0	5000 (d)

(a) USEPA primary MCL
(b) California public health goal for drinking water
(c) California primary MCL
(d) California secondary MCL
(e) Title 22 – California Toxics Rule

µg/L = microgram per liter; ng/L = nanograms per liter; ppt = parts per trillion

Figure 5-10

Excess nitrates (NO_3) in drinking water is a health concern and has caused the closure of more public water supply wells in California than any other contaminant (Bachman, 1997; Tuolumne County, 1999). Nitrate can also be a source of toxicity, which can cause methemoglobinemia[5], but is generally limited to children less than six months old. Nitrates were chosen for monitoring under the MRP due to the numerous potential sources within the PSA such as septic tank effluent, fertilizers, decomposing organic matter, and industrial and agricultural wastes. Nitrate is very soluble in water, is not readily absorbed by soil, and is therefore mobile in surface and groundwater. The USEPA has recently lowered the maximum contaminant level (MCL) for nitrate in drinking water down to 10 mg/L (as nitrate ion). The State is expected to adopt the 10 mg/L or stricter standard, based on USEPA's revision.

This Assessment found no obvious trends in nutrient concentrations; expect that there may be a surplus of nitrate in local creeks, to the extent, that enables abundant algal growth. However, the period of the dataset does not allow for observation of seasonal trends in nutrients except that nitrate concentrations were somewhat higher in winter as compared to the fall. **Table 5-4** provides dissolved nitrate data for each of the seven sites within the PSA. The highest measurement of 0.61 mg/L was obtained at site MM-1 on January 18, 2006. This measurement is substantially lower than the USEPA's MCL for drinking water. As provided in **Table 5-4**, the method reporting limit for nitrate is 0.500 mg/L. As the vast majority of the samples collected contained levels of nitrate that were not detectable, it can be reasonably assumed that waterways within the PSA are not contributing significant concentrations of nitrates to drinking water reservoirs. However, in recognition of the limited datasets to support this conclusion, additional discussion on nitrates is provided in Chapter 6.0.

Coliform Bacteria

Bacteriological sampling was conducted as part of Phase 1 of the MRP to verify the presence of coliform bacteria within waterways draining the PSA, based on concerns raised by local residents and the County's 1999 Groundwater Protection Report. Total coliform bacteria are microorganisms that live in large numbers in the intestines of warm- and cold-blooded animals, including humans. A specific subgroup of this collection is referred to as fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms are differentiated from the total coliform bacteria by their ability to grow at elevated temperatures and are associated with the fecal material of warm-blooded animals.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material from animals and/or humans. The presence of fecal coliform bacteria may also provide an indication that source waters may have been contaminated by other pathogens or disease-producing bacteria or viruses which can also exist in fecal matter. Some waterborne pathogenic diseases include typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform bacteria provides evidence that ambient waters have come into contact with human and/or animal waste and may be directly linked to overflow of domestic sewage or nonpoint sources of human and animal waste.

5 Process where excess nitrate in the bloodstream can prevent red blood cells from taking up sufficient oxygen.

Based on concerns raised by the general public and County staff, total and fecal coliform samples were grabbed at each of the seven monitoring locations during the three sampling events. The analytical results confirm the presence of fecal coliform at all the sampling sites. Even with limited data, fecal coliform bacteria levels were consistently reported at levels greater than 400 MPN/100 mL. At several sites fecal coliform were detected at levels in excess of 1,600 MPN/100 mL (SV-2, TB-1, WD-1, and GV-1).

The RWQCB applies a standard of 400 MPN/100mL[6] fecal coliform for waterways and/or bodies where the body-contact recreation beneficial use is applied. A stricter standard for fecal coliform may be applied when the geometric mean for five samples collected over a 30 day period exceeds 200 MPN/100mL. For this Assessment five samples were not available. Nonetheless, the values obtained during the December 2005 and January 2006 sampling events and summarized in **Table 5-4**, indicate that the maximum levels of fecal coliform detected were well above the applied standard.

The County's 1999 Ground Water Protection Report suggests that improperly functioning septic systems and grazing practices may be a probable cause for levels of fecal coliform bacteria recorded within all of the monitored waterways. The County inventoried a total of 497 problematic septic systems within the PSA as part of the County's Groundwater Protection Report (1999). However, with over 7,500 inventoried septic systems within the County, the number of undocumented problematic septic systems is likely greater than the total number inventoried as part of the Groundwater Protection Report (1999).

In the lower foothill sections of the PSA, grazing practices are also likely to contribute fecal coliform bacteria to the monitored waterways. This conclusion is supported by the fewer number of problematic septic systems within the lower sections of the Woods Creek, Sullivan Creek, and Curtis Creek watershed sub-units. Further, the fecal coliform levels recorded at the effluent discharge points for the Sonora and Jamestown WWTPs would suggest that these facilities are not major contributors to the levels of fecal coliform recorded at WD-1 (RWQCB Monitoring and Reporting Program No. R5-2002-0202).

In the lower foothill sections of the PSA, grazing practices are also likely to contribute fecal coliform bacteria to the monitored waterways. Grazing animals were observed near local waterways and, in some instances, within the actual channel as depicted in **Figure 5-11**. As a consequence, current unobstructed grazing practices result in the distribution of manure in and near waterways, thereby contributing to the fecal coliform levels recorded in the lower reaches of Woods, Sullivan, and Curtis Creeks.

6 Geometric Mean-10% of Samples for 30 days

Figure 5-11

5.4 General Conclusions

The results of the baseline monitoring under Phase 1 of the MRP in conjunction with other field studies suggest that waterways that drain the PSA currently do not exhibit detectable levels of typical urban pollutants. Rather, the data collected as part of the MRP suggest that pollutants (e.g. sediments and pathogens) found within local waterways are more commonly associated with rural forms of development and legacy land use practices. This conclusion is not to be taken out of context by broadly concluding that urban-type pollutants are not discharged within the watershed. Rather, a more appropriate conclusion would be that urban forms of pollutants are currently not detectable at the analytical method detection limits employed as part of this Assessment and at the monitoring locations identified in **Figure 5-1** and **Table 5-2**, which are indicative of all sources within the five watersheds that comprise the PSA.

By virtue that concentrations of urban pollutants were below detectable levels, it is appropriate to conclude that these pollutants are well below regulatory action levels and currently do not represent a significant threat to drinking water quality in downstream reservoirs. However, the County cautions that this conclusion should be taken in the context of the limited data available for this Assessment Report (e.g. three sampling events). Further, the implementation of Phase 1 was difficult from a logistical standpoint due to the number of sampling locations monitored and the substantial distances between each location. This factor resulted in the collection of samples at different points on the hydrograph[7] for each of the assessed waterways. Every attempt was made to collect samples prior to the peak on the hydrograph for each waterway. However, due to the varying sizes of the contributing drainage areas for each sampling location and the lack of continuous flow data for the assessed waterways, this proved to be unattainable. In light of these circumstances, these conclusions are subject to further refinement pending future monitoring efforts at more, site-specific monitoring locations in conjunction with Phase 2 of the MRP and additional monitoring goals set forth in the County's WQP.

7 Hydrographs are charts that display the change of a hydrologic variable (e.g., stream flow, rainfall, etc.) over time.

Chapter 6

Principal Findings and Recommendations

CHAPTER 6
Principal Findings and Recommendations

6.1 Principal Findings

An evaluation of surface water quality conditions within the foothill region of Tuolumne County reveals that prior land use management activities and their associated legacies are the leading causes of surface water quality degradation in the PSA. Based on the land use history summarized in Chapter 3.0, the most significant landscape alteration has occurred within the last 150 years as a result of road construction, the development of water supply infrastructure, mining, grazing and continued population growth. Observations within the PSA suggest that localized hydrology has been particularly influenced by the additions of impervious surfaces, as a result of the construction of roads, parking lots, and buildings. Although net increases in runoff were not quantified as part of this Assessment, there is sufficient evidence indicating that these increases have mobilized sediment within the upper, transport-oriented reaches of the PSA and re-deposited it in lower-gradient, transport-limited segments of each watershed.

Based on the limited data acquired in conjunction with this Assessment, water quality parameters or constituents identified as a concern or in need of further investigation are those generally associated with the legacies of prior land use activities. Contamination sources include residential and commercial on-site sewage disposal systems, leaking underground fuel tanks, and unobstructed grazing practices. Continued sedimentation to local waterways within the PSA is also a concern that requires the management of chronic erosion sources, such as unpaved driveways, and better controls on new development and construction. In this context, the primary focus of future water quality planning efforts and monitoring programs should be directed towards the following:

- Total and fecal coliform bacteria and other potential pathogens from on-site sewage disposal systems and unobstructed grazing. Nutrients (e.g. nitrates) may also be associated with these activities with additional contributions from fertilizer applications;

- Unknown causes for pH levels within receiving waters (e.g. levels lower than Basin Plan standards) and the potential for increased solubility of trace metals;

- Determination of the extent and impact from non-point sources (NPS) of urban pollutants (e.g. leaking USTs, improper disposal, etc.), namely in terms of isolating affected reaches; and

- Sedimentation to local water supply reservoirs, sediment accumulation in lower-gradient reaches, and potential transport of rural and/or urban-pollutants.

6.2 Watershed Catchment Vulnerability

The preliminary findings of this Assessment suggest that considerable dilution is occurring within the PSA, at least to the extent that typical urban pollutants are not detectable at cumulative loading sites. This finding suggests that some level of assimilative capacity exists within the lower reaches of the monitored waterways. With this understanding, the County is in a position to be proactive in terms of addressing future sources of urban pollutants by planning at a watershed scale. This level of planning will help the County to minimize adverse affects to surface water quality from existing sources identified in this Assessment and new ones that can be reasonably anticipated as build-out continues under the County's currently adopted General Plan.

To accomplish this, the five major watersheds that comprise the PSA were further delineated into drainage catchments, as described in Chapter 2.0 and depicted in **Figures 2-9**, **2-13**, **2-17**, **2-22**, and **2-25**. These drainage catchments were given unique identifiers (e.g. US01 – Upper Sullivan Creek, Catchment Unit No. 1) to allow for further analysis using geographic information systems (GIS). This delineation enables the County to identify specific drainage catchments where urban development will be the most concentrated at build-out; thereby providing an indication of each catchment's potential vulnerability to urban pollutants and, more importantly, enabling the prioritization of specific reaches within the PSA based on the associated vulnerability.

It is well documented that runoff from urbanized areas is generated from a number of sources including residential areas, commercial and industrial areas, roads, highways, and bridges. Essentially, any surface that does not have the capability to pond and infiltrate water will produce runoff with the timing and quantity of flow largely determined by a given storm event and the percentage of the drainage area covered by impervious surfaces. With additional impervious surface cover, such as rooftops, streets, parking lots, rainfall is no longer able to infiltrate into the soil column. As a result, the timing of peak flow is generally reduced and the quantity of flow is increased. A generally accepted method to measure watershed risk is to measure the level of impervious surface area increases in a given watershed unit or catchment, since it can be reasonably assumed that more rainfall will be converted to direct runoff. This phenomenon allows for a more rapid discharge of urban pollutants directly to receiving waters and, ultimately, could lead to cumulative water effects in higher order receiving waters.

Historically, as urbanization occurred and storm drainage infrastructure systems were developed the conventional reasoning was to limit the nuisance of increased runoff volumes by conveying the runoff off-site in the most efficient manner possible. As a result, streams that receive storm water runoff frequently cannot convey the large volumes of water generated during runoff events without degradation of the receiving stream. In addition to the problems associated with excess water volume, the levels of toxic or otherwise harmful pollutants in storm water runoff can cause significant water quality problems in receiving waters, which in the case of the PSA, drain to water supply reservoirs. It is also important to note that although typical urban pollutants were not detected during Phase 1 of the MRP, this finding may not hold true as future monitoring occurs and as build-out continues and further limits assimilative capacity of local waterways.

In recognition of the well-established correlation between impervious surfaces and water quality degradation, an estimation of impervious surface cover was considered an appropriate method for assessing the relative vulnerability of the numerous catchments that comprise the PSA. More over, it was considered necessary to further isolate those drainage catchments that would be the most vulnerable to urban development in order to enable prioritization from a planning perspective. This technique included the estimation of future impervious cover based on a County zoning build-out scenario. This was performed in conjunction with a road density analysis to isolate potentially chronic sources of sedimentation. Although the use of the zoning coverage carries the potential to over-estimate impervious cover, at least in the interim, it provides the best practical information to enable accurate watershed planning in terms of non-point sources of pollution and the large land area that comprises the PSA (224.8 square miles). Other methods, such as direct measurement which entails directly measuring individual components of impervious cover, were simply impractical by virtue of the limited time and funding available.

In order to assess relative vulnerability for individual drainage catchments that comprise the PSA, it was necessary to categorize County zones based on allowable development intensities as defined in Title 17 of the County's Zoning Ordinance and summarized in **Table 6-1**. Four development intensity categories (1 through 4) were developed to cover the range of development intensities present within the County. Category 1 includes all zones where the ultimate build-out would result in less than 5 percent of the property containing impervious surface cover. Zones in Category 2 have maximum development intensities that range from 5 to 25 percent impervious surface area. Development intensities in Category 3 range from 25 to 75 percent; while Category 4 development intensities are greater than 70 percent. The exception to these categories occurs where no zone is applied to the County's parcel coverage, which is generally limited to the City of Sonora. This classification scheme provided the best opportunity for isolating the highest concentrations of urbanized development (e.g. areas with greater than 70 percent impervious surface area), as shown in **Figure 6-1**.

The delineations illustrated in **Figure 6-1** provide an indication of where specific pollutant loadings could occur based on the types of land uses present in conjunction with maximum extent of impervious surface cover. For example, Category 4 includes a majority of the commercial and industrial uses and the highest densities of residential development. Likewise, Category 3 includes lower densities of residential and commercial development and major day-use recreational areas. Category 1 includes all agricultural lands, timber production zones, and extensions of public lands (e.g. National Forest) into the PSA.

TABLE 6-1
DEVELOPMENT INTENSITY CATEGORIES

Zone	Use Density (a)	cover (b)	Impervious Class (c)
R-1	6units/ac	up to 35%	3
R-2	12units/ac	up to 70%	4
R-3	15units/ac	up to 85%	4
RE-1	FAR = 0.5	50%	3
RE-2	FAR = 0.5	50%	3
RE-3	FAR = 0.5	50%	3
MU	15units/ac	up to 85%	4
K	1 unit/5000 ft2	50%	3
C-K	FAR=0.5	50%	3
C-O	1unit/2,500 ft2	up to 100%	4
C-1	1unit/2,500 ft2	up to 100%	4
C-2	1unit/2,500 ft2	up to 100%	4
M-1	1unit/7,500 ft2	up to 80%	4
M-2	1unit/7,500 ft2	up to 80%	4
BP	1unit/2,500 ft2	up to 100%	4
P	Variable	<5% assumed	1
AE-37	2units/37ac	<1%	1
A-20	1unit/10ac	<1%	1
A-10	1unit/5ac	1.1%	1
O	n/a	<1%	1
O-1	n/a	<1%	1
RE-5	FAR =0.2	20%	2
RE-10	FAR=0.2	20%	2
C-S	FAR=0.1	10%	2
TPZ	1unit/37ac	<1%	1
MPZ	1unit/20ac	<1%	1
Undefined	N/A	N/A	0(D)

(A) From Title 17, Zoning Code
(B) Assumptions: Indust. 1 unit 6,000 square feet
Res/Com 1 unit 2,500 square feet
(C) Cover classes - 1 = <5%;2 = 5-25%; 3 = 25-50%; 4 = >50%
(D) 0 – Applies to the undefined zones; most of which are limited to the City of Sonora.

Source: Tuolumne County, 1997; ESA, 2006

Figure 6-1

As previously indicated, water quality monitoring conducted in support of this Assessment did not sample site-specific reaches that drain one main land use. This approach was considered appropriate in the context of the numerous studies conducted by the U.S. EPA to characterize the nature of urban storm water runoff in conjunction with the need to obtain supporting evidence of whether County land uses are contributing significant concentrations of major pollutants. Data sources available from the EPA include the National Urban Runoff Program (NURP); the USGS Urban Stormwater Database; and the Federal Highway Administration (FHWA) study of storm water runoff loadings from highways. In addition to these federal sources, there is a great deal of information in the technical literature, as well as data collected by the State of California (e.g., Caltrans).

The most comprehensive study of urban runoff was the NURP, conducted by the EPA between 1978 and 1983. NURP was conducted in order to examine the characteristics of urban runoff and similarities or differences between urban land uses, the extent to which urban runoff is a significant contributor to water quality problems nationwide, and the performance characteristics and effectiveness of management practices to control pollution loads from urban runoff (U.S. EPA, 1983). Sampling was conducted for 28 NURP projects which included 81 specific sites and more than 2,300 separate storm events (U.S. EPA, 1983). NURP focused on the following ten constituents:

- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Phosphorus (TP)
- Soluble Phosphorus (SP)
- Total Kjeldahl Nitrogen (TKN)
- Nitrate + Nitrite (N)
- Total Copper (Cu)
- Total Lead (Pb)
- Total Zinc (Zn)

Since the NURP, other important studies have been conducted that characterize stormwater. The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b)3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) stormwater permit holders. The initial version of this database, the National Stormwater Quality Database Version 1.1 (NSQD) is currently being compiled (Center for Watershed Protection, 2004). Preliminary data results for the NSQD are included in **Table 6-2**.

TABLE 6-2
MEDIAN VALUES AND EVENT MEDIAN CONCENTRATIONS FOR SELECTED PARAMETERS IN THE NSDQ, VERSION 1.0

Parameter	Overall	Residential	Commercial	Industrial	Freeways	Open Space
Area (acres)	56	57.3	38.8	39	1.6	73.5
% Imperv.	54.3	37	83	75	80	2
Precip. Depth (in)	0.47	0.46	0.39	0.49	0.54	0.48
TSS (mg/L)	58	48	43	77	99	51
BOD (mg/L)	8.6	9	11.9	9	8	4.2
COD (mg/L)	53	55	63	60	100	21
Fecal Coliform MPN/100mL)	5,081	7,750	4,500	2,500	1,700	3,100
NH3 (mg/L)	0.44	0.31	0.5	0.5	1.07	0.3
NO2+NO3 (mg/L)	0.6	0.6	0.6	0.7	0.3	0.6
Nitrogen, Total Kjeldahl (mg/L)	1.4	1.4	1.6	1.4	2	0.6
Phos., total (mg/L)	0.27	0.3	0.22	0.26	0.25	0.25
Cd, total (ųg/L)	1	0.5	0.9	2	1	0.5
Cu, total (ųg/L)	16	12	17	22	35	5.3
Pb, total (ųg/L)	16	12	18	25	25	5
Ni, total (ųg/L)	8	5.4	7	16	9	ND
Zn, total (ųg/L)	116	73	150	210	200	39

ND = not detected, or insufficient data to present as a median value.

Source: Center for Watershed Protection, 2004

A major goal of the NSQD project is to provide a benchmark for comparison with locally collected data. The NSQD provides typical values for associated land use classes that enable comparisons with local monitoring data (e.g. Phase 2 of the MRP). **Table 6-3** provides a comparison of the NURP and NSQD studies in order to show current Event Median Concentrations (EMCs) for key constituents (Center for Watershed Protection, 2004). In general, the results from NURP and the NSQD indicate that there is not a significant difference in pollutant concentrations in runoff from different urban land use categories. However, the studies do show that there is a significant difference in pollutant concentrations in runoff from urban sources as compared to runoff produced from more rural, non-urban areas, such as those areas that characterize a vast majority of the PSA.

TABLE 6-3
COMPARISON OF NURP AND NSQD DATA

	Overall		Residential		Commercial		Open Space	
Parameter	NSQD Median	NURP Median	NSQD Median	NURP Median	NSQD Median	NURP Median	NSQD Median	NURP Median
Area (acres)	56	68.5	57.3	57.5	38.8	27.5	73.5	3775
TSS (mg/L)	58	100	48	101	43	69	51	70
Pb, total (ųg/L)	16	144	12	144	18	104	5	30
Cu, total (ųg/L)	16	34	12	33	17	29	NA	NA
Zn, total (ųg/L)	116	160	73	135	150	226	39	195
Nitrogen, Total Kjeldahl (mg/L)	1.4	1.5	1.4	1.9	1.6	1.18	0.6	0.97
NO2+NO3 (mg/L)	0.6	0.68	0.6	0.74	0.6	0.57	0.6	0.54
Phos., total (mg/L)	0.27	0.33	0.3	0.38	0.22	0.20	0.25	0.12

Source: EPA, 1983; Center for Watershed Project, 2004

A slight deviation during the last event of Phase 1 of the MRP, included the acquisition of more, site-specific runoff data for two urbanized sections of the County. These site locations were sampled to provide initial comparisons with the NURP and NSQD datasets. For comparison purposes, the data that was acquired provided TSS values that ranged from 46 to 100 mg/L. The turbidity values were notably higher at 66.3 and 183 NTUs. Similar to the pH results for the seven monitoring sites, the pH at the discharge locations were 5.7 and 5.68, respectively. Oil and grease were not detected at either location at the method reporting limit (5.0 mg/L). From these preliminary datasets, the TSS, turbidity, and pH values would suggest that additional site-specific testing is warranted.

Impervious Surface and its Effects

As shown in **Figure 6-1** and supported by the data provided in **Appendix D**, the total land area within the PSA expected to be covered by 70 percent or more impervious area at build-out is approximately 2.4 percent, while 18.4 percent of the PSA land area would be covered by 25 percent or more of impervious surface cover. Lands within the Deer Creek, Kanaka Creek, and Rough and Ready Creek sub-watershed units are planned for minimal development and do not receive drainage flows from more urbanized sections of the PSA. Therefore, these sub-watershed units are considered to have low vulnerability in terms of receiving substantial inputs of urban-type pollutants. In this context, these areas may represent viable mitigation lands.

Watershed units with the greatest vulnerability to urban runoff within the PSA include specific catchments contained within the Curtis Creek, Lower Sullivan, Mormon Creek, Turnback Creek, Upper Sullivan Creek, and Upper Woods Creek sub-watersheds. To a lesser extent, certain catchments within the Bear Creek and Big-Oak Flat-Groveland watershed units would also be moderately vulnerable. Although not reflected by the percentage of total sub-watershed area, the Curtis Creek sub-watershed unit and, more specifically, catchment CC04 contains the highest concentration of lands classified Category 4 (63.8 percent) at build-out (see **Figure 6-**1 and **Appendix D**). Further, more than 35 percent of the land base within catchments CC01A (35.6 percent), CC02 (54.7 percent), and CC03 (37.5 percent) is classified as Category 3 or 4. Given these findings, the upper reaches of the Curtis Creek sub-watershed unit would be considered highly vulnerable to urban pollutant loading and should receive prioritization for future NPS programs.

Likewise portions of the Woods Creek, Upper and Lower Sullivan Creek, Mormon Creek, Big-Oak Flat-Groveland, and Turnback Creek watershed units are vulnerable to additions of impervious surfaces, as shown in **Figure 6-1**. More specifically, catchments within the Lower Sullivan Creek sub-watershed unit that would contain large areas within Categories 3 and 4 include LS02 (58.6 percent), LS03 (79.4 percent), and LS06 (41.8 percent). Within the Upper Sullivan Creek sub-watershed unit, catchments delineated as containing large areas of Categories 3 and 4 include US01 (48.7 percent), US03 (56.9 percent), and US04 (49.2 percent), US12 (69.4 percent), US13 (39.2 percent), and US14 (43.9 percent). Other catchments within the PSA that would be rated as having moderate to high vulnerabilities include: BG04 (78.7 percent), BG12 (79.0 percent), BG13 (58.7 percent), MC01A (42.1 percent) MC01B (66.2 percent), MC01C (69.9 percent), TC04 (44.1 percent), TC05 (40.8 percent), WC03B (35.4 percent), and (WC12 (42.7 percent). It is also important to note that the City of Sonora was not rated and, therefore, Appendix D underrates the potential impervious cover for catchments WC04, WC05, WC07, and US05.

In the context of the high fraction of Categories 3 and 4 within the above-identified catchments, a direct relationship may be demonstrated between the level of impervious surface cover within each watershed catchment and increased bank scour within receiving waters. A direct-relationship between urbanization (i.e. % watershed imperviousness) and the number of bankfull flows occurring annually is well-established (Leopold, 1968; EPA, 1999); whereby it has been estimated that a watershed with 25% impervious surfaces is subjected once every five years to an event of peak volume equivalent to the 100-year storm under completely forested conditions. At 38% imperviousness, this same event occurs every 2.5 years, and at 65% imperviousness it occurs annually (Klein 1979; EPA, 1999). These processes also contribute direct increases in contaminant loadings, such as petroleum byproducts, pesticides, industrial solvents, which partition strongly to fine particles with high ratios of surface area to volume. This phenomenon demonstrates the need for a comprehensive drainage ordinance that requires new projects to maintain runoff volumes and peak timing to pre-project levels.

In many instances, the impacts on receiving streams due to high storm water flow rates or volumes may be more significant than those attributable to the contaminants found in storm water discharges. The discussion provided in Chapter 4.0 of this Assessment generally supports this hypothesis, in that at a broad scale, there is a large fraction of controllable sediment (see **Table 4-2**). Impacts of urbanization and increased storm water discharges to receiving streams documented in this Assessment include:

1. Evidence of increases in the number of bankfull events and increased peak flow rates;
2. Sedimentation and increased sediment transport;
3. Increased siltation (burial of stable habitats);
4. Stream bed scouring (e.g., undercutting);
5. Aesthetic degradation (e.g., loss of shade); and;
6. Changes in stream morphology (e.g., channelization, reduced depth).

6.3 Response to the Findings

The principal findings of the Assessment Report would suggest that the County's Water Quality Plan place emphasis on addressing three principal water quality concerns. This section provides additional discussion on the principal findings and identifies potential actions that could be taken in response to the principal water quality concerns including (1) fecal coliform bacteria and nutrients, (2) urban non-source point pollutants (e.g. leaking USTs, disposal practices, pH uncertainties, etc.), and (3) sedimentation. These three topics are covered under the following subheadings.

Fecal Coliform Bacteria and Nutrients

As described in Chapter 5.0, fecal coliform levels in all the monitored waterways were above Basin Plan standards at one or more times during the first phase of the MRP. The two primary non-point sources thought to contribute to these elevated levels include concentrated areas of failing individual septic systems and unobstructed grazing practices. Alterations in natural drainage patterns within the PSA, mainly from roadways, likely create additional pathways that enable coliform bacteria to enter waterways; similar to that of sediment transport.

Nutrient inputs are also generally associated with these septic tank effluent and grazing practices and are further influenced by applications of various fertilizers. Due the complexity of the nutrient cycle (e.g. plant uptake, etc.) for various macro-nutrients[1], specific nutrients may be detected at higher concentrations at more, site-specific reaches within the PSA. The low concentrations detected at the Phase 1 monitoring sites are likely attributed to higher level dilution from less-affected land areas and, thus may be less-representative of more-specific reaches.

The County has identified three primary factors that limit the performance of on-site waste water systems. These include shallow depths to bedrock, coarse-textured soils, and restrictive lot sizes and/or configurations. Unobstructed grazing practices become problematic at a point when livestock congregate in close proximity to or within creek channels and/or contributing drainages where manure accumulates. The preferable method for mitigating grazing affects is to establish riparian buffer standards, which outline minimum setback requirements.

Corrective measures for failing septic systems are more problematic in that each system in need of replacement may require expensive on-site improvements and/or specially engineered systems. In some instances on-site restrictions may only be corrected through an extension of sewer service, which would only be cost-effective for clusters of development. However, regardless of the corrective action taken, water quality improvements in terms of fecal coliform reductions would not be expected immediately following the corrective action due to the preexisting contamination and the extent of its down-slope migration.

Due to the diffuse nature of NPS loadings from grazing practices and differing management practices employed on a property-by-property basis, it is difficult to isolate specific areas that should receive priority. In general, the County's Agricultural Commissioner and/or Farm Advisor would need to have the ability to document and map problematic areas verses non-problematic areas on a parcel-by-parcel basis; similar to the approach of identifying problematic septic systems. Such an effort, however, would be both time consuming and costly as it would be labor intensive. As a result, the idea of establishing buffer standards would likely be more cost-effective in the context that grazing operations blanket the entire land area within the lower reaches of the PSA.

1 Essential elements used by plants in relatively large amounts for plant growth are called macronutrients. The major macronutrients are nitrogen (N), phosphorous (P), and potassium (K). Calcium (Ca), magnesium (Mg), and sulfur (S) are also macronutrients.

Urban Non-Point Source Pollution

Data collected through Phase 1 of the MRP indicates that urban land uses are currently not discharging high concentrations of urban pollutants (e.g. trace metals, VOC, etc.) into downstream water supply reservoirs. The leading factor thought to contribute to these non-detectable levels (see Tables 5-5 and 5-6) is attributed to the existing land development pattern. In general terms, urban and residential areas are concentrated in the middle to upper reaches of the PSA while agricultural and grazing uses comprise much of the PSA within the lower reaches. This development pattern is thought to provide considerable dilution to upper, more developed reaches in the PSA (e.g. East Sonora) prior to flows entering Don Pedro Reservoir. However, this dilution effect is likely less influential within the Mormon Creek Watershed, due to the closer proximity of residential development to New Melones Reservoir. Further, the actual quantities of dilution provided in the lower reaches of the PSA have not been quantified as part of this Assessment and, therefore, even gross drainage calculations would be desirable to support this finding.

Based on the analytical results and work completed as part of this Assessment, the County is in an advantageous position to manage the watersheds that comprise the PSA in a way that minimizes adverse water quality effects to local waterways and, more importantly, downstream water supply reservoirs. The WQP can be developed in a way that minimizes polluted runoff by incorporating a watershed or drainage catchment scale planning methodology and employing a sensible combination of pollutant source control and site specific treatment control measures. Watershed planning at the catchment scale enables the prioritization of smaller drainage units containing high concentrations of existing or planned forms of urban development. As some of these areas could have runoff similar in quality to the data provided in Table 6-2 and 6-3, this planning methodology will allow the County to focus outreach efforts, potential grant funding opportunities, and testing preferred best management practices (BMPs) at these locations.

This concept is illustrated in **Figure 6-2**; whereby localized drainage catchments are rated based on the level of impervious surface area provided in **Figure 6-1** and the ratings based on the maximum allowable building intensity as provided in **Table 6-1**. Prioritized watershed catchments should be the primary focus of urban stormwater controls and future monitoring activities. Monitoring activities should be focused to those catchments with the highest priority ratings. Due to large capital expenditures associated with the construction and maintenance of treatment-oriented BMPs, the first step in planning the location and type of treatment BMP is to understand that large reductions in treatment BMP size and investment can be made by (1) reducing the runoff volumes that need to be captured, infiltrated, or treated, and (2) controlling sources of pollutants. These two strategies are the most cost-effective in managing urban runoff.

Figure 6-2

There are four basic strategies for treating runoff prior to it entering a waterway and include (1) infiltrating runoff into the soil, (2) retaining runoff for later release with the detention providing treatment, (3) conveying runoff slowly through vegetation (e.g. bioretention[2]), and (4) treating runoff on a flow-through basis using various treatment technologies (e.g. oil and grease separators). Incorporating these design features into new development is generally less difficult as opposed to existing development. In existing developments the County is limited in terms of options for the placement of structural water quality BMPs, such as detention facilities, since these facilities can not be cost-effectively integrated at a site-specific level. For new development, the California Stormwater BMP Handbook identifies general gross-area thresholds for the inclusion of treatment-oriented BMPs (CASQA, 2003):

- Residential ≥ 10 units
- Commercial ≥ 1 acre
- Parking lots, road project ≥ 5,000 square feet
- Redevelopment ≥ 5,000 square feet impervious
- Retail Gasoline Outlets
- New and Redevelopment projects above 1 acre or 10,000 square feet of impervious area.

There are many factors that may affect runoff discharge from a particular site; some of these include: precipitation, soil permeability, watershed area, ground cover, antecedent moisture, storage in the watershed, and time parameters. Given the varying influences to runoff at any one site, it is often difficult to obtain an accurate prediction of the amount of runoff to ensure the integrity of a particular treatment. However, too partially account for this problem control measures should be designed based on anticipated runoff velocities from smaller, more discrete catchments within the drainage network. The drainage catchments delineated in **Figure 6-2** provide insight as to possible drainage influences for future engineering applications based on localized hydrology. Newly prescribed BMPs should be designed based on the maximum expected runoff volumes (e.g. 50-year, 24-hour rainfall intensity) from both on- and off-site influences. Modeling efforts should also include an accurate characterization of land use and soil type to determine an appropriate Runoff Curve Number (RCN). These concepts and more specific BMPs are expected to be more thoroughly evaluated and integrated into the County planning process as part of the WQP.

In addition to planning for increased runoff, the County's objective of controlling urban non-point sources of pollution includes isolating specific drainage catchments containing contaminated sites. As part of the County's Groundwater Protection Report (1999), a database of sites was created. Currently, the database documents 58 sites with Class V injection wells[3], 45 sites with WDRs issued by the Regional Water Quality Control Board, 67 sites with underground fuel storage tanks, and 74 active commercial sites with on-site sewage disposal. Although designed to be GIS compatible, to date, much of this data has not been integrated into the GIS. The ability to overlay these data with drainage catchments would further enhance the prioritization ratings depicted in **Figure 6-2**.

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2 Bioretention basins direct sheet flow across a grass buffer strip to a ponding area for infiltration. They utilize soils and both woody and herbaceous plants to remove pollutants from stormwater runoff (EPA, 1999).

3 Typically, Class V injection wells are shallow "wells," such as septic systems and drywells, used to place nonhazardous fluids directly below the land surface. Some examples of Class V wells are agricultural drainage wells, storm water drainage wells, large capacity septic systems, sewage treatment effluent wells, mine backfill wells, special drainage wells, heat pump/air conditioning return flow wells, and industrial wells. For facilities that generate nonhazardous wastes, Class V wells provide for disposal when there is no access to a sewer system.

Due to various complexities in treating NPS pollution from urban sources, emphasis within the WQP should be placed on approaches that minimize existing on-site effects (e.g., erosion control, good housekeeping, etc.) and combining this effort with a well-focused education and outreach program and limited site-specific monitoring program (e.g., outfall sampling). The County's MRP provides the initial framework for future monitoring and should be adjusted to enable site-specific monitoring at the base of the prioritized catchments. In addition to those parameters identified in Table 5-2, more site-specific water quality testing may also include the following constituents based on the plausible range of localized land uses:

1. Polycyclic Aromatic Hydrocarbons [PAHs] (EPA 610).
2. Organochlorine Pesticides (EPA 8081A).
3. Organophosphorus Pesticides (EPA 8141B).
4. Semi-Volatile Organic Compounds (EPA 8316, EPA 8270C).
5. PCBs (EPA 8082).

In addition to the collection of grab samples from site-specific urban runoff locations, which will require the use of an analytical laboratory, the County has allocated funding associated with this grant project for the purchase of field monitoring equipment. The instrumentation available will allow County staff and local citizen monitors to track pH, specific conductance, temperature, turbidity, and flow at the existing monitoring sites and new monitoring sites that will be identified in the WQP. The existing monitoring sites that should be carried forwarded into Phase 2 of the MRP include SV-2, CT-1, TB-1, GV-1, and WD-1. The tracking of pH is considered especially critical due to the low pH values recorded during the first phase of the MRP and the need to establish trends and further isolate potential influences.

Erosion and Sedimentation

As provided in Chapter 4.0, the coarse-scale sediment budget suggests that there is a controllable fraction of current sediment production within the Sullivan Creek watershed. Conservative estimates indicate that erosional processes are generating sediment volumes almost 10 times greater as compared to natural conditions. Further, based on the extent of topographic alteration, primarily from road development, the average quantity of eroded sediment delivered to the stream network is more than 20 times greater as opposed to natural conditions. Based on local observations, roads, property ground coverage, and unpaved driveways are thought to account for the largest fraction of the total sediment and associated delivery. Based on limited observations outside the Sullivan Creek watershed, these concepts are also applicable to the other four watershed units that comprise the PSA.

In the context of the cumulative sediment sources identified in Chapter 4.0, the County's ability to manage erosion is best focused on the existing roadway system, which has altered local drainage pathways, thereby enhancing the delivery of eroded sediment. In general terms, roads efficiently intercept surface runoff and subsurface flow, concentrate it within roadside ditches, and redirect it toward natural drainages and creeks through culverts and/or over-side drains. Increasing slope steepness and length further intensifies this effect. Due to this association, prioritization of individual catchments by road density was considered an appropriate method to isolate those drainage catchments with the highest potential risks for enhanced sediment delivery. **Figure 6-3** illustrates the relative rankings. As shown, drainage catchments US03, US04, US12, LS02, LS05, and BG13 exhibit the highest rankings; while several other catchments are identified as a moderately high priority. In the future, to further enhance the prioritization ratings provided in **Figure 6-3**, the inclusion of construction sites would be ideal to further enable correlation between sediment production and relative delivery.

By virtue that roads in themselves are expensive to construct and important to the County's economic base, road realignments and/or decommissioning are not considered feasible options for the management of sediment delivery. Rather, the control of sediment delivery from roadways needs to work within the confinements of the existing roadways system. To accomplish this, it is important that improvements be focused at minimizing high runoff velocities along roadway conveyance ditches and enhancing soil protection below over-side drains and culverts. As commonly observed throughout the PSA, even if roadside embankments are well-vegetated and actively eroding, the enhanced connectivity provided by roadside ditches to local waterways effectively conveys runoff from adjacent properties, which in many instances is highly turbid (see **Figure 6-4**, Photographs A and B). This connectively is further enhanced by roadways that are oriented parallel or diagonally along the dominant slope angle and more so in instances where slope lengths exceed 100 feet. At points where runoff is diverted away from the roadway, the increased velocity may result in the formation of larger erosion features (e.g. gullies) in down-slope locations. In instances where its impractical to minimize the length of roadside ditches, emphasis should be placed on providing down-slope erosion protection measures such as riprap for initial energy dissipation and bioengineering[4] methods further down-slope to maintain slower runoff velocities (see **Figure 6-4**, Photograph B).

Since inputs of sediment into roadside ditches are highly contingent upon adjacent land use practices, alterations in natural drainage patterns from roadways is considered only part of the problem. As discussed in Chapter 4.0, local observations indicate that management of residential and commercial properties is highly variable from a soil erodability perspective. The principal factor contributing to the removal of sediment on adjacent properties, which leads to enhanced delivery into roadside ditches, is the exposure of bare ground to the erosive effects of precipitation and its subsequent runoff. For this reason, the maintenance of some form of groundcover (e.g. plant cover, leaf litter, gravel, etc.) to limit the exposure of bare ground is critical to controlling these sources of sediment. Due to the frequent disturbance and direct connection to roadside ditches, unpaved driveways will be more problematic in terms of sediment control. Short of requiring the paving of entire driveway segments, solutions may include adding a gravel base, installing down-slope sediment traps, waterbars, and/or a combination thereof.

4 Bioengineering uses plants and structures together in mutually reinforcing or complimentary roles. The structural components initially protect and stabilize the site and create a stable zone for the plants to grow. Bioengineering techniques are used to prevent erosion on upland slopes, to protect streambanks and channels against erosion, and provide slope stability.

Figure 6-3

Figure 6-4

In terms of the erosive forces affecting waterways within the PSA, the contributing sources of sediment are the most practical means at which to control additional inputs. However, as previously indicated, the increased flows produced by both the roadway system and additions of impervious surface cover, have resulted in channel widening and aggradation in lower gradient segments of the stream network and channel incision and bank scouring in higher gradient segments. This phenomenon has resulted in excessive contributions of sediment that has overwhelmed lower gradient reaches, due to the waterway's inability to transport it.

By virtue that the movement of sediment within channels is more episodic (e.g., just during large events), options for controlling sediment within the channels are limited, short of manually removing the sediment in sections exhibiting excessive accumulation. Rather, the most practical route would be allow the channel to naturally flush the sediment out over time and, in limited instances, identifying riparian enhancement projects in efforts to stabilize banks, minimize undercutting and bank scour, and increasing channel roughness (e.g. introduction of large-woody debris, boulders, etc.). Improvements within riparian zones should also be focused at increasing structural complexity in contributing drainages below urbanized areas in efforts to slow flow velocities and to limit their erosive power. Further, since development in many instances occurs up to the edge of natural waterways and/or contributing drainages, riparian enhancement projects should also focus on the removal of invasive plant species through the reintroduction of native forms of groundcover and mid-level tree canopies to enhance natural filtering processes.

The restoration of riparian communities are critical to maintaining good water quality within the five watersheds that comprise the PSA, since the physical and biological processes in the riparian area can modify water and its constituents in route from upland hillslopes to waterways as well as from upstream to downstream areas (Karr and Schlosser, 1978). Streamside soils and vegetation regulate the entry of groundwater, surface runoff, nutrients, sediments and other particulates, and fine and coarse organic matter to streams. During significant rainfall events, plant roots and fallen trees help stabilize the soil and streambanks. Vegetative protection of streambanks against erosion effectively reduces sediment delivery to downstream reaches. This role as a buffer and filter is often relied upon to limit stream degradation from land use activities in the uplands and should be integrated with current planning practices (e.g. approval of tentative maps, etc.).

In the context of the above-mentioned concepts, the following monitoring, planning, and BMP recommendations should be integrated into the WQP to the extent feasible to control excessive erosion and sedimentation and minimize the effects of continued urbanization within the PSA:

- As erosion control planning progresses, the County should isolate those priority watershed catchments that contain high proportions of the granitic and Mehrten (moderately erodible) HGUs that underlie much of the forested area in the upper sections of the PSA. Where feasible, the County should establish erosion test plots to confirm the validity of the values used in Table 4-2. Such plots should be established along road cuts in grus soil materials, natural areas (as a control), below culvert outfalls, and on distributed bare ground. A more detailed classification of the road system and percent distribution of the various erosion sources based on a road sampling scheme combined with more detailed estimates of sediment deliverability should also be established to refine the sediment production and the sediment delivery values.

- New development projects should be required to calculate pre- and post-project runoff volumes for affected watershed catchments. This approach would focus on changes to runoff in terms of timing, velocity, and attenuation requirements.
- Photo-document the mouth of Lower Sullivan Creek from the Jacksonville Road turn-out to track bar deposits over the next 10 years; measuring width and length of major deposits, their movement, and changes in vegetation
- The County should investigate the use of various erosion control techniques (e.g. erosion control blankets and mats, fiber roles, riprap, hydraulic plantings, mulching, biofilters, and cellular confinement systems) to identify preferable control methods, especially for steep roadway cutbanks and embankments that are exhibiting chronic forms of erosion.
- The County should develop and identify a preferred native plant list to provide direction for local landowners and developers to facilitate the establishment of a permanent vegetative cover in addition to temporary erosion control.
- A riparian and aquatic inventory should be conducted for the Woods, Sullivan, Mormon and Turnback Creek Watersheds to establish an indication of the relative health. Riparian enhancement projects should be prioritized for urbanized areas (see Figure 6-3) and areas immediately downstream. Additionally, an invasive species eradication program should be developed and implemented with willing landowners.
- Develop a road drainage and conveyance database to enable the tracking and isolation of chronic erosion and/or sedimentation sources (e.g. lack of down-slope protection) within the roadway system. Figure 6-2 should be used in prioritizing these investigations. All sources should be logged with a GPS and entered into a GIS.
- Inventory current construction projects according to APNs and overlay with drainage catchments in a GIS to aid in SWPPP monitoring. Figure 6-3 should be used in prioritizing these investigations.
- Initiate an annual, long-term monitoring program at Station SCR-1 (Upper Sullivan Creek below Potato Ranch Road) to track changes in the channels cross-section. Additionally, work with TUD to conduct a second bathometric survey for Phoenix Reservoir to provide additional comparison to values provided in Table 4-2 (see Chapter 4.0)
- As sediment production in up-slope locations is largely influenced at the property ownership level, the County should develop a technical assistance program to help landowner's better manage sediment production.
- As part of the WQP, develop a County-suggested list of site-specific BMPs to encourage uniform implementation and maintenance practices throughout the County.
- Watershed-scale drainage modeling should be conducted to establish a realistic SPI for varying rainfall intensities within each of the five watersheds that comprise the PSA.
- Using information provided in Figures 6-2 and 6-3 the County should identify several more site-specific water quality monitoring locations to enable comparisons between runoff generated from highly urbanized areas and those values provided in Tables 6-2 and 6-3.
- The County should coordinate with TUD in studying the feasible of extending sewer service into those areas identified as high priority in by the County Department of Environmental Health.

6.4 Limitations of this Report

This assessment provides useful and valuable information and represents a considerable effort of the involved agencies, contractors, and public. It was limited in duration, scope, detail, and analysis level due to constraints in budget, time, access, and overall resources. Where data are limited, hypotheses were developed along with recommendations to test or improve the understanding of watershed processes. Specific limitations are presented below to put the Assessment in the necessary context.

- This report does not seek to predict drainage within the foothill watersheds.

- Sediment delivery values provided in this report were derived from a combination of research and professional judgment. Values obtained were derived from gross estimates in the context of the assumption provided in Chapter 4.0. The calculations are not intended for site specific application. Coarse-scale sediment delivery budgets do a poor job rating site-specific erosion hazards as observed from properties with differing land covers and roadways. The input data required by the model is aimed at assessing the potential for sediment delivery based on a generalization of locally observed conditions. As a monitoring tool, the model is misaligned with what appears to be the primary source of erosion from roadways, unpaved driveways, and tracts with high proportions of bare soil.

- The analysis of fluvial and hillslope conditions is limited, ongoing, and incomplete. Data collection has been abbreviated at many locations due to access restrictions. Although the best available data were used in this study, the predicted sediment rates should be used with caution. No assessment of potential erosion and sediment delivery were conducted to determine what changes would occur as a result of catastrophic wildfire.

- Evaluation of aquatic and riparian habitat within the PSA was limited to roadway crossings and therefore is not considered representative of the entire stream length.

- There was only time to compare the broadest contrasts between land use impacts and habitat conditions. More subtle analysis of habitat changes to properly characterize recent land use activities requires a larger and more detailed database to make significant conclusions.

- The water chemistry analysis was limited to three sampling events, with supplemental data acquisition anticipated through, at minimum, 2009. Nonetheless, the sampling frequency remains limited and discontinuous and does not allow temporal analysis.

- The absence of sequential data for suspended loads, specific conductance and turbidity are limitations in this report. However, the monitoring framework established in the County's MRP provides a means for acquiring this data over the longer term and throughout the implementation of the WQP.

Chapter 7
Report Authors, Citations, and Persons Consulted

CHAPTER 7

Report Authors, Citations, and Persons Consulted

7.1 Report Authors

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7.2 Report Citations

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7.3 Other Persons Consulted

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Appendix A
Sediment Budget Calculations

Entire Sullivan Creek Hydrologic Area – Natural Conditions

Natural Conditions

SDR = Sediment Delivery Ratio

Sum of acres		GRIDCODE																
PWSNAME	ToBufDist	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM	
Curtis Creek	164	2,349	1,473	46	3,868	0.020	0.030	0.050	47.0	44.2	2.3	93.5	0.25	11.7	11.0	0.6	23.4	
	328	1,329	1,320	37	2,685	0.020	0.030	0.050	26.6	39.6	1.8	68.0	0.15	4.0	5.9	0.3	10.2	
	492	483	621	12	1,116	0.020	0.030	0.050	9.7	18.6	0.6	28.9	0.1	1.0	1.9	0.1	2.9	
	493	63	117	2	182	0.020	0.030	0.050	1.3	3.5	0.1	4.9	0	0.0	0.0	0.0	0.0	
Curtis Creek Total		4,224	3,530	97	7,851							195.2					36.5	
Lower Sullivan Creek	164	3,234	1,401	70	4,706	0.020	0.030	0.050	64.7	42.0	3.5	110.2	0.25	16.2	10.5	0.9	27.6	
	328	2,135	1,102	40	3,277	0.020	0.030	0.050	42.7	33.1	2.0	77.7	0.15	6.4	5.0	0.3	11.7	
	492	925	493	12	1,429	0.020	0.030	0.050	18.5	14.8	0.6	33.9	0.1	1.8	1.5	0.1	3.4	
	493	160	116	4	280	0.020	0.030	0.050	3.2	3.5	0.2	6.9	0	0.0	0.0	0.0	0.0	
Lower Sullivan Creek Total		6,454	3,111	127	9,692							228.8					42.6	
Soulsbyville Creek	164	2,019	1,455	30	3,505	0.020	0.030	0.050	40.4	43.7	1.5	85.6	0.25	10.1	10.9	0.4	21.4	
	328	974	1,269	38	2,282	0.020	0.030	0.050	19.5	38.1	1.9	59.5	0.15	2.9	5.7	0.3	8.9	
	492	318	674	24	1,015	0.020	0.030	0.050	6.4	20.2	1.2	27.8	0.1	0.6	2.0	0.1	2.8	
	493	55	212	7	274	0.020	0.030	0.050	1.1	6.4	0.3	7.8	0	0.0	0.0	0.0	0.0	
Soulsbyville Creek Total		3,366	3,611	99	7,076							180.6					33.1	
Upper Sullivan Creek	164	3,017	4,883	244	8,144	0.020	0.030	0.050	60.3	146.5	12.2	219.0	0.25	15.1	36.6	3.1	54.8	
	328	1,587	3,437	153	5,177	0.020	0.030	0.050	31.7	103.1	7.7	142.5	0.15	4.8	15.5	1.1	21.4	
	492	553	1,254	40	1,847	0.020	0.030	0.050	11.1	37.6	2.0	50.7	0.1	1.1	3.8	0.2	5.1	
	493	94	215	5	313	0.020	0.030	0.050	1.9	6.4	0.2	8.6	0	0.0	0.0	0.0	0.0	
Upper Sullivan Creek Total		5,251	9,788	443	15,481							420.8					81.2	
Grand Total		19,295	20,040	766	40,100							1025.4	total tons				193.4	total tons
												0.026	total tons per acre				0.005	total tons per acre

Undeveloped Area Outside of the Developed Area

Undeveloped area outside of the "developed area."

Sum of acres		GRIDCODE																
PWSNAME	ToBufDist	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM	
Curtis Creek	164	1764	1203	36	3003	0.020	0.030	0.050	35.3	36.1	1.8	73.2	0.25	8.8	9.0	0.4	18.3	
	328	1028	1099	26	2153	0.020	0.030	0.050	20.6	33.0	1.3	54.8	0.15	3.1	4.9	0.2	8.2	
	492	380	506	9	895	0.020	0.030	0.050	7.6	15.2	0.5	23.2	0.1	0.8	1.5	0.0	2.3	
	493	42	99	2	143													
Curtis Creek Total		3213	2907	74	6194							151.2					28.8	
Lower Sullivan Creek	164	1847	973	56	2875	0.020	0.030	0.050	36.9	29.2	2.8	68.9	0.25	9.2	7.3	0.7	17.2	
	328	1229	746	31	2005	0.020	0.030	0.050	24.6	22.4	1.5	48.5	0.15	3.7	3.4	0.2	7.3	
	492	534	324	7	865	0.020	0.030	0.050	10.7	9.7	0.4	20.8	0.1	1.1	1.0	0.0	2.1	
	493	109	71	2	183													
Lower Sullivan Creek Total		3718	2114	96	5928							138.2					26.6	
Soulsbyville Creek	164	560	730	16	1306	0.020	0.030	0.050	11.2	21.9	0.8	33.9	0.25	2.8	5.5	0.2	8.5	
	328	295	598	26	919	0.020	0.030	0.050	5.9	17.9	1.3	25.1	0.15	0.9	2.7	0.2	3.8	
	492	135	336	18	489	0.020	0.030	0.050	2.7	10.1	0.9	13.7	0.1	0.3	1.0	0.1	1.4	
	493	27	111	4	142													
Soulsbyville Creek Total		1018	1774	63	2856							72.7					13.6	
Upper Sullivan Creek	164	1142	2603	143	3888	0.020	0.030	0.050	22.8	78.1	7.2	108.1	0.25	5.7	19.5	1.8	27.0	
	328	648	1765	84	2497	0.020	0.030	0.050	13.0	53.0	4.2	70.1	0.15	1.9	7.9	0.6	10.5	
	492	229	610	23	862	0.020	0.030	0.050	4.6	18.3	1.2	24.0	0.1	0.5	1.8	0.1	2.4	
	493	30	95	2	127													
Upper Sullivan Creek Total		2048	5073	253	7374							202.2					39.9	
Grand Total		9998	11868	486	22352							564.3	total tons				109.0	total tons
												0.025	total tons per acre				0.005	total tons per acre

Developed Area

Developed area defined by road buffer.

Sum of acres_1		GRIDCODE_1																SDR	SDR	Erosion
PWSNAME_1	ToBufDis_1	1	2	3	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM			
Curtis Creek	164	555	260	10	825	0.360	0.700	0.100	199.7	181.7	1.0	382.5	0.5	99.9	90.9	0.5	191.2			
	328	288	213	10	512	0.360	0.700	0.100	103.7	149.2	1.0	254.0	0.34	35.3	50.7	0.4	86.3			
	492	100	113	2	215	0.360	0.700	0.100	35.9	78.9	0.2	115.1	0.17	6.1	13.4	0.0	19.6			
	493	20	18	0	38															
Curtis Creek Total		963	603	23	1,589							751.5					297.2			
Lower Sullivan Creek	164	1,310	414	14	1,738	0.360	0.700	0.100	471.5	289.6	1.4	762.5	0.5	235.7	144.8	0.7	381.3			
	328	861	343	9	1,213	0.360	0.700	0.100	309.9	240.2	0.9	551.1	0.34	105.4	81.7	0.3	187.4			
	492	373	164	4	541	0.360	0.700	0.100	134.1	240.2	0.4	374.8	0.17	22.8	40.8	0.1	63.7			
	493	48	43	2	93															
Lower Sullivan Creek Total		2,591	963	30	3,584							1688.4					632.3	0.98	619.7	1654.6
Soulsbyville Creek	164	1,383	698	14	2,095	0.360	0.700	0.100	497.7	488.6	1.4	987.8	0.5	248.9	244.3	0.7	493.9			
	328	646	652	12	1,310	0.360	0.700	0.100	232.4	456.4	1.2	690.1	0.34	79.0	155.2	0.4	234.6			
	492	177	329	6	511	0.360	0.700	0.100	63.6	230.4	0.6	294.5	0.17	10.8	39.2	0.1	50.1			
	493	25	99	3	127															
Soulsbyville Creek Total		2,230	1,778	35	4,043							1972.3					778.6			
Upper Sullivan Creek	164	1,786	2,190	97	4,073	0.360	0.700	0.100	642.8	1533.3	9.7	2185.9	0.5	321.4	766.7	4.9	1092.9			
	328	888	1,597	67	2,552	0.360	0.700	0.100	319.8	1117.8	6.7	1444.3	0.34	108.7	380.0	2.3	491.1			
	492	306	617	17	940	0.360	0.700	0.100	110.2	431.6	1.7	543.5	0.17	18.7	73.4	0.3	92.4			
	493	60	114	2	177															
Upper Sullivan Creek Total		3,040	4,518	184	7,742							4173.7					1676.4	0.978	1639.5	4081.8
Grand Total		8,824	7,863	272	16,958							8460.3	total tons				3334.9			
												0.50	total tons per acre				0.20			

Reduced for Twain Harte
Reduction factor is 0.978

Reduced for Sonora Hills
Reduction factor is 0.98

Roads

Sum of acres		GRIDCODE				Roads												
PWSNAME	ToBufDist	1.00	2.00	3.00	Grand Total	Low Erod	Mod Erod	High Erod	1	2	3	SUM	**SDR**	1	2	3	SUM	
Curtis Creek	164	31.57	10.46	0.23	42.26	0.900	1.000	1.100	28.4	10.5	0.3	39.1	0.8	22.7	8.4	0.2	31.3	
	328	13.10	8.00	0.15	21.25	0.900	1.000	1.100	11.8	8.0	0.2	20.0	0.5	5.9	4.0	0.1	10.0	
	492	3.65	2.99	0.04	6.68	0.900	1.000	1.100	3.3	3.0	0.0	6.3	0.2	0.7	0.6	0.0	1.3	
	493	0.71	0.30		1.01													
Curtis Creek Total		49.03	21.76	0.42	71.21							65.4					42.5	
Lower Sullivan Creek	164	78.83	15.46	0.15	94.43	0.900	1.000	1.100	70.9	15.5	0.2	86.6	0.8	56.8	12.4	0.1	69.3	
	328	45.84	12.74	0.12	58.70	0.900	1.000	1.100	41.3	12.7	0.1	54.1	0.5	20.6	6.4	0.1	27.1	
	492	18.56	5.38	0.16	24.11	0.900	1.000	1.100	16.7	5.4	0.2	22.3	0.2	3.3	1.1	0.0	4.5	
	493	3.03	1.70	0.12	4.86													
Lower Sullivan Creek Total		146.27	35.28	0.55	182.11							163.0					100.8	
Soulsbyville Creek	164	77.06	27.71	0.55	105.32	0.900	1.000	1.100	69.4	27.7	0.6	97.7	0.8	55.5	22.2	0.5	78.1	
	328	33.58	20.17	0.16	53.91	0.900	1.000	1.100	30.2	20.2	0.2	50.6	0.5	15.1	10.1	0.1	25.3	
	492	6.14	8.91	0.08	15.13	0.900	1.000	1.100	5.5	8.9	0.1	14.5	0.2	1.1	1.8	0.0	2.9	
	493	1.92	2.98		4.90													
Soulsbyville Creek Total		118.70	59.76	0.79	179.25							162.8					106.3	
Upper Sullivan Creek	164	90.29	90.46	3.91	184.67	0.900	1.000	1.100	81.3	90.5	4.3	176.0	0.8	65.0	72.4	3.4	140.8	
	328	51.92	75.66	2.25	129.83	0.900	1.000	1.100	46.7	75.7	2.5	124.9	0.5	23.4	37.8	1.2	62.4	
	492	18.49	27.19	0.39	46.07	0.900	1.000	1.100	16.6	27.2	0.4	44.3	0.2	3.3	5.4	0.1	8.9	
	493	3.35	5.84	0.09	9.28													
Upper Sullivan Creek Total		164.05	199.15	6.64	369.85							345.2					212.1	
Grand Total		478.05	315.95	8.41	802.41							736.3	total tons				461.7	total tons
												0.92	total tons per acre				0.58	total tons per acre

Values Used for Sediment Loading

Values for Sullivan Creek Sediment Budget

	Natual Erosion Rate tons per acre per year	Rationale	Developed Erosion Rate - tons per acre per year	Rationale	Road Erosion Rate - tons per acre per year	Rationale
High	0.05	3	0.9	6	1.1	9
Medium	0.03	2	0.7	5	1	8
Low	0.02	1	0.36	4	0.9	7

1, 2 & 3. Based on values of 0.02-0.04 tons/acre/year for Scott River from Sommarstrom et al. (1990); 0.04 tons/acre/year reported by Euphrat (1992); and 0.04 tons/acre/year in Idaho Rice et al. (1972).

4. Based on Euphrat's (1992) non-reservoir erosion rate of 0.1 acre-ft/mi2/yr, used 2,308 tons per ac-foot/yr which is 0.36 tons/acre/year.

5. Based on Kattleman's (1996) report of California Department of Forestry and Fire Protection Sierra Nevada-wide value of 0.2 acre-ft/mi2/yr, non-reservoir value, using 2,308 tons/ac-ft/yr the value is 0.72 tons/acre/year.

6. Value is scaled up from the Kattleman (1996) value indicated in number 5 above.

7. McGurk et al. (1996) use 0.9 T/acre-yr for paved roads after 3rd yr. Value is for acreage of paved road (22-24') + 8' for shoulder. Our road acreage is based on 22 foot road bed without shoulder so it should be a reasonable conservative estimate.

8. Scaled up from number 7 above.

9. Scaled up from number 8 above.

Phoenix Lake Sedimentation Rate Estimate

Based on values reported in Union Democrat newspaper article Wolfson (2005)
Lake created in 1852 and is approximately 88 acres in size.
Average depth is 10 to 15 feet but 5 feet or less in silt clogged areas.
Phoenix Lake dredged once in the 1980s but this did not remove much sediment (assume 20 acre-feet for this analysis).

	Estimate 1 (low)	**Estimate 2**	**Estimate 3** (maximum)
End Year	2005	2005	2005
Start Year	1852	1880	1890
207 acre-feet of Sedimentation in 'X' Years	153	125	115
acre-feet/year of sedimentation	1.35	1.66	1.80

20	Acre-feet dredged in 1980s (Assumed)
227	Total a-f of sed in 115 yrs
1.97	acre-feet/year

	Estimate 1	Estimate 2	Estimate 3
tons per year	2,484.1	3,040.5	3,624.2
Acres in Upper Sullivan Creek	15,481	15,481	15,481
Tons per acre per year delivered to Phoenix Lake	**0.16**	**0.20**	**0.23**

Phoenix Lake Trapping Efficiency (TE)

1 cubic feet = 0.028317 cubic meters

Need volume of Phoenix Lake in m3			ft3/ac-ft	ft3	m3/ft3	m3
Original volume =	825	acre-feet	43560	35,937,000	0.028317	1,017,623
Current volume =	618	acre-feet	43560	26,920,080	0.028317	762,292

Capacity-watershed ratio (C/W) (m3 capacity per km2 catchment area)	C/W	Trap Effec	t/ac-yr low value	**t/ac yr total w TE low value**	t/ac yr high value	**t/ac yr total w TE high value**
Original C/W	15,874	0.75	0.16	**0.21**	0.23	**0.31**
Current C/W	11,891	0.7	0.16	**0.23**	0.23	**0.33**

Based on the numbers reported in the Union Democrat article (Wolfson, 2005):
the minimum sedimentation rate would be from 1852-2005 or 0.16 tons per acre per year (0.21 tons/ac-yr including trapping efficiency);
the maximum sedimentation rate would be from 1890-2005 + what was removed by dredging in the 1980s or about 0.23 tons per acre per year (or 0.31 tons/ac-yr including trapping efficiency).

Phoenix Lake Sedimentation Rate Estimate, continued

Values for converting acre-feet to tons	
tons per cubic foot 10%(gr), 60%(s), 25%(si), 5%(cl)	0.04215
square feet per acre or cubic feet per acre-foot	43560
tons per acre-foot of sediment	**1,836**

Maximum Phoenix Lake Capacity

88	acres
15	feet deep
1,320	acre-feet

Therefore, 825 acre-feet capacity seems reasonable

Capacity late 1800s	825	acre-feet
Current capacity	618	acre-feet
Total Amount of Sedimentation	207	acre-feet

References

Snyder, N.P., D.M. Rubin, C.N. Alpers, J.R. Childs, J.A. Curtis, L.E. Flint, and S.A. Wright, Estimating Accumulation Rates and Physical Properties of Sediment Behind a Dam: Englebright Lake, Yuba River, Northern California, Water Resources Research, Volume 40, Paper W11301, 19 pp., 2004.

Verstraeten, G. & J. Poesen, Estimating Trap Efficiency of Small Reservoirs and Ponds: Methods and Implications for the Assessment of Sediment Yield, Progress in Physical Geography, Volume 24 (2), pp. 219-251, 2000.

Wolfson, J., Shrinking Lake a Growing Concern, Union Democrat, September 30, 2005.

Appendix B
Channel Reach
Photo-Documentation

(See Figures Folder)

Appendix C

Phase 1 MRP
Data Summary Report

ESA Water

8950 Cal Center Drive
Building 3, Suite 300
Sacramento, CA 95826
916.564.4500 phone
916.564.4501 fax

www.esassoc.com

March 24, 2006

Mark Houghton
Tuolumne County Public Works Department
2 South Green Street
Sonora, CA 95370

Subject: Monitoring Report for Phase 1 of the Tuolumne County Surface Water Monitoring and Reporting Program

Dear Mr. White:

Environmental Science Associates (ESA) is pleased to present the attached Monitoring Report for Phase 1 of the County's Surface Water Monitoring and Reporting Program (MRP), which meets requirements of the County's Quality Assurance and Project Plan (QAPP).

Field samples were collected and analyzed with pre-calibrated field sampling equipment utilizing standard protocols to eliminate the chance for error and cross-contamination. Post-field calibration checks were performed for all field samples. Samples requiring laboratory analysis were stored in a chilled cooler and delivered under chain of custody to California Laboratory Services (CLS) and AquaLab Water Analysis (AquaLab) for sample analysis and processing. Frontier Geosciences Inc.(Frontier) conducted laboratory low-level mercury analysis.

An analytical summery report is included as Exhibit A. Full laboratory results; including QA/QC data have been included as attachments to the summery report.

ESA appreciates the opportunity to provide our services to Tuolumne County. If you have any questions regarding this report, please call me at (916) 564-4500.

Sincerely,

Clint Meyer
Project Manager

204254-2.0

ESA Water

EXHIBIT A
ANALYTICAL SUMMERY REPORT

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	SV-1		
Sample Location:	Algerine Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	4.8	5.7		
pH	Field	Grab	units	+/- 0.2	6.89	5.2	6.27	5.20	6.89
Temperature	Field	Grab	Deg. F	+/- 0.27	54.89	50.58	45.9	45.90	54.89
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	8.58	9.64	10.39	8.58	10.39
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	239	84	118	84.00	239.00
Turbidity	Field	Grab	NTU	+/- 2%	0.8	25.9	25.2	0.80	25.90
TSS	EPA 160.2	Grab	mg/L	5.0	ND	53	20	20.00	53.00
Hardness	SM-2340B	Grab	mg/L	1.0	120	38	49	38.00	120.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.46	ND	0.46
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	27	500	300	27.00	500.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	240	1600	1100	240.00	1600.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				

Report Approved By: ________________________

Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND		
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND		
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND		
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.23		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: ________________________

Notes on Receiving Water Conditions at SV-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 12/1/05, 1/18/06); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

Report Approved By: ________________________

PHOTO DOCUMENTATION FOR SV-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	SV-2		
Sample Location:	Potato Ranch Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second						
pH	Field	Grab	units	+/- 0.2	1.75	5.9	5.1	5.27	6.48
Temperature	Field	Grab	Deg. F	+/- 0.27	6.48	5.27	5.76	44.80	52.48
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	52.48	47.946	44.8	9.20	10.85
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	9.2	10.42	10.85	89.00	112.00
Turbidity	Field	Grab	NTU	+/- 2%	112	102	89	2.34	85.40
TSS	EPA 160.2	Grab	mg/L	5.0	ND	110	20	20.00	110.00
Hardness	SM-2340B	Grab	mg/L	1.0	44	43	35	35.00	44.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.41	ND	0.41
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	600	600.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1700	1600	16000	1600.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	NS				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	NS				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	NS				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	NS				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	NS				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	NS				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	NS				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	NS				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	NS				
Benzene	EPA 8260B	Grab	ug/L	0.5	NS				
Bromoform	EPA 8260B	Grab	ug/L	2.0	NS				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	NS				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	NS				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	NS				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	NS				
Chloroform	EPA 8260B	Grab	ug/L	0.5	NS				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	NS				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	NS				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	NS				
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	NS				

Report Approved By: ________________________

Naphthalene	EPA 8260B	Grab	ug/L	10	NS		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	NS		
Toluene	EPA 8260B	Grab	ug/L	2.0	NS		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	NS		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	NS		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	NS		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	NS		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected
NS: Not Sampled

Report Approved By: ________________________

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Notes on Receiving Water Conditions at SV-2

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 1/18/06); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: Small fish on 11/8/05

Report Approved By: ________________________

PHOTO DOCUMENTATION FOR SV-2

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	WD-1		
Sample Location:	Bell Mooney Crossing	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	5.5	5.5	5.93	7.24
pH	Field	Grab	units	+/- 0.2	7.24	5.93	6.27	46.85	54.36
Temperature	Field	Grab	Deg. F	+/- 0.27	54.36	51.66	46.85	9.26	10.95
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.26	9.44	10.95	207.00	380.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	380	273	207	1.48	29.50
Turbidity	Field	Grab	NTU	+/- 2%	1.48	29.5	29.1	5.93	7.24
TSS	EPA 160.2	Grab	mg/L	5.0	ND	25	18	18.00	25.00
Hardness	SM-2340B	Grab	mg/L	1.0	210	150	91	91.00	210.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.5	ND	0.50
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	170	1600	1700	170.00	1700.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	9000	1600.00	9000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: ________________________

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.48		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: ________________________

Notes on Receiving Water Conditions at WD-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05); Sediment (12/1/05, 1/18/06)

Visible films, sheens, or coatings Y☒ N☐

If yes, describe: Rock crevices on 12/1/05

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☒ N☐

If yes, describe: Sulfur smell on 11/08/05

Aquatic life: Beaver (?) crossing Bell Mooney on 1/18/06

Report Approved By: ________________________

PHOTO DOCUMENTATION FOR WD-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	MM-1		
Sample Location:	Mormon Creek Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		1	3.5	4.5	6.40	7.76
pH	Field	Grab	units	+/- 0.2	7.76	6.4	6.61	45.35	54.75
Temperature	Field	Grab	Deg. F	+/- 0.27	54.75	52.3	45.35	9.29	10.39
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.29	9.45	10.39	373.00	408.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	408	373	400	4.45	13.60
Turbidity	Field	Grab	NTU	+/- 2%	9.97	4.45	13.6	6.40	7.76
TSS	EPA 160.2	Grab	mg/L	5.0	6.2	ND	8	6.20	8.00
Hardness	SM-2340B	Grab	mg/L	1.0	240	220	200	200.00	240.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.61	ND	0.61
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	240	500	500	240.00	500.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	900	1600	1400	900.00	1600.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: ________________________

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	5.5	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	1.91		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: ________________________

Notes on Receiving Water Conditions at MM-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris on 12/1/05

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid on 1/18/06

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

PHOTO DOCUMENTATION FOR MM-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	CT-1		
Sample Location:	Lime Kilm Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	4.5	8.6	6.04	6.73
pH	Field	Grab	units	+/- 0.2	6.73	6.04	6.07	45.23	54.23
Temperature	Field	Grab	Deg. F	+/- 0.27	54.23	50.54	45.23	9.37	11.34
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.37	9.85	11.34	116.00	269.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	158	269	116	2.06	70.70
Turbidity	Field	Grab	NTU	+/- 2%	2.29	2.06	70.7	6.04	6.73
TSS	EPA 160.2	Grab	mg/L	5.0	ND	ND	44	44.00	44.00
Hardness	SM-2340B	Grab	mg/L	1.0	73	120	49	49.00	120.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	0.41	ND	0.41
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	300	130	1100	130.00	1100.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	300	1600	16000	300.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: ________________________

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	2.61		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Notes on Receiving Water Conditions at CT-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris, foam on 12/1/05; Sediment 1/18/06

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06) – Reddish hue on 1/18/06

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☐ N☒

If yes, describe:

Aquatic life: None observed.

PHOTO DOCUMENTATION FOR CT-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	TB-1			
Sample Location:	Box Factory Road Bridge		Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water		Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):			Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 11/8/05	12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		<1.0	6.5	8.4	4.88	6.24
pH	Field	Grab	units	+/- 0.2	6.24	4.88	5.55	44.73	53.09
Temperature	Field	Grab	Deg. F	+/- 0.27	53.09	47.85	44.73	7.65	10.31
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	7.65	8.87	10.31	98.00	137.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	137	113	98	2.68	70.40
Turbidity	Field	Grab	NTU	+/- 2%	2.68	28.4	70.4	4.88	6.24
TSS	EPA 160.2	Grab	mg/L	5.0	ND	17	42	17.00	42.00
Hardness	SM-2340B	Grab	mg/L	1.0	61	50	43	43.00	61.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	5.1	ND	ND	5.10
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	ND	ND	ND
Microbiological									
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	17	1600	1300	17.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1600	16000	1600.00	16000.00
Volatile Organics									
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND				
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND				
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND				
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND				
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND				
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND				
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND				
Benzene	EPA 8260B	Grab	ug/L	0.5	ND				
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND				
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND				
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND				
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND				
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND				
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND				
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND				
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND				

Report Approved By: ________________________

Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND		
Naphthalene	EPA 8260B	Grab	ug/L	10	ND		
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND		
Toluene	EPA 8260B	Grab	ug/L	2.0	ND		
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND		
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND		
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND		
Inorganic Analysis (Metals)							
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND	ND
Low Level Mercury	EPA 1631	Grab	ng/L	0.50	3.43		
Herbicides							
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND		
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND		
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND		
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND		
Picloram	EPA 8151A	Grab	ug/L	1.0	ND		
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND		
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND		

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: ________________________

Notes on Receiving Water Conditions at TB-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (11/8/05, 12/1/05, 1/18/06); Sediment and trash/18/06; sediment and foam 12/1/05

Visible films, sheens, or coatings Y☐ N☒

If yes, describe:

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☒ N☐

If yes, describe: Algae visible on rocks (11/8/05)

Odor/Other nuisance conditions Y☒ N☐

If yes, describe: Sulfur smell on 12/1/05; Bank-side trash and mulch disposal 1/18/06

Aquatic life: None observed.

PHOTO DOCUMENTATION FOR TB-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP

Sample ID:	GV-1		
Sample Location:	CSD Access Road Bridge	Sampling Dates:	11/8/2005, 12/1/2005, 1/18/2006
Sample Matrix:	Water	Lab Received Dates:	AquaLab: 11/8/2005, 12/1/2005, 1/18/2006 CLS, Labs: 11/9/2005, 12/9/2005, 1/19/2006
Sampler(s):		Report Date:	3/15/2006

Sampling Results

Analysis	Method	Sample	Units	RL/IAL	Sampling Dates 12/1/05	1/18/06	Min.	Max.
Flow	Field	Grab	feet/second		3	3.8	4.78	5.87
pH	Field	Grab	units	+/- 0.2	4.78	5.87	45.27	49.78
Temperature	Field	Grab	Deg. F	+/- 0.27	49.78	45.27	9.73	10.71
Dissolved Oxygen	Field	Grab	mg/L	+/- 2%	9.73	10.71	102.00	127.00
Specific Conductance	Field	Grab	uS/cm	+/- 0.5%	102	127	30.20	30.30
Turbidity	Field	Grab	NTU	+/- 2%	30.2	30.3	4.78	5.87
TSS	EPA 160.2	Grab	mg/L	5.0	56	6.2	6.20	56.00
Hardness	SM-2340B	Grab	mg/L	1.0	68	47	47.00	68.00
Oil and Grease	EPA 1664	Grab	mg/L	5.0	ND	ND	ND	ND
Nitrate and Nitrite (as N)	EPA 300.0	Grab	mg/L	0.500	ND	ND	ND	ND
Microbiological								
Fecel Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	70	70.00	1600.00
Total Coliform	SM 9221B/E	Grab	MPN/100 mL	2.0	1600	1400	1400.00	1600.00
Volatile Organics								
1,1-Dichloroethane	EPA 8260B	Grab	ug/L	1.0	ND			
1,1-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND			
1,1,1-Trichloroethane	EPA 8260B	Grab	ug/L	2.0	ND			
1,1,2-Trichloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
1,1,2,2-Tetrachloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
1,2-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
1,2-Dichloroethane	EPA 8260B	Grab	ug/L	0.5	ND			
cis-1,2-Dichloroethene	EPA 8260B	Grab	ug/L	0.5	ND			
1,2-Dichloropropane	EPA 8260B	Grab	ug/L	0.5	ND			
1,2,4-Trichlorobenzene	EPA 8260B	Grab	ug/L	5.0	ND			
1,3-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
1,3-Dichloropropene	EPA 8260B	Grab	ug/L	0.5	ND			
1,4-Dichlorobenzene	EPA 8260B	Grab	ug/L	2.0	ND			
Benzene	EPA 8260B	Grab	ug/L	0.5	ND			
Bromoform	EPA 8260B	Grab	ug/L	2.0	ND			
Bromomethane	EPA 8260B	Grab	ug/L	2.0	ND			
Carbon tetrachloride	EPA 8260B	Grab	ug/L	0.5	ND			
Chlorobenzene (mono chlorobenzene)	EPA 8260B	Grab	ug/L	2.0	ND			
Chloroethane	EPA 8260B	Grab	ug/L	2.0	ND			
Chloroform	EPA 8260B	Grab	ug/L	0.5	ND			
Chloromethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dibromochloromethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dichlorobromomethane	EPA 8260B	Grab	ug/L	0.5	ND			
Dichloromethane	EPA 8260B	Grab	ug/L	2.0	ND			
Ethylbenzene	EPA 8260B	Grab	ug/L	2.0	ND			
Hexachlorobutadiene	EPA 8260B	Grab	ug/L	1.0	ND			

Report Approved By: ________________________

Naphthalene	EPA 8260B	Grab	ug/L	10	ND	
Tetrachloroethene	EPA 8260B	Grab	ug/L	0.5	ND	
Toluene	EPA 8260B	Grab	ug/L	2.0	ND	
trans-1,2-Dichloroethylene	EPA 8260B	Grab	ug/L	1.0	ND	
Trichloroethene	EPA 8260B	Grab	ug/L	2.0	ND	
Vinyl chloride	EPA 8260B	Grab	ug/L	0.5	ND	
Inorganic Analysis (Metals)						
Arsenic	EPA 200.8	Grab	ug/L	1.0	ND	ND
Cadmium	EPA 200.8	Grab	ug/L	0.25	ND	ND
Mercury	EPA 200.8	Grab	ug/L	0.5	ND	ND
Antimony	EPA 200.8	Grab	ug/L	5.0	ND	ND
Beryllium	EPA 200.8	Grab	ug/L	1.0	ND	ND
Chromium (total)	EPA 200.8	Grab	ug/L	2.0	ND	ND
Copper	EPA 200.8	Grab	ug/L	0.5	ND	ND
Lead	EPA 200.8	Grab	ug/L	100.0	ND	ND
Nickel	EPA 200.8	Grab	ug/L	20.0	ND	ND
Selenium	EPA 200.8	Grab	ug/L	5.0	ND	7.3
Silver	EPA 200.8	Grab	ug/L	5.0	ND	ND
Thallium	EPA 200.8	Grab	ug/L	1.0	ND	ND
Zinc	EPA 200.8	Grab	ug/L	1.0	ND	ND
Herbicides						
Bentazon	EPA 8151A	Grab	ug/L	2.0	ND	
2,4-D	EPA 8151A	Grab	ug/L	1.0	ND	
Dalapon	EPA 8151A	Grab	ug/L	2.0	ND	
Dinoseb	EPA 8151A	Grab	ug/L	1.0	ND	
Picloram	EPA 8151A	Grab	ug/L	1.0	ND	
2,4,5-TP (Silvex)	EPA 8151A	Grab	ug/L	1.0	ND	
Pentachlorophenol	EPA 8151A	Grab	ug/L	1.0	ND	

RL/IAL: Reporting Limit/Instrument Accuracy Level
nd: Not detected

Report Approved By: ________________________

Notes on Receiving Water Conditions at GV-1

Floating or suspended matter Y☒ N☐

If yes, describe: Plant Debris (12/1/05, 1/18/06); Sediment (12/1/05, 1/18/06); Trash 12/1/05

Visible films, sheens, or coatings Y☒ N☐

If yes, describe: Oily sheen visible on 12/1/05

Discoloration Y☒ N☐

If yes, describe: Turbid (12/1/05, 1/18/06)

Algae, fungi, slimes, or objectionable growths Y☐ N☒

If yes, describe:

Odor/Other nuisance conditions Y☐ N☒

If yes, describe: Foam at base of step pools on 1/18/06

Aquatic life: None observed.

PHOTO DOCUMENTATION FOR GV-1

FALL/WINTER (2005-06)
ANNUAL SURFACE WATER MONITORING SUMMARY REPORT – PHASE 1
TUOLUMNE COUNTY WQP
Quality Control Data for Field Instrumentation

Post-Field Calibration Check		11/8/05	12/01/05	1/18/06
pH (4)	Observed	4.17	4.11	3.97
	Actual	4	4	4
	Difference	-0.17	-0.11	0.03
pH (7)	Observed	7.03	7.08	7.04
	Actual	7	7	7
	Difference	-0.03	-0.08	-0.04
pH (10)	Observed	10.14	10.21	10.18
	Actual	10	10	10
	Difference	-0.14	-0.21	-0.18
Specific Conductance	Observed	1000	996	
(uS/m)	Actual	1002	1000	N/A
	Difference	2	4	
Turbidity	Observed	0.31	0.28	0.45
(NTU) - <0.1	Actual	<0.1	<0.1	<0.1
	Difference	0.21	0.18	0.35
Turbidity	Observed	19.12	21.41	20.65
(NTU) - 20.0	Actual	20	20	20
	Difference	0.88	-1.41	-0.65
Turbidity	Observed	98	102	97
(NTU) - 100	Actual	100	100	100
	Difference	2	2	0

Insert Quality Control Data for Field Instrumentation

Insert Excel Tabloid Page

ANALYTICAL DATA FOR NOVEMBER 8, 2005

ANALYTICAL DATA FOR DECEMBER 1, 2005

ANALYTICAL DATA FOR JANUARY 18, 2006

FALL/WINTER 2005-06
ANNUAL SURFACE WATER MONITORING REPORT - PHASE 1
QUALITY CONTROL DATA

QC Data

Parameter	Units	RL/IAL	11/8/2005 SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	12/1/2005 SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	1/18/2006 SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1
Field																							
pH	units	+/- 0.2			6.26		7.43		7.22	5.2	5.33	4.66	5.9	6.34	4.75	5.84	6.27	5.73	5.66	6.03	6.84	5.9	6.92
Temperature	Deg. F	+/- 0.27			53.13		54.62		54.37	50.22	47.57	48.15	54.36	52.28	49.8	51.66	50	44.78	44.64	45.23	49.37	45.3	46.87
Dissolved Oxygen	mg/L	+/- 2%			7.77		9.25		9.29	9.15	10.37	8.2	9.83	9.42	9.83	10.03	10.62	10.87	10.99	11.35	10.34	10.6	10.92
Specific Conductance	uS/cm	+/- 0.5%			136		409		378	84	102	113	269	373	100	272	117	96	98	116	397	228	208
Turbidity	NTU	+/- 2%								28.2	75	25.1	2.11	5.14	34.8	28.2	25.9	31.5	70	71.4	13	28.8	28.2
Conventual									ND														
TSS	mg/L	5.00	ND	ND	ND	ND	9		200						24								
Hardness	mg/L	1.00	120	45	60	72	240		ND						69								
Oil and Grease	mg/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Nitrate and Nitrite (as N)	mg/L	0.50	ND	ND	ND	ND									ND								
Bacteriaological																							
Fecel Coliform	MPN/100 mL	2.00													500		500	500	1300	2400	900	70	1700
Total Coliform	MPN/100 mL	2.00													>1600		1300	16000	>1600	16000	2100	1100	16000
Volatile Organics																							
1,1-Dichloroethane	ug/L	1.00	ND		ND	ND	ND		ND						ND								
1,1-Dichloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,1,1-Trichloroethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,1,2-Trichloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,1,2,2-Tetrachloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,2-Dichloroethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
cis-1,2-Dichloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2-Dichloropropane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,2,4-Trichlorobenzene	ug/L	5.00	ND		ND	ND	ND		ND						ND								
1,3-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
1,3-Dichloropropene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
1,4-Dichlorobenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Benzene	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Bromoform	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Bromomethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Carbon tetrachloride	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Chlorobenzene (mono chlorobenzene)	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Chloroethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Chloroform	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Chloromethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dibromochloromethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dichlorobromomethane	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Dichloromethane	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Ethylbenzene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Hexachlorobutadiene	ug/L	1.00	ND		ND	ND	ND		ND						ND								
Naphthalene	ug/L	10.00	ND		ND	ND	ND		ND						ND								
Tetrachloroethene	ug/L	0.50	ND		ND	ND	ND		ND						ND								

FALL/WINTER 2005-06
ANNUAL SURFACE WATER MONITORING REPORT - PHASE 1
QUALITY CONTROL DATA

Parameter	Units	RL/IAL	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1	SV-1	SV-2	TB-1	CT-1	MM-1	GV-1	WD-1
Toluene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
trans-1,2-Dichloroethylene	ug/L	1.00	ND		ND	ND	ND		ND						ND								
Trichloroethene	ug/L	2.00	ND		ND	ND	ND		ND						ND								
Vinyl chloride	ug/L	0.50	ND		ND	ND	ND		ND						ND								
Inorganic Analysis (Metals)																							
Arsenic	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Cadmium	ug/L	0.25	ND	ND	ND	ND	ND		ND						ND								
Mercury	ug/L	0.50	ND	ND	ND	ND	ND		ND						ND								
Antimony	ug/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Beryllium	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Chromium (total)	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
Copper	ug/L	0.50	ND	ND	ND	ND	ND		ND						ND								
Lead	ug/L	100.00	ND	ND	ND	ND	ND		ND						ND								
Nickel	ug/L	20.00	ND	ND	ND	ND	ND		ND						ND								
Selenium	ug/L	5.00	ND	ND	ND	ND	6.2		ND						ND								
Silver	ug/L	5.00	ND	ND	ND	ND	ND		ND						ND								
Thallium	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Zinc	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Herbicides																							
Bentazon	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
2,4-D	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Dalapon	ug/L	2.00	ND	ND	ND	ND	ND		ND						ND								
Dinoseb	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Picloram	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
2,4,5-TP (Silvex)	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								
Pentachlorophenol	ug/L	1.00	ND	ND	ND	ND	ND		ND						ND								

Appendix D
Impervious Surface Cover by Watershed Catchment

Appendix D - Project Impervious Cover By Catchment

Sub-Watershed Units	Catchment ID	Total Acreage	Impervious Cover (Total) >70 %	Impervious Cover (Total) >25 %	Road Density (Percent Area)
Bear Creek	**BC01A**	1248.4	1.9	23.9	0.6
	BC01B	855.4	9.2	36.5	1.1
	BC01C	541.7	0.0	24.7	0.3
	BC01D	564.6	0.0	52.9	0.6
	BC02	1704.5	0.3	19.9	0.4
Total		**4914.6**	**2.2**	**28.1**	
Big Oak Flat-Groveland	**BG01**	1603.1	9.5	43.0	3
	BG02	503.6	0.0	0.8	1.2
	BG03	1536.7	0.0	4.3	1.6
	BG04	501.4	0.0	78.7	2.8
	BG05	593.9	0.0	43.3	2.8
	BG06	1234.6	0.0	1.1	0.9
	BG07	2210.6	0.0	1.8	1.2
	BG08	3020.6	0.0	1.6	0.8
	BG09	1441.8	0.0	3.0	1
	BG10	1366.9	0.0	12.1	1.1
	BG11	873.8	0.0	8.7	0.4
	BG12	587.1	0.0	79.0	2.6
	BG13	662.3	4.8	58.7	3.7
	BG14	2272.7	0.0	9.8	0.7
	BG15	2620.7	0.0	35.9	1.3
	BG16A	1032.7	0.0	0.0	0
	BG16B	978.2	0.0	0.0	0
	BG16C	263.2	0.0	0.0	0
	BG16D	911.2	0.0	0.0	0
	BG16E	680.9	0.0	0.0	0
Total		**24895.8**	**0.7**	**15.3**	
Curtis Creek	**CC01A**	1796.5	7.0	35.6	3.1
	CC01B	2151.0	1.7	30.5	1.9
	CC02	988.0	7.4	54.7	3.4
	CC03	664.5	3.4	37.5	2
	CC04	503.3	63.8	73.8	3.5
	CC05	988.8	10.1	25.5	1.8
	CC06	1461.4	7.9	25.5	1.8

Appendix D - Project Impervious Cover By Catchment

	CC07	693.7	0.0	6.6	1.1
	CC08	1530.6	0.0	15.2	1.2
	CC09	635.4	0.0	0.2	1.2
	CC10	630.4	0.0	0.0	0.1
	CC11	1999.5	0.0	0.2	0.5
	CC12	927.1	0.0	0.0	0.4
Total		**14970.2**	**5.3**	**22.5**	
Deer Creek	**DC01**	2537.6	0.0	0.3	0.7
	DC02	1515.3	0.0	0.0	0.6
	DC03	1109.6	0.0	0.0	0.7
	DC04	939.9	0.0	0.0	0.5
	DC06A	1344.7	0.0	0.0	0.6
	DC06B	213.6	0.0	0.0	0.1
	DC06C	1186.0	0.0	0.0	0.2
	DC07	1489.5	0.0	0.0	0.0
	DC08	1054.4	0.0	0.0	0.4
	DC09A	671.7	0.0	0.0	0.2
	DC09B	556.4	0.0	0.7	1.4
	DC09C	1955.1	0.0	0.7	1.2
Total		**14573.9**	**0.0**	**0.2**	
Kanaka Creek	**KC01**	2551.6	0.0	9.7	0.6
	KC02	1105.8	0.0	5.4	1.3
	KC03	991.0	0.0	3.5	0.7
	KC04	2359.8	0.0	5.0	0.7
	KC05A	1029.7	0.0	3.4	0.9
	KC05B	376.4	0.0	0.1	0.6
Total		**8414.3**	**0.0**	**5.9**	
Lower Sullivan Creek	**LS01**	1190.2	5.0	32.2	2.0
	LS02	825.5	13.6	58.6	4.8
	LS03	598.7	32.4	79.4	3.4
	LS04	1148.6	7.2	19.9	2.4
	LS05	530.9	26.1	31.3	4.0
	LS06	1105.8	0.0	41.8	2.3
	LS07	802.2	11.1	26.4	1.0
	LS08	953.6	0.0	0.6	0.4

Appendix D - Project Impervious Cover By Catchment

	LS09	602.5	0.4	3.2	0.6
	LS10	1059.0	0.0	7.0	0.5
	LS11	566.4	0.0	0.4	0.0
Total		**9383.4**	**7.2**	**26.8**	
Mormon Creek	**MC01A**	700.9	19.5	42.1	2.06
	MC01B	551.9	42.3	66.2	2.51
	MC01C	1076.0	15.5	69.9	3.19
	MC02	703.9	14.1	30.3	2.51
	MC03	1836.6	0.1	17.0	1.44
	MC04	746.3	0.4	10.1	1.24
	MC05	1070.7	0.7	14.8	0.77
	MC06	3694.3	0.0	29.9	0.31
Total		**10380.7**	**6.2**	**25.4**	
Rough and Ready Creek	**RR01**	3672.3	0.0	6.5	0.4
	RR02	1166.7	0.0	0.8	0.4
	RR03	1880.1	0.0	0.2	0.0
	RR04	417.5	0.0	0.0	0.0
	RR06	807.3	0.0	6.9	0.0
	RR07	648.5	0.0	0.0	0.0
	RR08	1371.2	0.0	0.3	0.0
	RR09	804.4	0.0	0.2	0.0
Total		**10768.0**	**0.0**	**2.9**	
Turnback Creek	**TC01**	1313.8	0.2	26.8	2.4
	TC02	933.3	0.0	15.9	1.3
	TC03	1308.2	0.0	24.8	2.1
	TC04	1274.4	0.0	44.1	1.7
	TC05	986.4	6.1	40.8	2.1
	TC06	822.2	0.0	19.0	1.3
	TC07	4794.0	1.4	11.7	1.0
Total		**11432.4**	**1.1**	**21.9**	
Upper Sullivan Creek	**US01**	2226.5	0.0	48.7	3.2
	US02	1133.8	0.0	23.0	2.1
	US03	1946.9	3.9	56.9	4.2
	US04	479.9	0.0	49.2	3.7
	US05	967.2	1.7	27.2	2.4

Appendix D - Project Impervious Cover By Catchment

	US06	903.7	0.4	1.5	1.0
	US07	606.9	0.0	9.6	1.7
	US08	1226.3	0.0	4.3	1.2
	US09	703.0	1.5	32.3	1.2
	US10	1302.6	0.0	17.5	1.1
	US11	938.2	0.0	32.1	1.1
	US12	637.6	0.0	69.4	3.8
	US13	510.7	0.0	39.2	1.9
	US14	660.1	0.0	43.9	2.7
	US15	1027.7	0.0	33.5	2.6
Total		**15271.0**	**0.7**	**33.5**	
Woods Creek	**WC01A**	738.2	6.7	14.5	1.8
	WC01B	557.7	0.0	8.2	2.6
	WC01C	351.2	0.4	24.4	1.4
	WC02	1006.7	0.7	30.7	2.5
	WC03A	593.5	0.0	3.4	0.8
	WC03B	313.0	16.4	35.4	2.4
	WC04	1847.0	5.7	24.6	2.8
	WC05	2224.5	3.9	16.2	3.3
	WC07	1565.7	9.4	29.0	3.4
	WC08	2089.0	7.1	34.8	2.4
	WC09	1416.3	0.5	12.4	1.5
	WC10	1519.8	11.3	30.3	3.2
	WC11	862.3	0.0	8.1	1.3
	WC12	648.2	26.3	42.7	0.7
	WC13	1687.6	0.3	10.3	1.1
	WC14	1472.3	2.5	4.0	0.8
	WC15	573.9	0.0	0.2	0.0
Total		**19466.8**	**5.1**	**20.0**	
PSA Total		**149371.3**	**2.4**	**18.4**	