PHILIP WILLIAMS & ASSOCIATES, LTD
ENVIRONMENTAL HYDROLOGY
550 Kearny Street, Suite 900
San Francisco, California 94108-2404
TEL 415.262.2300 FAX 415.262.2303
www.pwa-ltd.com

Pilarcitos Integrated Watershed Management Plan
Watershed Assessment Update

Prepared for

Pilarcitos Creek Restoration Workgroup

Prepared by

Philip Williams & Associates, Ltd.

with

Sound Watershed Consulting
H.T. Harvey & Associates
D.W. Alley & Associates
Jerry Smith, PhD
Weber-Hayes & Associates

September 29, 2008

PWA REF. # 1884 - T3A

Services provided pursuant to this Agreement are intended solely for the use and benefit of the San Mateo Resource Conservation District.

No other person or entity shall be entitled to rely on the services, opinions, recommendations, plans or specifications provided pursuant to this agreement without the express written consent of Philip Williams & Associates, Ltd., 550 Kearny Street, Suite 900, San Francisco, CA 94108.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1. BACKGROUND

The Pilarcitos Creek watershed, located in the steep coastal hills of San Mateo County, California (Figure 1), covers a 28-square-mile area originating on the east side of Montara Mountain above the City of Half Moon Bay. The watershed encompasses seven subwatersheds containing the following smaller tributaries: Nuff Creek, Corinda Los Trancos Creek, Apanolio Creek, Albert Canyon, Madonna Creek, Mills Creek, and Arroyo Leon. Pilarcitos Creek can be divided into three broad reaches: Upper Pilarcitos, above the confluence with the seven tributaries; Middle Pilarcitos, primarily confined to an agricultural and residential floodplain valley; and Lower Pilarcitos, which flows through the City of Half Moon Bay to the Pacific Coast (Figure 1).

The Pilarcitos Creek watershed is host to a number of plant and animal species, including steelhead trout, which are listed as "threatened" by the Federal government (PWA 1996, RCD 2007b). Over recent history, physical and biological impacts resulting from human activity have degraded the overall watershed condition, threatening native plant and animal species including steelhead (PWA 1996, RCD 2007b). In addition, water demand has increased with the growth of residential, agricultural, and industrial development in the Pilarcitos Creek watershed, decreasing the amount of water available for surface flow in streams. Activities impacting watershed health include:

- agricultural land-use along creek floodplain and riparian corridors;
- water supply management including operation of two large dams, many smaller instream diversions, and several groundwater extraction well systems;
- a large landfill operation;
- local sand and gravel operations;
- urbanization; and
- transportation corridors (e.g., roads).

The San Francisco Public Utilities Commission (SFPUC) owns a majority of the lands in the Upper Pilarcitos region and has stored water in two locations within the watershed since 1910: Pilarcitos Lake behind Pilarcitos Dam, and a very small reservoir behind Stone Dam (Freeman 1912, RCD 2007b). Below the dams, the watershed includes a mix of public and private lands, including agricultural areas. Public landowners include the Coastside County Water District (CCWD), the City of Half Moon Bay (HMB), California State Parks (State Parks), and the Sewer Authority Mid-Coastside (SAM).

These public and private stakeholders have been working intermittently together since the mid-1990s as part of the Pilarcitos Creek Watershed Restoration Project funded by the California Department of Fish and Game (CDFG) and the San Francisco Regional Water Quality Control Board (RWQCB). The Pilarcitos Creek Advisory Committee (PCAC) was formed to advise the CDFG and RWQCB with the Restoration Project. In 1999, the San Mateo Resource Conservation District (RCD) became responsible for implementing the 1996 Restoration Plan (PWA 1996). The PCAC continued in its role as advisor and stakeholder advocate of issues concerning Pilarcitos Creek.

Members of the PCAC and other stakeholders formed the Pilarcitos Creek Restoration Workgroup (Workgroup), which aims to implement restoration and management actions in the Pilarcitos watershed. The Workgroup, with funding and support from the RWQCB and SFPUC, is developing an Integrated Watershed Management Plan (IWMP) with the assistance of the present consultant team. The RCD is acting as the contact manager and convener of the Workgroup meetings. The goal of the IWMP is to restore steelhead trout and other native plant and animal species in the riparian community while minimizing the potential impacts to public health, water supply, and other beneficial uses and economic interests (RCD 2007b).

The Updated Watershed Assessment is a synthesized update of the information provided in the Restoration Plan (PWA 1996) and subsequent studies. This introduction comprises Chapter 1 of the Assessment. Section 2 is a brief overview of watershed processes that provides context for evaluating existing watershed conditions. Section 3 provides a description of the existing watershed conditions. Section 4 summarizes the prioritized alternatives recommended in the 1996 Restoration Plan and provides information on the status and progress of implementation of the Plan.

A spatial inventory of geographic information systems (GIS) data is located in Appendix A, and records of interviews with watershed stakeholders are included in Appendix B.

2. EXECUTIVE SUMMARY

This document provides an update of the description of the Pilarcitos Watershed provided in the 1996 Restoration Plan. Below, key aspects of the watershed description provided by this document are summarized.

2.1 HYDROLOGY

The Pilarcitos Creek watershed encompasses 28 square miles in the steep coastal hills above the City of Half Moon Bay, CA in San Mateo County. Pilarcitos Creek originates on the east side of Montara Mountain and is divided by seven subwatersheds containing the following smaller tributaries: Nuff Creek, Corinda Los Trancos Creek, Apanolio Creek, Albert Canyon, Madonna Creek, Mills Creek, and Arroyo Leon. Recorded precipitation values range from a low of 13.1 inches per year to a high of 65.5 inches per year. A majority of the subwatersheds receive a mean annual precipitation of approximately 33 inches.

The hydrologic conditions are highly variable within the watershed, and stream flows are significantly impacted by flow diversions for both local and regional purposes. Pilarcitos Reservoir and Stone Dam (built circa 1900) have modified flow dramatically, eliminating all of the summer flows from the upper watershed in most years. Hydrologic modification of tributaries (e.g., Corinda de las Trancas) has also modified surface flows in the lower watershed. Section 3 provides detailed hydrologic data for each of the sub-watersheds in the Pilarcitos system.

2.2 GEOMORPHOLOGY

Stream channel geomorphology is determined by the runoff and sediment characteristics of a watershed. In a stable stream channel, runoff and sediment are in balance and the channel neither erodes nor aggrades over time though channel will adjust dynamically to individual runoff events. When watershed runoff or sediment characteristics are altered rapidly by human activity, stream channels are often unable to adjust quickly enough to maintain a stable configuration. Throughout the Bay Area, many stream channels have responded to development-induced runoff increases by “incising” (narrowing and deepening) into the landscape, so that flood flows are not able to access the surrounding floodplain. Stream flow reductions due to dams and/or diversions also have the potential to affect long-term channel morphology, causing excessive deposition and/or channel braiding. Dams can also reduce sediment supply by trapping coarse sediment, causing or exacerbating channel erosion in the downstream channel.

Channels throughout the Pilarcitos watershed are incised, possibly due to long-term land-use impacts that have altered flow patterns, contributing to higher peak flows. Streamside riparian management may also play a role in reducing bed stability within the watershed. An evaluation of sediment sources and transport indicates that two primary sources of sediment in the Pilarcitos Watershed are Apanolio Creek and Upper Pilarcitos Creek below Stone Dam. Section 4 provides a more detailed summary of geomorphic and sediment transport characteristics of the Pilarcitos watershed.

2.3 WATER QUALITY

In addition to water supply, water quality is essential to maintaining public health and often is considered a good indicator of the health of riparian habitats. Riparian habits with native vegetation and dynamically-stable stream channels tend to have clean water in which species such as steelhead trout and the California red-legged frog (CRLF) can thrive. Pollutants, high temperatures, and turbid waters degrade water quality and, therefore, habitat for endangered and special status species. Thus, water quality for multiple beneficial uses is measured or monitored by tracking the presence of contaminants as well as physical and chemical properties of the water such as temperature and turbidity.

Extensive water quality monitoring in the Pilarcitos Creek watershed has resulted in large part from increasing concern about degraded conditions at Venice Beach, where Pilarcitos Creek enters Half Moon Bay. A detailed investigation of water quality in Pilarcitos Creek was initiated by the San Mateo County Public Health and Environmental Protection Division (SMCPHEPD) to determine the cause of the conditions at Venice Beach. Both the SMCPHEPD data, and those collected by the Monterey Bay Sanctuary Citizen Watershed Monitoring Network (Network), a consortium of 20 volunteer monitoring groups on the Central Coast, show consistently high fecal coliform counts compared to other coastal streams (HTB 2004; Network 2003a, 2004b, 2005b, 2006a; SMCPHEPD 2006). The Network data also indicate that trace metals, nitrates, and suspended sediment concentrations were elevated periodically over the period from 2003 to 2006. Potential sources of contaminants include horse manure from trails, fecal waste from a large seagull population, which may be related to the proximity to the Browning-Ferris Industries (BFI) Ox Mountain Landfill, and streamside defecation by agricultural laborers and transient residents of Half Moon Bay (SMCPHEPD 2006).

2.4 RIPARIAN ECOLOGY

The riparian plant community native to the Pilarcitos watershed includes of a wide diversity of native plant species, including alders, willows, and bigleaf maples. Historically, the vegetation structure included a riparian tree over story, a shrub layer and a dense herbaceous layer with no bare ground, supporting diverse and abundant wildlife. Healthy riparian vegetation can also help to stabilize stream banks and reduce inputs of sediment to the streams from bank erosion or by acting as a filter for sediment from upslope or adjacent land. Reduced stream flow and lack of summer base flow due to diversions can affect riparian stand recruitment and evolution. Beneficial riparian species like willow, alder and maple require wetter riparian conditions. Dryer riparian soils promote non-native species like Eucalyptus and various conifer species, which offer lower habitat value.

Invasive non-native species are present in all seven tributaries of Lower Pilarcitos, frequently occurring with high percent cover. Blue gum eucalyptus and Cape ivy appear to be the most pervasive and cover the greatest surface area. The most highly invaded areas appear to be along lower Nuff Creek near the confluence with Pilarcitos Creek, Mills Creek, and the lower reaches of Pilarcitos Creek. Among the five special-status plant species known to occur in riparian habitats within the vicinity of the watershed, only

Hickman's cinquefoil (*Potentilla hickmanii*), western leatherwood, and fragrant fritillary have been reconfirmed in recent years. Section 5 provides further information regarding riparian and other plant communities occurring in the Pilarcitos watershed.

2.5 WILDLIFE HABITAT

Section 6 describes habitat conditions for special-status wildlife species within the Pilarcitos watershed. Species of interest include steelhead (*Oncorhynchus mykiss*), San Francisco garter snake *(Thamnophis sirtalis tetrataenia),* California red-legged frog (*Rana aurora draytonii*), western pond turtle (*Emys marmorata*), riparian-associated bird species, and marbled murrelet (*Brachyramphus marmoratus*).

Steelhead habitat requirements change as they go through different life phases. Adult steelhead require their natal streams to be free of significant barriers to migration, as the majority of spawning often occurs in the upper reaches of tributaries. Adults also need access to spawning gravel in areas free of heavy sedimentation with adequate flow of cool, clear water. For steelhead eggs and pre-emergent fry, the most important consideration in terms of habitat is cool water with adequate dissolved oxygen, free of fine sediment. Deep pools and cover structures, such as boulder clusters and root wads, provide both summer and winter rearing and refuge habit.

Significant factors limiting steelhead habitat in the Pilarcitos watershed include reduced stream flow due to flow diversions, barriers to fish passage, scarcity of spawning habitat (due in part to the presence of fine sediments), and poor quality of rearing habitat. Habitat conditions in the Pilarcitos stream system are summarized by reach within Section 6. Other sections describe habitat conditions and abundance for the other special status species.

2.6 IMPLEMENTATION STATUS AND PROGRESS SUMMARY

Section 7 summarizes the implementation status of recommendations provided in the 1996 Restoration Plan. The recommendations are summarized in a table that lists the current status of each recommendation and provides a brief summary of actions. Recommendations that applied to the whole watershed are listed first, and the remainder of the table is organized by sub-watershed. A brief description of each of the ongoing and completed alternatives follows the table.

3. HYDROLOGY

The Pilarcitos Creek watershed encompasses 28 square miles in the steep coastal hills above the City of Half Moon Bay, CA in San Mateo County (Figure 1). Pilarcitos Creek originates on the east side of Montara Mountain and is divided by seven subwatersheds containing the following smaller tributaries: Nuff Creek, Corinda Los Trancos Creek, Apanolio Creek, Albert Canyon, Madonna Creek, Mills Creek, and Arroyo Leon. For the purposes of this review, Pilarcitos Creek is divided into three broad reaches: Upper Pilarcitos, above the confluence with Albert Canyon; Middle Pilarcitos, primarily confined to an agricultural and residential floodplain valley upstream of the confluence of Arroyo Leon; and Lower Pilarcitos, which flows through the City of Half Moon Bay to the Pacific Coast (Figure 1).

The Pilarcitos watershed rises steeply from the outlet at Half Moon Bay at sea level into the Santa Cruz mountains reaching a maximum drainage relief (difference between the highest and lowest elevation) of approximately 2,044 feet near Montara Mountain. Precipitation is influenced heavily by the change in elevation and associated change in temperature and barometric pressure (Table 1 and Figure 2). Recorded precipitation values range from a low of 13.1 inches per year to a high of 65.5 inches per year. Mean annual precipitation increases from 29 inches in Lower Pilarcitos to 41 inches in Upper Pilarcitos, based on PRISM data that covers a period of approximately 30 years (1961-1990). While Upper Pilarcitos receives more precipitation annually, Pilarcitos Reservoir and Stone Dam capture much of the water converted to runoff. The Upper Arroyo Leon and Mills Creek subwatersheds receive slightly higher precipitation than the remaining subwatersheds, but the range in precipitation is also higher in these two subwatersheds. A majority of the subwatersheds receive a mean annual precipitation of approximately 33 inches or more each year (Table 1 and Figure 2).

Table 1. Pilarcitos Creek Subwatershed Characteristics

Name	Drainage Area (mi^2)	Drainage Relief (ft)	Weighted Mean Annual Precipitation (in)
Upper Pilarcitos Creek	9.1	1737	35.6
Mills Creek	3.9	1646	32.8
Upper Arroyo Leon	2.6	1844	33.5
Middle Pilarcitos Creek	2.2	916	30.9
Apanolio Creek	2.0	1649	33.4
Lower Arroyo Leon	2.0	839	28.1
Madonna Creek	1.7	1132	31.4
Lower Pilarcitos Creek	1.3	436	27.5
Albert Canyon	1.2	1175	32.8
Nuff Creek	1.1	1422	33.0
Corinda Los Trancos Creek	0.9	1627	32.4

* *Weighted mean precipitation derived from the intersection of PRISM precipitation and subwatershed polygons in GIS model.*

The hydrologic conditions are highly variable within the watershed, and subject to considerable modification from flow diversions for both local and regional purposes. Pilarcitos Reservoir and Stone Dam (built circa 1900) have modified flow dramatically, eliminating all of the summer flows from the upper watershed in most years. In 2007, experimental flow releases below Stone Dam have resulting in flow increases of 260 percent relative to the 1997-2006 period. Agricultural use in the watershed spiked after World War II, but farming and total lands under irrigation have declined in recent years (Hank Sciaroni, pers. comm.). Hydrologic modification of tributaries (e.g. Corinda de las Trancas) has also modified surface flows in the lower watershed. The following sections evaluate the existing hydrologic data and information available for the watershed.

3.1 DATA SOURCES & METHODS

Streamflow data for Pilarcitos Creek was obtained from United States Geological Survey (USGS) gage stations located near Half Moon Bay and below Stone Dam (Table 2). The Half Moon Bay gage (11162630) has operated continuously from July 1, 1966 to the present. The Stone Dam gage (11162620) has operated from October 1, 1997 through present. Data from these stations were compiled by SWC and PWA and are discussed in Section 3.2 Instream Flows. Streamflow measurements for several tributaries have also been developed for various studies (e.g., Balance 2001, 2003a, 2003b).

Table 2. Available Data for USGS Gages in the Pilarcitos Watershed

Station Number	Station Name	Available Data	Average Annual Runoff (acre-feet)
11162630	Pilarcitos Creek at Half Moon Bay	Daily streamflow values for 07/1/66 - 9/30/05 Unpublished streamflow data for 10/1/05 - 6/20/07	11,430
11162620	Pilarcitos Creek below Stone Dam, near Hillsborough	Daily streamflow values for 10/1/97 - 9/30/05 Unpublished streamflow data for 10/1/05 - 6/20/07	1,540
11162618	Pilarcitos Lake near Hillsborough	Water stage values for 9/16/99 - 9/30/05 Unpublished stage values for 10/1/05 - 6/20/07	

Rainfall records for the upper watershed were provided by SFPUC, and represent daily rainfall totals for a precipitation gage located on the Pilarcitos Dam. Rainfall records for the lower watershed were obtained from the Western Regional Climate Center archive for the Half Moon Bay National Weather Service Station (NCDC 043714-4). Annual rainfall statistics for each station are presented in Figure 3 and Figure 4 and summarized in Table 3.

Table 3. Annual Rainfall Statistics for Pilarcitos Dam and Half Moon Bay Weather Stations

Annual Precipitation (in)		
	Pilarcitos Dam	**Half Moon Bay**
Min	18.4	13.1
25th percentile	30.1	19.3
Median	36.4	24.8
75th percentile	46.1	30.9
Max	65.5	55.0

Monthly precipitation values for Half Moon Bay indicate that peak precipitation usually occurs in January, and usually ranges from nearly three inches/month to nearly eight inches/month (Figure 5). Precipitation from May through September is typically less than 0.4 inches/month. By contrast, the gage at Pilarcitos Dam indicates that maximum daily precipitation values there often exceed three inches/day and can exceed six inches/day (Figure 6).

3.2 INSTREAM FLOWS

The following sections evaluate available instream flow information for the gaging stations at Half Moon Bay, Below Stone Dam, and tributary subwatersheds.

3.2.1 Pilarcitos at Half Moon Bay

The average daily discharge values for Pilarcitos Creek at Half Moon Bay provide a 43-year record of flows (Figure 7). Total annual flow patterns show an influence of climatic variability consistent with regional patterns (Figure 8). Such patterns include drought periods (e.g. 1975-1977), extreme events (e.g. 1982), and continuous wet periods (e.g. 1994-2000). Such patterns are often cyclical, and are often influenced by offshore oceanic cycling (e.g. El-Nino Southern Oscillation and the Pacific Decadal Oscillation).

Annually, flows follow a regular pattern consistent with Mediterranean rainfall-dominated runoff patterns (Figure 9). The median annual hydrograph typically peaks in February and March near 20 cubic feet per second (cfs). Flows are typically below two cfs from June through mid-November. The rising and falling limbs of the annual hydrograph typically take 40-60 days each.

Peak instantaneous values for the Half Moon Bay gage demonstrate a very wide range of peak flow variability (Figure 10). Several storm events produce peak flows below 500 cfs, while extreme events (e.g. 1982) may produce over 4,500 cfs. A flood frequency analysis using a Log Pearson III method (U.S. Interagency Advisory Committee on Water Data, 1982) suggests a 50 percent probability of a peak flow equal to 700 cfs or more and a one percent probability of a peak flow of 3,800 cfs or more in any given year (Figure 11).

Historically, baseflow[1] discharge at Half Moon Bay has been very low (Figure 12). Until about 1998, summer flow would often be zero for several weeks at a time. Since 1998, some level of average daily flow has been maintained in all but a single day, usually exceeding 0.5 cfs. However, this period has been relatively wet when compared to the historical record (Figure 8).

The USGS has rated the stream gage at Half Moon Bay as "fair," which implies that the hydraulic control at the stream gage location is somewhat dynamic. The rating curve for peak discharges (Figure 13) indicates that similar discharges occur over a two to three-foot range in the gage height over time. Since the rating curves are continually updated by the USGS, the effect on the discharge record is somewhat constrained. However, the record of the shifts in the rating curve can be used to explore the pattern of channel change at the gage location. Such changes can be attributed to deposition, channel widening, channel deepening, or vegetative growth/removal. Figure 14 shows several cycles of change that appear to be consistent with translation of sediment deposits through the site.

3.2.2 Pilarcitos at Stone Dam

The average daily discharge values for Pilarcitos Creek below Stone Dam provide a nearly 10-year record of flows (Figure 15). Flow patterns show a strongly reduced flow and truncated hydrograph relative to the contributing basin area, driven primarily by a few weeks of peak runoff each year. Most runoff is retained by Pilarcitos Reservoir.

The annual hydrograph below Stone Dam clearly shows the effects of water supply regulation (Figure 16). Winter flows rarely exceed five cfs and typically do so only during extreme flow years. The duration of peak flows is short, usually only a few weeks each year. The majority of flows below Stone Dam are well below one cfs. However, since the channel is relatively small here (Table 4), a discharge of one cfs is equivalent to a flow depth of about 0.31 feet (Figure 17).

Table 4. Typical Wetted Channel Dimensions During Site Discharge Measurements

USGS Gage Site	Discharge (cfs)	Wetted Channel Width (ft)	Wetted Channel Area (ft^2)	Average Wetted Depth (ft)	Mean Velocity (ft/s)	Gage Height (ft)
Below Stone Dam Station	0.39	2.5	0.82	0.38	0.55	4.83
Half Moon Bay Station	4.50	9.5	3.81	0.41	1.42	2.72

The USGS has rated the stream gage below Stone Dam as "poor," which implies that the hydraulic control at the stream gage location is significantly dynamic. This may be in part due to the very low quantity of discharge and the relatively small channel that can dramatically limit the accuracy of streamflow measurements. The existing rating curve for peak discharges (Figure 17) indicates that flows rarely exceed a stage of two feet. Observed shifts in the rating curve (Figure 17) suggest chronic

[1] Baseflow refers to the dry season flow not associated with any particular storm, but representative of the "base" of the hydrograph.

aggradation prior to December 2002 when a significant channel change occurred (most likely a large deposit of sediment or debris). Based on the rating curve, the channel appears to have naturally recovered from this disturbance by October 2004 and has been relatively stable since.

The summer of 2007 has been an unusual period for Pilarcitos Creek. While most other Central Coast streams reflected low water years (based on USGS exceedance records), Pilarcitos experienced a high water year, on most days exceeding 90 percent of the historical flows for any given day. A period of "experimental" flow releases below Stone Dam occurred in the summer of 2007, and these flows appear to be at least partially responsible for the higher-than-normal flows in the lower watershed. Despite the modest quantity of water released at Stone Dam in 2007, the proportion of flows from the upper watershed increased by 37 percent from May through September.

Table 5. Average Monthly Flow Conditions for Pilarcitos Creek

	2007 Average Monthly Discharge (cfs)		Proportion of Flows from Above Stone Dam	
	Stone Dam	**HMB**	**2007**	**1997-2006 Average**
Oct	1.65	2.69	57%	14%
Nov	2.70	5.22	64%	8%
Dec	2.07	6.74	44%	7%
Jan	1.12	5.52	19%	11%
Feb	4.05	29.52	13%	10%
Mar	6.58	17.63	25%	8%
Apr	1.55	6.81	24%	8%
May	1.67	4.11	39%	9%
Jun	1.51	3.40	46%	11%
Jul	1.25	1.95	65%	14%
Aug	0.63	1.39	50%	16%
Sep	0.55	1.14	53%	18%

3.2.3 Contribution from Tributary Streams

The watershed below Stone Dam is a significant contributor to flows in Pilarcitos Creek at Half Moon Bay (Figure 18, Figure 19, and Figure 20). Anecdotal reports suggest that Apanolio and Arroyo Leon also contribute significant flows to the lower watershed, though the former subwatershed is not large relative to the other subwatersheds.

While existing gage records are limited for the subwatersheds, stream gages were installed in two tributaries as reported in Balance (2001). Summary hydrologic statistics are provided for one to three years of data when instream gages were operational. These studies were developed to address specific land-use issues and opportunities, and did not seek to compare streamflow conditions in these watersheds against those in other subwatersheds within the Pilarcitos watershed.

While acknowledging the limitations of these data sources, we developed an estimate of the relative contribution of annual flow from each of the subwatersheds (Table 6). Adjusted annual flows do not distinguish between peak runoff and baseflow runoff periods, and therefore extrapolation to other hydrologic evaluations must be considered carefully. For example, Pilarcitos Creek below Stone Dam (Pilarcitos at Sare, located a short distance downstream from where Highway 92 crosses Pilarcitos Creek) contributes over 33 percent of the total annual flow for the watershed. However, most of this flow occurs during peak runoff periods when Pilarcitos Reservoir and Stone Dam are releasing flows. During low-flow periods, the contribution from this reach is much less. By contrast, Apanolio Creek has been observed to offer flows during low-flow periods, when its relative contribution to baseflows probably exceeds 12 percent.

In general, flows in Middle and Lower Pilarcitos Creek are predominantly provided by the subwatersheds of Middle Pilarcitos, Arroyo Leon, and Apanolio. This preliminary analysis does not consider the influence of groundwater exchange or local diversions.

Table 6. Estimated Annual Water Budget

			Unit Mean Flow * (cfs/mi^2)			Total Adjusted Annual Flow (ac-ft/yr) **					
	Functional Drainage Area (sq mi)	Total Subwatershed Area (sq mi)	1998	1999	2000	1998		1999		2000	
Upper Arroyo Leon	2.6	2.58	2.42	1.0	0.92	4,531	12%	1,872	10%	1,723	11%
Mills Ck at Higgins Road	3.82	3.81	2.23	0.94	0.84	6,163	17%	2,598	14%	2,321	15%
Lower Arroyo Leon		*2.15*	*2.33*	*0.97*	*0.88*	3,621	10%	1,511	8%	1,371	9%
Pilarcitos Ck at Sare	3.9	3.9	3.97	2.23	1.91	11,217	30%	6,301	35%	5,397	36%
Madonna Ck at POST	1.13	1.68	1.94	0.78	n/a	2,356	6%	947	5%	n/a	
Apanolio Ck	1.12	2.05	2.57	1.67	1.21	3,824	10%	2,485	14%	1,800	12%
Corinda Los Trancas		0.39	*2.57*	*1.67*	*1.21*	726	2%	472	3%	342	2%
Nuff Ck		0.88	*2.57*	*1.67*	*1.21*	1,638	4%	1,065	6%	771	5%
Middle Pilarcitos Ck		3.93	*2.57*	*1.67*	*1.21*	7,317	20%	4,755	26%	3,445	23%
Pilarcitos Ck at Hwy 1	20.77	20.77	2.45	1.20	1.01	36,865	100%	18,057	100%	15,198	100%

** Italicized data inferred from monitored sites. **Italicized data adjusted to remove upstream subwatersheds already included in budget*

Note: Unit Mean Flow and Drainage Area from Balance Hydrologics (2003a). All percentages relative to Pilarcitos Creek at Hwy 1. Budget does not account for flow diversions or net loss (gain) to groundwater.

3.2.4 Hydrologic Effect of Eucalyptus Globulus

The presence of *Eucalyptus globulus* (blue gum eucalyptus) in the Pilarcitos Watershed is thought to be a potential factor affecting streamflows and hydrologic processes. (See also Section 5, Riparian Ecology, for a discussion of the prevalence of this tree species in the watershed and its role in the condition of riparian habitat.) The basis for this hypothesis is described below.

E. globulus shows high rates of evapotranspiration, even in low water conditions (Pryor 1976). Many drought-tolerant plants have developed methods to slow their water losses but the blue gum appears to have taken a different strategy by developing an extensive root system capable of extracting water from great depths (Bell and Williams 1997). In addition to deep roots, eucalyptus trees can extract water at higher tension levels than some other plants (Pryor 1976), which means they can out-compete plants with inferior water extraction capabilities. Eucalyptus water consumption exceeds that of "ecologically comparable evergreen California chaparral species" (Bell and Williams 1997). In studying whether growing *E. globulus* commercially would impact a municipal water supply, researchers in South Africa found that not only did eucalyptus trees reduce available surface water, they eliminated any evidence of flow in what was once a perennial stream (Scott and Lesch 1997).

In addition to groundwater extraction, *E. globulus* has been associated with high levels of soil hydrophobicity. Soil hydrophobicity, also referred to as soil water repellency, is the condition where soil resists wetting; water applied to the soil surface either runs off or remains on the surface rather than infiltrating the soil (Doerr 1998, Ferriera et al. 2000, Shakesby et al. 2000). Areas of eucalyptus forest in the Mediterranean climates of Portugal exhibited some of the highest levels of soil water repellency ever measured (Leighton-Boyce et al. 2005). Soil under *E. globulus* has shown greatly elevated hydrophobicity when compared to soil under nearby *Quercus agrifolia* (coast live oak) in coastal California hillslopes (Thompson 2006). Environmental impacts of elevated hydrophobicity include increased flood risk, enhanced "preferential flow and associated leaching of nutrients and agrochemicals," reduced microbial activity, and reduced seed germination and crop growth (Doerr et al. 2005).

Shakesby et al. (2000) observed several effects of elevated soil hydrophobicity at small scales and in lab experiments, associating it with reduced aggregate stability, reduced infiltration, enhanced overland flow, increased rainsplash-induced detachment of soil particles, and increased soil erosion. Greater splash detachment is associated with more erosion (Shakesby et al. 2000).

3.3 REVIEW OF WATER SUPPLY RESOURCES

Water in the Pilarcitos Creek watershed is used by the SFPUC, the CCWD, the Ocean Colony Golf Course, and local agricultural and domestic users. Figure 21 shows the Pilarcitos Creek Water Supply System currently used by the SFPUC and CCWD, which diverts water from the upper portion of Pilarcitos Creek at Pilarcitos Dam and Stone Dam.

The state of water supply diversions for the Pilarcitos watershed is complex and our understanding is still evolving. There are several remaining data gaps associated with specific water supply diversions. In some cases, data may be available, but are not available in easily useable formats. In other cases, specific water supply usage data has not been historically collected (e.g. private residential uses, etc.). The following sections summarize our current understanding.

3.3.1 San Francisco Public Utilities Commission

The SFPUC operates reservoir facilities in the upper Pilarcitos watershed. The facilities include Pilarcitos Reservoir, Stone Dam, water conveyance pipelines and tunnels, various buildings and roads. The SFPUC owns the land comprising the upper watershed of Pilarcitos Creek and the stream corridor from Stone Dam Reservoir extending downstream approximately one mile. SFPUC controls access to these lands to protect water quality, and has managed the upper watershed for a number of environmental benefits. EOA (1990) indicated that SFPUC diversions capture 28 percent of the total watershed runoff, the largest amount among existing water users.

Pilarcitos Reservoir has a catchment area of 3.8 square miles (about 2400 acres) and storage capacity of approximately 3,100 acre-feet (1,010 million gallons [MG]). Approximately half of this capacity is maintained as emergency storage for the SFPUC system (pers. comm., Tim Ramirez 2007). Approximately 1,150 acre-feet of water is available for gravity release to Pilarcitos Creek.

Stone Dam Reservoir is located approximately 2.3 miles downstream of Pilarcitos Reservoir. Kennedy/Jenks (2006) indicates that it has a capacity of approximately 14.5 acre-feet (five MG). However, it is unclear whether that capacity is currently available or some percentage is lost due to sedimentation in the reservoir. Stone Dam Reservoir captures and directs water either to CCWD via Lower Crystal Springs Reservoir (Kennedy/Jenks 2006).

Pilarcitos Reservoir is supplied by runoff, primarily during the rainy season. Pilarcitos Reservoir storage is used to supply water transfers to the SFPUC's Reservoir system in the San Mateo Creek watershed (San Andreas and Crystal Springs Reservoirs) and for use by CCWD. Water is diverted into San Andreas Reservoir via a conveyance tunnel from Pilarcitos Reservoir and to Lower Crystal Springs reservoir via a conveyance tunnel diversion at Stone Dam. Most of the water in the San Andreas and Crystal Springs reservoirs comes from the Hetch Hetchy water system. Water deliveries to CCWD are provided directly from Pilarcitos Reservoir through Pilarcitos Creek via diversions operated by CCWD at Stone Dam. Excess capacity is transferred from Pilarcitos Reservoir to San Andreas Reservoir and from Stone Dam to Crystal Springs Reservoir. Flows exceeding the capacity of Pilarcitos Reservoir and the capacity for deliveries are spilled over Stone Dam, providing instream flows to Pilarcitos Creek. Until recently, releases from Stone Dam to Pilarcitos Creek were limited to these brief periods of excess capacity, and stream flow immediately below the dam consisted only of leakage through the spillway boards and seepage through the dam. In 2007, experimental releases were made as part of a study of aquatic resources. These releases have resulted in average streamflow below Stone Dam between June and September 2007 of 1.96 cubic feet per second (cfs).

3.3.2 Coastside County Water District

Coastside County Water District's (CCWD) service area includes the City of Half Moon Bay and unincorporated areas of San Mateo County including Miramar, Princeton-by-the-Sea, and El Granada. CCWD's current service area is 14 square miles and the current estimated population is 19,000 (ABAG, 2008). CCWD owns and operates two treatment plants, 6 pump stations, 17 miles of transmission pipeline, 83 miles of treated water distribution pipeline and 11 treated water storage tanks.

CCWD utilizes three water sources in the Pilarcitos watershed: Pilarcitos Lake (reservoir), a well field in Upper Pilarcitos Creek, and Upper Crystal Springs Reservoir. CCWD owns and operates the well field and purchases raw water from the San Francisco Public Utilities Commission, which is supplied by Pilarcitos Lake and Upper Crystal Springs Reservoir. Although the SFPUC may divert water from the Pilarcitos watershed into Crystal Springs Reservoir, a significant amount of water from Upper Crystal Springs Reservoir is imported from the Hetch Hetchy System. CCWD's agreement with the SFPUC entitles CCWD to a maximum of 2,446 ac-ft per year from Upper Crystal Springs and Pilarcitos Lake combined. In addition to the sources in the Pilarcitos watershed, CCWD owns and operates a surface water diversion and a well field in the Denniston Creek watershed.

The yield from each of CCWD's sources can vary year to year, depending on hydrological conditions and operational constraints. For the purposes of this report, a ten-year average was used to describe the amounts of water used from CCWD's various supply sources. The average annual supply is about 2,725 ac-ft of water from all of CCWD's sources. Annual raw water purchases from SFPUC average about 1906 ac-ft or 70 percent of CCWD's total supply. Pilarcitos Lake supplies 1093 ac-ft year or 40 percent of CCWD's total supply and Upper Crystal Springs Reservoir supplies 813 ac-ft or 30 percent of CCWD's total supply. CCWD's well field in Upper Pilarcitos Canyon supplies 138 ac-ft per year or five percent of CCWD's total supply. Pilarcitos Lake and the Upper Pilarcitos Creek well field combined account for approximately 45 percent of CCWD's total supply.

Pilarcitos Lake is an important supply to CCWD because it flows by gravity and is a reliable source that has low operating cost and high water quality. The theoretical yield of Pilarcitos Lake, during normal hydrological conditions, was estimated to be approximately 1,596 ac-ft per year based on how the Lake is currently being managed. CCWD is limited by the current infrastructure to about 7.1 ac-ft per day from Pilarcitos Lake. If demand is higher than 7.1 ac-ft per day, CCWD must turn off the Pilarcitos Lake source and switch to Upper Crystal Springs Reservoir. CCWD is not currently able to utilize both sources at the same time.

CCWD has a water right license, issued by the State Water Resources Control Board, to operate the well field in Upper Pilarcitos Creek from November 1 to March 31. The license limits CCWD to a maximum of 360 ac-ft per pumping season and it also limits the pumping rate to a maximum of 1.5 cfs. Historically, CCWD has self-imposed an operational constraint to not let the creek go dry from operating the well field. CCWD's well field is located downstream of Stone Dam reservoir, approximately 4,500 feet to 7,300 feet north of Highway 92, in Pilarcitos Canyon.

It is estimated that CCWD's current theoretical yield from the Pilarcitos watershed, which would be Pilarcitos Lake and the well field on Upper Pilarcitos Creek, is approximately 1900 ac-ft per year. Crystal Springs Reservoir is not included because the majority of the water in that source is imported from the Hetch Hetchy System.

3.3.3 Other Water Rights

We updated the previous summary of permitted and unpermitted water rights diversions using SWRCB WRIMS database (http://www.waterrights.ca.gov/ accessed on June 20, 2007). Figure 22 is a map of authorized diversions as registered at the WRIMS database from the Restoration Plan (PWA 1996) and from 2007. Table 7 summarizes permitted appropriative water rights diversions, as well as statements of pre-1914 diversions for each subwatershed. The amount of permitted appropriative diversions in the watershed total about 878 acre-feet per year. Most appropriative users are prohibited by conditions in their permit or licenses from diverting water during the summer. The amount of riparian diversion and pre-1914 appropriative diversions are reported in statements filed with the SWRCB as 2,296 acre-feet per year. The details of both permitted diversions and statements are provided in Table 7.

The total amount of water available to be diverted from the streams amounts to 3,174 acre-feet per year. However, actual usage varies considerably. Not all water rights can be exercised every year. In addition, some water rights uses are consumptive (e.g. water is completely removed from the system), while other uses are less consumptive. For example, agricultural uses may include irrigation practices that return some water to the stream via return flow or infiltration to local floodplain aquifers. As a result, accurate water budgets for the basin are difficult to develop.

Table 7. Summary of Permitted Appropriative Diversions and Statement of pre-1914 Diversions

Creek	Permitted Appropriative Water Rights Diversions (acre-feet)	Statement of pre-1914 Water Diversions (acre-feet)
Pilarcitos Creek	528	1,426
Arroyo Leon	107	30
Apanalio Creek	75	667
Nuff Creek	96	106
Albert Canyon	72	66
TOTAL	**878**	**2,296**

3.4 GROUNDWATER RESOURCES

The groundwater setting of the Pilarcitos watershed is characterized by two aquifers. The first is a coastal plain aquifer (the Lower Pilarcitos Creek Groundwater Basin) which is located generally beneath the town of Half Moon Bay (Kennedy/Jenks 2006). This aquifer is composed of shallow, unconfined and semi-confined, unconsolidated terrace deposits and alluvial sediments. This aquifer is thin, usually with less than 40 feet of saturated thickness, and is underlain by Purisima Sandstone bedrock at 40-80 feet.

The second aquifer is a narrow mountain valley system formed by Pilarcitos Creek and its tributaries. This alluvial aquifer is bounded by a variable depth, low-permeability bedrock channel with shallow alluvial aquifers comprised of loose unconsolidated sand and gravels. It is discontinuous, limited in area, and has high transmissivities in some existing wells (such as the CCWD Pilarcitos Canyon well field). It is likely to be in direct hydrologic connection with the Pilarcitos surface water, so pumping can affect streamflows and may not draw directly on water stored in the aquifer.

3.4.1 Upper Pilarcitos

In the Upper Pilarcitos Creek Watershed (above the confluence with Albert Canyon), available groundwater appears to be stored in alluvial deposits in a narrow bedrock channel following the surface flow, bounded by low permeability bedrock. Six of the seven CCWD wells in Upper Pilarcitos are older, low-efficiency wells drilled prior to 1970. The exception is one recent, more efficient and high-yielding well, 4A, completed in 1995. All seven wells are completed and screened in the shallow alluvium, with total depths of less than 50 feet, and water levels at less than 10 feet deep (Balance 1997).

These wells are in direct connection with stream flow, and reportedly have the ability to dry up the stream when pumped during periods of low stream flow (Kennedy/Jenks 2006). During a 1995 test pumping of new well 4A, pumping at a rate of 265 gallons per minute (gpm) reduced flow in Pilarcitos Creek from approximately 200 gpm to about 20 gpm (Balance 1997). This indicates that the Pilarcitos Canyon well field and the Pilarcitos Creek flow are directly linked, and surface flow can be effectively captured by pumping from the alluvial aquifer. This pumping test also indicated a high transmissivity for this alluvial aquifer, meaning that the operational pumping limits of the existing well field (total pumping rate of 1.5 cfs) are due to limits from the existing well design and construction, not limits of the aquifer. Two recent reports (Balance 1997, Kennedy/Jenks 2006) have reviewed the operation of Pilarcitos Reservoir, Stone Dam Reservoir, and the Pilarcitos Canyon well field to evaluate options to improve aquatic habitat, including increasing the stream flows in a portion of Pilarcitos Creek below Stone Dam and recapturing the water at the Pilarcitos Canyon well field.

3.4.2 Middle Pilarcitos

In the middle section of the Pilarcitos Creek watershed (defined here to include the confluence with Arroyo Leon), available groundwater is limited to alluvial deposits in a narrow bedrock channel following the surface flow, bounded by low permeability bedrock. There are a number of poorly documented surface diversions and private groundwater wells in alluvium for agricultural and domestic use, but no municipal groundwater production. Water extraction by both surface diversions and groundwater pumping from alluvial wells in connection with surface flow is believed to limit and reduce dry season flow in Pilarcitos Creek (Balance 1997).

3.4.3 Lower Pilarcitos

Below the confluence with Arroyo Leon, Pilarcitos Creek emerges from the mountain valley drainage system onto the coastal plain, and flows through the town of Half Moon Bay and into the Pacific Ocean. This area is underlain by the Lower Pilarcitos Creek Groundwater Basin, which is composed of shallow, unconfined and semi-confined, unconsolidated terrace deposits and alluvial sediments (Todd Engineers 2003). This aquifer has less than 40 feet of saturated thickness and is underlain by Purisima Sandstone bedrock at 40-80 feet. Groundwater elevations fluctuate by 10-20 feet seasonally, which is a dramatic change in an aquifer with potentially only 30 feet of saturated thickness in some areas. Because of the proximity and connection to the Pacific Ocean, this aquifer is vulnerable to seawater intrusion from over pumping. No seawater intrusion has been identified.

Many wells have been drilled in this portion of the watershed over time, but many wells have been abandoned due to changes in land use, and to availability of municipal water from the CCWD. The most important groundwater pumping in this basin is the Ocean Colony Partners Balboa well field, used for irrigation of two golf courses. Todd Engineers (2003) estimates total pumping in this basin for export or consumption of 510 acre-feet per year in 2003.

The Lower Pilarcitos Creek aquifer is no longer being used as a source of drinking water. In 1997, five test wells were installed and pumped by the CCWD to evaluate potential for increased groundwater production from the Lower Pilarcitos Creek Groundwater Basin (Nelson 1997, 1998). These wells have been (or are in the process of being) decommissioned by CCWD for a number of reasons. These wells had promising yields, and CCWD hired Todd Engineers to complete a water balance for the aquifer and to estimate a sustainable pumping yield. Todd Engineers (2003) estimated a total remaining sustainable annual pumping of 1,300 acre-feet per year from this aquifer (based on 60 percent of estimated outflow to Pacific Ocean) and suggested a total average annual yield from the proposed five-well Lower Pilarcitos well field of 595 acre-feet per year. This pumping was proposed to be seasonal to avoid creating seawater intrusion and was intended to capture groundwater outflow to the ocean from the aquifer, not reduce existing streamflows in Pilarcitos Creek. Todd Engineers (2003) also recommended blending groundwater with Crystal Springs water to reduce dissolved minerals, and conducting stream flow monitoring in the lower reaches of Pilarcitos Creek to assess the potential for inducing groundwater recharge to the aquifer from the creek by pumping. An engineering evaluation of this proposed well field for CCWD found that the cost of water from the proposed Pilarcitos Creek well field was expected to be similar to the cost of water from Crystal Springs Reservoir (Teter 2002).

3.5 WATER QUALITY

Nitrogen and phosphate are necessary elements for plant growth (Network 2005b) and their abundance can in turn control the abundance of aquatic plants and algae (as can light and substrate). Sources of nitrate include runoff from fertilized lawns, agricultural and pasture lands, construction sites, and septic and sewer system leachate. Orthophosphate is a form of phosphorus commonly bound to soil particles, sewage, fertilizers, and some detergents. Phosphate is relatively common in marine derived rocks, such as those in the Pilarcitos Creek watershed. While phosphate is abundant in the watershed, plants require nitrogen to sustain growth, which generally means that nitrogen is likely to be the limiting nutrient for aquatic plant growth. Large algal blooms can occur when both nitrogen and phosphate are abundant in aquatic systems; such blooms can create water quality conditions that can be toxic to aquatic life or create dissolved oxygen problems when photosynthesis is blocked at night or on overcast days.

Total coliform and Escherichia coli (E. coli) indicate the presence of fecal waste and the associated pathogens that can cause disease in humans and wildlife (Network 2005b). E. coli is a member of the fecal coliform group, a subset of the total coliform group.

Trace metals in stormwater runoff can produce significant toxicity to early life stages of aquatic organisms in coastal urban areas (Network 2005b). The effects include reduced reproduction, developmental deformities, and fatality. The RWQCB (1995) has established general water quality criteria for total zinc (Zn), total copper (Cu), and total lead (Pb) for water bodies. Typical sources of metals are vehicle brake pads, vehicle exhaust, industrial waste, and metal roofs or downspouts.

Suspended and dissolved solids can carry pollutants. Because suspended solids provide a polar charge that attracts contaminants, high levels of sediment are a warning signal for potentially high levels of pollutants. Suspended solids are also harmful to fish populations in fresh water systems because they destroy habitat by suffocating eggs and/or limiting the food supply. Turbidity is a measure of suspended particles in water, and natural turbidity levels vary from stream to stream. Excessive turbidity can indicate erosion, nutrient loading, or artificial algae growth.

Cool water is essential for the survival of steelhead during all portions of their life cycle. Elevated water temperatures (>70° F) can impair growth rates of juvenile steelhead if adequate food is not available and can be fatal at a certain level. Warmer water also can increase the susceptibility to disease among fish (Flosi, 1998). Water diversions and dams decrease streamflow, and removal of streamside vegetation increases exposure to sunlight. Both of these anthropogenic impacts increase water temperature.

3.5.1 Data Sources and Methods

Extensive water quality monitoring in the Pilarcitos Creek watershed has resulted in large part from increasing concern about degraded conditions at Venice Beach, where Pilarcitos Creek enters Half Moon Bay (Figure 23). PWA reviewed a number of different sources related to water quality in Pilarcitos Creek. These sources ranged from volunteer monitoring efforts on Pilarcitos Creek and Venice Beach to detailed studies of Pilarcitos Creek and its tributaries.

Heal the Bay's Annual Beach Report Card provides water quality information regarding California coastal waters. The report card grades over 370 locations year-round on an A to F scale based on daily and weekly fecal bacteria pollution levels in the surf zone. San Mateo County performs weekly water quality sampling in accordance with the AB411 regulatory monitoring.

The San Mateo County was awarded funding from the SWRCB to study and mitigate contaminants causing periodic posting of the state beaches at the Pilarcitos and Gazos Creek mouths. The project was a comprehensive study for the period from July 01, 2001 through March 31, 2006. The water quality sampling and subsequent reports were conducted by the San Mateo County Public Health and Environmental Protection Division (SMCPHEPD).

PWA reviewed all First Flush (FF) and Snapshot Day (SSD) reports from 2000 to 2006 available from the Monterey Bay Sanctuary Citizen Watershed Monitoring Network (Network), a consortium of 20 volunteer monitoring groups on the Central Coast. The Network started the FF and SSD monitoring programs to characterize the water flowing into the Monterey Bay National Marine Sanctuary (MBNMS) including streams in San Mateo County such as Pilarcitos Creek (Network 2000a, 2001a, 2003a, 2004a, 2004b, 2005a, 2005b, 2006a). FF measures pollutant concentrations during the first storm of the year that generates significant runoff. SSD is a one-day event in partnership with the Coastal Watershed Council that utilizes citizen volunteers to collect and analyze water samples. Both programs are developing a core dataset to establish trends in water quality data when compared to Water Quality Objectives (WQOs) designated by the Central Coast Ambient Monitoring Program (CCAMP), the General Basin Plan established by the Regional Water Quality Control Board or the US Environmental Protection Agency. Pilarcitos Creek has been a part of SSD since the monitoring program began in 2000. However, it was not included in the FF effort until 2003.

The RWQCB issues discharge requirements for commercial land users in various watersheds in the Bay area including the discharge of treated wastewater at Ox Mountain Sanitary Landfill by Browning-Ferris Industries (BFI), a trademark of Allied Waste. PWA reviewed the 2007 BFI Cease and Desist order issued by the RWQCB to determine the status of the impacts from the landfill (RWQCB 2007).

3.5.2 Water Quality Conditions

Pilarcitos Creek consistently shows high fecal coliform counts when compared to other coastal streams (Network 2003a, 2003b, 2004a, 2004b, 2005a, 2005b, 2006a). Data from the FF monitoring program also indicate high levels of Zn and Cu from 2003 to 2005 and high levels of nitrate and orthophosphate during their First Flush (FF) monitoring campaign of 2005. The Network reports from the FF and SSD programs do not identify a source for pollutants, but cite human activity as a likely cause. Effluent from the Ox Mountain Landfill operated by BFI is a potential source for the trace metals (see below). In 2003, the Network (2003a) measured a Total Suspended Solids (TSS) concentration of 1920 mg/l compared to an action level of 500 mg/l and higher than 16 other watersheds along the central coast. However, both Total Dissolved Solids (TDS) and TSS remain within typical range for other central coast watersheds in the monitoring years following 2003.

Heal The Bay’s (HTB) 14th Annual Beach Report Card (2004) assigned the lowest rating for water quality (F) to Venice Beach for both dry and wet weather conditions, based on San Mateo County’s AB411 regulatory weekly water quality sampling. Because of continued low ratings on beach water quality, SMCPHED performed a monitoring study which showed consistently high counts of fecal coliform (E. coli) from 2002 to 2004 (SMCPHED 2006). The County of San Mateo's AB411 weekly water quality sampling data shows high fecal coliform during the same period as the SMCPHED and continues to show high fecal coliform counts since that period.

Potential sources of contaminants include horse manure from trails, fecal waste from a large seagull population, which may be related to the proximity to the BFI Ox Mountain Landfill, and streamside defecation by agricultural laborers and transient residents of Half Moon Bay (SMCPHEPD 2006). SMCPHEPD (2006) noted that conditions near this site improved in the sampling period following the removal of the manure pile. However the most recent HTB Annual Beach Report Card (2007) reports that Venice Beach still has poor water quality in dry and wet weather conditions.

In the Corinda Los Trancos Creek tributary, there is extensive groundwater and surface water quality monitoring data associated with operation of the BFI Ox Mountain Sanitary Landfill. The RWQCB (2007) notes that BFI maintains a groundwater extraction and treatment system consisting of two 2,000-pound granular activated carbon filtration units installed in series. BFI treats only naturally occurring groundwater that contains pollutants as a result of infiltration into the landfill or contact with the landfill liner system. The RWQCB increased the effluent limits for trace metals such as mercury, cyanide, copper, nickel, and silver beyond BFI's current ability to limit trace metals in its discharge waters (RWQCB 2007). However, in conjunction with BFI, the RWQCB established a schedule for the reduction of these contaminants by October 2011 through monitoring and adaptive maintenance and improvements to the existing groundwater treatment system.

3.5.2.1 Water Treatment Facilities

The Sewer Authority Mid-Coast (SAM) owns and operates a water treatment plant located at Half Moon Bay. The plant provides secondary level treatment for domestic and industrial wastewater from the City of Half Moon Bay, Montara Sanitary District, and Granada Sanitary District. SAM's service area presently has a population of 20,000. The treatment plant has an average dry weather flow design of 2.0 MG per day (mgd), and can treat up to 2.5 mgd during the wet weather flow period. The plant presently discharges an average dry weather flow of 1.5 mgd, and an annual average effluent flow of 1.525 mgd. Treated wastewater is currently discharged into the Pacific Ocean within the Monterey Bay National Marine Sanctuary, an area of special biological significance. The discharge point is west of the outlet of Pilarcitos Creek. Discharge occurs through a submerged diffuser about 1900 feet offshore at a depth of 37 feet below mean lower low water. Water is discharged with an initial dilution ratio of 119:1.

4. GEOMORPHIC CONDITIONS

Stream channel geomorphology is determined by the runoff and sediment characteristics of a watershed. In a stable stream channel, runoff and sediment are in balance and the channel neither erodes nor aggrades over time though channel will adjust dynamically to individual runoff events. Different reaches can be sources of sediment, transport sediment, or be sinks of sediment depending on their location in the watershed. In general, headwater tributary channels are sediment sources as they erode into the surrounding landscape, mid-section reaches are transportational, and downstream reaches are depositional as their lower gradient causes sediment eroded upstream to deposit out on a floodplain. However, over geological time, erosion, transport and deposition are in balance and the stream channel remains dynamically stable.

When watershed runoff or sediment characteristics are altered rapidly by human activity, stream channels are often unable to adjust quickly enough to maintain a stable configuration. Watershed development, including grazing and other agricultural uses, can cause rapid increases in runoff frequency, intensity and volume, which in turn trigger channel erosion. Throughout the Bay Area, stream channels commonly respond to these changes by “incising” into the landscape, so that flood flows are not able to access the surrounding floodplain. Concentrated runoff in incised channels can scour channel beds and undermine banks, generating increased sediment and destabilizing both channel and banks.

Streamflow regulation due to dams and/or diversions also has the potential to affect long-term channel morphology. Reduced peak flows and shorter flow durations reduce sediment transport, causing excessive deposition and/or channel braiding. On the other hand, dams can also reduce sediment supply by trapping coarse sediment, causing or exacerbating channel erosion in the downstream channel.

4.1 DATA SOURCES AND METHODS

The primary data sources for our description of the geomorphic evolution of the watershed were previous reports by Balance (2001, 2003a, 2003b) and the Restoration Plan (PWA 1996). In addition to these reports, we reviewed the oral histories collected from local stakeholders (Appendix B), aerial photos of the watershed, and historic USGS quadrangle maps.

As a foundation for this assessment, we compiled a spatial database of physical watershed parameters that affect channel sedimentation and morphology (Appendix A). We also acquired the following data layers for use in Geographic Information System (GIS):

- Roads in the Pilarcitos watershed,
- Digital Elevation Model from the USGS Seamless Data Distribution System (SDDS),
- Soils from the National Resources Conservation Service SSURGO database,

- Geology of San Mateo County (Brabb et al. 1998) available via the USGS Open Online Geologic Map Database,
- Debris flows in San Mateo County resulting from the 1982 storm (Ellen et al. 1997).

We spatially defined hydrology in the watershed using several GIS tools, including the ESRI ArcHydro Tools extension and IDRISI’s Kilimanjaro raster analysis tools. We used these tools to classify channel characteristics such as stream gradient and morphology, develop longitudinal profiles of mainstem channels, develop statistics of hillslope and channel gradient by subwatershed, and develop slope hazard maps. We also digitized features from the Restoration Plan (PWA 1996) such as gullies, bank erosion sites, road-related erosion sites, and landslides.

4.2 WATERSHED GEOLOGY

Geology in the Pilarcitos watershed is primarily a mixture of sedimentary and volcanic rocks (Figure 24) (Brabb et al. 1998). Sedimentary rocks of the Franciscan assemblage and the Monterey Formation are found throughout the eastern part of the watershed in the Madonna, Mills, and Arroyo Leon subwatersheds and are found to a lesser degree in the Apanolio and Corinda Los Trancos subwatersheds. Limestone and greywacke exist in Upper Pilarcitos above Pilarcitos Reservoir. Volcanic rocks, predominantly granitic rocks of Montara Mountain (Brabb et al. 1998), are found throughout the western part of the watershed in the Upper Pilarcitos, Apanolio, Corinda Los Trancos, and Nuff Creek subwatersheds.

Rocks of the Franciscan assemblage vary in composition and texture, and therefore in erodibility. The sedimentary rocks underlying the Mills Creek and Arroyo Leon subwatersheds are consolidated (Balance 2001) and generally considered fine-grained. The Monterey and Lompico formations are also fine-grained in texture and are susceptible to erosion. The granite and granodiorite on Montara Mountain are deeply fractured and highly weathered, transforming to coarse sand. Balance (2001) measured sediment delivery at the base of each of five of the Pilarcitos subwatersheds (Upper Pilarcitos, Apanolio, Corinda Los Trancos, Madonna, Mills, and Upper and Lower Arroyo Leon) and noted that the granite, due to the softness of the minerals, crumbles easily.

The parent material (bedrock) in the Pilarcitos Watershed is reflected by the soil particle size assigned in the SSURGO soils database compiled by the United States Department of Agriculture (USDA) (Figure 25). Soils in the Pilarcitos watershed are predominantly of mixture sand and silt with fewer soils dominated by clay (Figure 25). Higher percentages (~63 to 96 percent) of sand are coincident with granitic rocks, and moderate percentages of silt (~34 to 53 percent) mixed with sand are coincident with sedimentary rocks primarily in the Mills Creek and Arroyo Leon subwatersheds (Figure 25).

4.2.1 Landslides, Debris Flows and Hillslope Erosion

In 1982, a high magnitude rainfall event occurred over a wide region of the San Francisco Bay area including San Mateo County and the Pilarcitos watershed (Brabb et al. 1998). This event triggered hundreds of debris flows in the Pilarcitos watershed. Such debris flows can be a significant source of sediment depending on their proximity to the channel (Figure 26). PWA (1996) performed a watershed reconnaissance to catalogue gullies, landslides, bank erosion sites, and road-related erosion events (Figure 26). The lack of spatial correlation between the location of 1982 debris flows and the location of gullies and landslides catalogued in the Restoration Plan (PWA, 1996) underscores the stochastic nature of hillslope erosion. Figure 26 also demonstrates the widespread contribution from hillslope failure to available sediment in the Pilarcitos watershed.

The extent to which natural hillslope erosion (gullies, landslides, debris flows) contributes to channel sedimentation is defined by the source-area gradient or slope, convergence, deposition-site conditions, and connectivity with the Pilarcitos Creek mainstem and/or the tributary channels (Benda and Cundy 1990). This connection between the hillslope and the channel is influenced heavily by the steepness of the slopes in the watershed. Steeper, convergent slopes also tend to be more erosive as they are more prone to failure in the form of landslides and debris flows (Deitrich and Dunne 1978). Upon failure, such features create a “hollow” that cyclically fills and evacuates over a period of decades to millennia (Dietrich et al 1987). The proportion of each watershed that contains these sources of landslide and debris flow sediment was evaluated by integrating a two different DEM analysis tools (convergent channel network and slope) and performing basic statistics for the distribution of these features. The convergence channel network was defined for all linear features with a contributing area greater than five acres, and equals over 416 miles for the entire watershed, 61 percent of which includes hollows (Table 8). The steep convergent channels are predominant in the reach below Stone Dam, Nuff Creek and Apanolio Creek (Figure 27).

Table 8. Convergent Channel Network

Convergent Channel Distribution				Greater Than 60 percent Slope			Total Length	
	90th percentile	Median	Watershed Area (ac)	Length (ft)	percent	Density (ft/ac)	Total Length (ft)	Density (ft/ac)
Upper Arroyo Leon	57	31	1,654	14,828	8%	9	189,101	114
Mills Ck	54	32	2,441	17,469	6%	7	289,915	119
Lower Arroyo Leon	34	13	5,470	792	0%	0	164,992	30
Lower Pilarcitos Ck	6	2	17,949	2,302	1%	0	199,024	11
Middle Pilarcitos Ck	45	21	11,516	7,735	3%	1	264,372	23
Madonna Ck	47	25	1,073	2,566	2%	2	116,811	109
Apanolio Ck	61	38	1,314	20,412	12%	16	167,029	127
Cordina Los Trancos	54	25	561	3,962	6%	7	65,461	117
Nuff Ck	62	40	247	10,791	13%	44	80,176	325
Stone Dam Reach	*116*	*2*	*1,758*	*32,221*	*16%*	*18*	*200,609*	*114*
Regulated Reach	*50*	*31*	*4,048*	*14,300*	*3%*	*4*	*461,283*	*114*
Upper Pilarcitos Ck	56	33	5,806	46,521	7%	8	661,891	114

We used the DEM to calculate the slopes in each sub-watershed (Figure 28). The smaller subwatersheds in the Middle Pilarcitos region, such as Apanolio, Corinda Los Trancos, and Nuff, have a higher average hillslope gradient (Table 8 and Figure 28). The section of Pilarcitos Creek below Stone Dam and above Albert Canyon, Upper Arroyo Leon and Mills Creek also has a high average hillslope gradient (Table 8 and Figure 28).

These results are consistent with measurements of sediment discharge in five of the Pilarcitos subwatersheds performed by Balance (2003a) during Water Year 2000 (October 1, 1999 – September 30, 2000). They measured sediment discharge near the downstream outlet of Mills Creek, Upper Arroyo Leon, Corinda Los Trancos, and Apanolio Creek. They also measured sediment discharge along Pilarcitos Creek just below the confluence with Albert Canyon and the road crossing at Highway 92. Data from their study confirms that the primary sediment sources include Apanolio Creek and Upper Pilarcitos Creek.

Balance (2003a) suggested that this result was counter-intuitive because of the sedimentary rocks found in the Arroyo Leon and Mills Creek, which they described as more erodible than the granitic rocks of Montara Mountain. However, both Balance (2003b) and Brabb et al. (1998) note the highly fractured and deeply weathered nature of the granitic rocks found in the Apanolio, Corinda Los Trancos, and Nuff Creek subwatersheds and in the lower portion of Upper Pilarcitos below Stone Dam (Figure 24). These subwatersheds also contain a high average hillslope gradient and a larger area with slopes greater than 60 percent (Figure 27 and Figure 28).

4.2.2 Land Use Impacts

One of the biggest impacts in the history of the Pilarcitos watershed was the increase in sedimentation resulting from the failure of the diversion dam at the downstream end of the Browing-Ferris Industries Landfill in 1992 (PWA 1996, RCD 2007b). This event in the Corinda Los Trancos watershed contributed massive quantities of sediment to Pilarcitos Creek. Fine sediment destroyed habitat by covering riffles and filling pools, and by creating a flat and shallow sandy substrate (Marston 1993).

Two land uses, roads and agriculture, are likely a large source of human-induced or anthropogenically-generated sediment in the watershed (Table 9). PWA (1996) noted the historic channel modifications to Pilarcitos Creek in the Middle Pilarcitos region as a part of agricultural development. SFPUC provided a partial map of roads for the entire Pilarcitos watershed (Figure 29). Based on quick review of aerial photographs, it appears this road map is incomplete. This coverage is sufficient to identify unpaved roads along Pilarcitos Creek above Highway 92 and along most of the tributaries (Nuff, Corinda Los Trancos, Apanolio, Madonna, Mills, Upper Arroyo Leon). Balance Hydrologics (2003b) performed an inventory of sediment sources in the Apanolio watershed and noted many locations where poorly-maintained or failing roads are contributing to sedimentation in the Apanolio Creek channel. Balance (2003a) also noted that the Highway 92 road crossing (see Section 2.3.4) with Pilarcitos Creek may have increased the sediment discharge measured in water year 2000.

The 1996 Restoration Plan stated that approximately 400 acres of floodplain and hillslope are cultivated for agriculture within the Pilarcitos Creek watershed (PWA 1996). Top soil eroded from the farmed area by sheet erosion is carried toward creeks, and in areas with no riparian buffer, the sediment contribution from agriculture may be high. Agricultural runoff contributes to sedimentation in Apanolio Creek (Balance 2003b). Aerial photographs reveal that much of the floodplain in Middle Pilarcitos is used for agricultural purposes.

Grazing, agriculture and, more recently, urbanization, have changed the relationship between rainfall and the resulting runoff that enters streams and rivers. As a watershed area becomes more intensively developed, a greater proportion of rainfall appears as runoff (as opposed to infiltrating into the soil or being trapped by vegetation), resulting in more frequent runoff events with greater volume and higher peak flows. These flow regime changes disturb the channel equilibrium and often cause erosion of the bed and banks. This process generally is known as hydromodification.

Impacts from hydromodification likely are greatest in Lower Pilarcitos and Corinda Los Trancos. Increasing residential development in Half Moon Bay increases the impervious surface in Lower Pilarcitos increasing the amount of runoff. Lower Pilarcitos is particularly susceptible to impacts from hydromodification because the channel substrate is predominantly sand. The BFI landfill covers a majority of the Corinda Los Trancos watershed ultimately reducing infiltration and therefore summer flows. However, as noted above, the reduction in sediment in Corinda Los Trancos is subject to retention structures that can fail. The Pilarcitos Quarry also increases runoff in the Nuff Creek watershed.

Land-use factors have not been evaluated in any systematic manner to date. PWA contacted the Association of Bay Area Governments (ABAG) for a GIS coverage of land use in the watershed to help quantify the impacts from various land uses. Delivery of this coverage is currently pending further communication from ABAG, and it is beyond the scope of the current phase of the IWMP to develop a land use map from aerial photographs. A more accurate sediment budget incorporating current land use coverage can be developed for the watershed to estimate which land uses are most significantly affecting sediment delivery to Pilarcitos Creek and its tributaries.

Table 9. Land Use Change and Associated Hydrologic and Geomorphic Effects

Change in Land or Water Use	Outcomes of Change	Possible Hydrologic Effect	Possible Geomorphic Effect
STREAMSIDE AGRICULTURAL ACTIVITIES	Drainage reconfiguration (e.g., reducing the number of small ephemeral channels)	Increase in peak discharge. Decrease in lag times of floods.	Increase of erosive stresses in the channel resulting in increases in bank failures. Undermining of banks. Increase in sediment yield.
	Homogenization of land surface	Reduction in the amount of depression storage. Decrease in infiltration rates. Increase in peak discharge. Decrease in lag times of floods.	Increase in erosive stresses in the channel resulting in increases in bank failures. Undermining of banks. Increase in sediment yield.
	Compaction of land	Decrease in infiltration rates coupled with increase in overland flow	Increase in surface runoff and some increase in bank erosion. Some increase in sediment yield.
	Vegetation removal on floodplain		Increase in sheetwash erosion. Rilling.
	Removal of native stream-side vegetation	Reduced evapotranspiration and interception.	Riparian areas are eliminated or degraded. Bank resistance decreases resulting in increased number and extent of failures. Increase in sediment yield.
	Water diversions for agricultural purposes and groundwater pumping	Decrease in flow between points of diversion and disposal, lowering soil moisture in riparian zone. Concentrating of ground water discharge to a point source.	Riparian areas are eliminated or degraded. Bank resistance decreases resulting in increased number and extent of failures. Increase in sediment yield.
	Stream channels put in artificial channels or culverts	Increased flood damage if culverts are undersized. Increased backup flows. Increased downstream peak flood flows if channelized.	Changes in channel geometry and sediment load. Increases in stream channel stability problems. Aggradation and flooding upstream of project structure. Loss of floodplain storage.
	Removal of trees or vegetation	Reduction in infiltration. Reduction in evapotranspiration and interception. Increase in streamflows.	Riparian areas are eliminated or degraded. Bank resistance decreases resulting in increased number and extent of failures. Increase in sediment yield.

Change in Land or Water Use	Outcomes of Change	Possible Hydrologic Effect	Possible Geomorphic Effect
INCREASING LEVEL OF URBANIZATION	Increase in impervious surfaces (including roads)	Decrease in infiltration. Increase in streamflows. Increase in peak discharge. Decrease in lag times of floods. Decrease in water table levels. Flow concentration.	Increase in erosive stresses in the channel resulting in increases in bank failures. Undermining of banks. Gully formation. Increase in sediment yield.
	Stream channels put in artificial channels or culverts	Increased flood damage if culverts are undersized. Increased backup flows. Increased downstream peak flood flows if channelized.	Changes in channel geometry and sediment load. Increases in stream channel stability problems. Aggradation and flooding upstream of project structure. Loss of floodplain storage.
	Removal of trees or vegetation	Reduction in infiltration. Reduction in evapotranspiration and interception. Increase in streamflows.	Riparian areas are eliminated or degraded. Bank resistance decreases resulting in increased number and extent of failures. Increase in sediment yield.

Roads have significant hydrologic and sedimentary influences on the channel network. Road cuts intercept slow natural runoff and routes water into ditch drainage systems that increase flood magnitude, decrease baseflows, and typically transport large volumes of road and ditch sediment. Road drainage systems also can increase the rate of erosion from hillslope swales that receive road drainage from cross-draining culverts. Road systems can also route road sediment directly into tributary channels. Improperly designed or maintained roads also present an increase risk of landslides in the form of hillslope failures. The most damaging road systems tend to be stream-adjacent roads (which have very high rates of sediment delivery), and mid-slope roads (which typically have large hydrologic impacts and sediment delivery rates. Well-designed road systems that are properly maintained can significantly reduce these potential impacts. At the present time, only limited information for existing road conditions is available, although anecdotal evidence of poor road conditions is abundant within the watershed.

4.2.3 Channel Form and Erosion

A number of different factors influence channel morphology including channel bed and bank material, cross-section geometry (width and depth), and channel slope. We used an easily attainable parameter, channel slope, to qualify channel form in the Pilarcitos watershed based on the slope classifications by Montgomery and Buffington (1997) (Figure 30). Channel gradient is a useful parameter in this case for defining the transport potential of the various tributaries in the Pilarcitos watershed. This method discounts local variations in slope and is intended solely for watershed-scale evaluation of channel slope.

A review of current and historic aerial photos suggests that few large-scale channel planform changes have occurred over the last six decades. Planform changes typically occur in response to deposition of coarse sediment or accumulations of large woody debris, both of which are limited in the watershed. Coarse sediment and woody debris also provide important habitat structure, and the lack of structure may also be a limiting factor in habitat creation within the watershed.

Smaller subwatersheds have steeper channels that are typically dominated by cascade, step-pool, and plane-bed morphologies (Figure 30). For example, Corinda Los Trancos and Nuff Creek maintain at least a 2.5 percent slope until the confluence with Pilarcitos Creek. A steeper gradient can contribute to higher velocities and shear stresses in the stream channel, resulting in greater potential for sediment transport.

Larger subwatersheds and portions of Pilarcitos Creek have less steep channels more typically associated with pool-riffle morphology (Figure 30). Pilarcitos Creek maintains a slope of less than 2.5 percent below the confluence with Albert Canyon, and Lower Arroyo Leon maintains a similar slope below the confluence with Mills Creek. Where channel slope decreases, the potential for sediment deposition and storage increases. Sediment deposition in the form of channel bars can be beneficial for habitat, flow diversity, and channel bed stabilization. However, it also can contribute to channel aggradation, which can cause lateral migration and bank erosion.

Another factor that may contribute to sediment is the degree of channel bed instability throughout the watershed. Channels throughout the watershed are incised, possibly due to long-term land-use impacts that have altered flow patterns, contributing to higher peak flows. Streamside riparian management may also play a role in reducing bed stability within the watershed.

4.2.4 Sediment Discharge Rates

In order to estimate the relative sediment contribution from select subwatersheds, we developed a rough estimate of subwatershed peak flows by using data from preliminary estimates of total annual flow for each subwatershed (Table 6) with peak runoff frequencies for the Pilarcitos Creek at Half Moon Bay station (Figure 31). Peak runoff values were assigned to each subwatershed based on the relative proportion of total annual runoff for that subwatershed. Flow values were then input into the sediment rating curves identified by Balance (2003a) to provide preliminary estimates of sediment discharge for various flow probabilities. Given the limits of the available data, we could only apply this approach to peak flow return periods less than five years. This is not an ideal estimate, but is the best approach given the available data.

Results from this estimate are provided in Tables 10 and 11, and indicate that the two primary sources of sediment in the Pilarcitos Watershed are from Apanolio Creek and Upper Pilarcitos Creek below Stone Dam. Balance (2003a) reported that measured rates of sediment discharge as a function of flow from the Apanolio and Corinda Los Trancos subwatersheds were the highest for the watershed. However, Corinda Los Trancos actually has among the lowest total sediment discharges when flow is considered. Corinda

Los Trancos, Upper Arroyo Leon, and Mills Creek each experience sediment bedloads that are roughly three to five percent of the loads of Apanolio Creek when normalized by flow, based on our preliminary estimate.

The results from Apanolio and Upper Pilarcitos may be somewhat high relative to their actual contribution, given the method for deriving our estimates. A more accurate estimate of sediment discharge for each subwatershed may be possible through analysis of 15-minute flow data that will more accurately capture peak flow magnitude and storm duration values. Such data may be available through special request to the USGS and Balance Hydrologics (who report such data being available in their 2001 and 2003 reports). Such data was not available at the time of this writing.

Table 10. Preliminary Estimate of Normalized Bedload Production Rate

		Normalized Bedload Production Rate (tons/day)				
Return Period (yrs)	**Exceedance Probability**	**Mills Ck at Higgins Road**	**Upper Arroyo Leon**	**Pilarcitos at Sare**	**Apanolio**	**Corinda Los Tancos**
1.5	0.67	59	93	1,800	2,000	85
2	0.5	68	107	2,000	2,300	95
2.5	0.4	118	186	3,400	3,900	148
5	0.2	381	602			374

Table 11. Preliminary Estimate of Normalized Suspended Load Production Rate

		Normalized Suspended Load Production Rate (tons/day)				
Return Period (yrs)	**Exceedance Probability**	**Mills Ck at Higgins Road**	**Upper Arroyo Leon**	**Pilarcitos at Sare**	**Apanolio**	**Corinda Los Tancos**
1.5	0.67	460	370	1,000	3,000	240
2	0.5	530	430	1,100	3,500	270
2.5	0.4	920	740	1,800	6,000	410
5	0.2	3,000	2,400			1,000

5. RIPARIAN ECOLOGY

The riparian plant community native to the Pilarcitos watershed includes of a wide diversity of native plant species. Historically, the vegetation structure included a riparian tree over story, a shrub layer and a dense herbaceous layer with no bare ground, supporting diverse and abundant wildlife. Riparian vegetation also helps to stabilize stream banks and reduce inputs of sediment to the streams from bank erosion or by acting as a filter for sediment from upslope or adjacent land. Reduced streamflow and lack of summer baseflow can affect riparian stand recruitment and evolution. Beneficial riparian species like willow, alder and maple require wetter riparian conditions. Dryer riparian soils promote non-native species like Eucalyptus and various conifer species, which offer lower habitat value for instream fisheries.

Riparian vegetation provides shade that regulates thermal heating of the stream. However, shade also reduces the light that allows algae and rooted aquatic plants to grow, and so may also reduce the abundance of invertebrates that act as food for steelhead. Light also allows fish to more easily feed on drifting insects, and increased water temperature increases fish digestive rates. Therefore, a cool, unshaded stream actually provides the best fish growth, provided it is not too cold to significantly slow food digestion. In cooler northern or higher elevation streams, cool and unshaded habitats are common, but along the Central Coast the proper balance between the food benefits of sun and the increased metabolic cost for steelhead associated with stream heating are harder to achieve. The native streamside trees are mostly deciduous (alders, willows, bigleaf maples). Therefore, the dense riparian canopy may be open in spring and late fall to allow algal growth and more efficient feeding. Evergreen forests (redwood, tanoak, and Douglas fir) in upstream riparian corridors and invasive eucalyptus in downstream riparian corridors provide perennial canopies that reduce stream productivity and may reduce fish growth. The deciduous trees also provide softer, nontoxic, more easily digestible leaves that support invertebrates (shredders) that also serve as fish food. Although the riparian corridor along many of the Pilarcitos watershed streams has been narrowed by urban and agricultural development, stream shading is generally quite high because the channels are usually narrow and incised.

Riparian and upland trees (particularly large native evergreens) are also a source of large wood to the stream, where logs, rootwads and branches provide valuable escape cover (especially for larger juvenile steelhead), overwintering shelter from high stormflows and scour objects for deeper, more complex pools. In many small stream channels of the watershed, even small logs (four-inch diameter or less) can provide significant improvement of pool habitat in terms of increased escape cover. Logs also can produce logjams, which can offer important structural habitat components.

5.1 DATA SOURCES AND METHODS

Assessment of riparian conditions is based on available information from previous watershed analyses, various biological reports, and electronic databases. Following a thorough search, information about the condition of vegetation communities has principally relied on existing literature such as the Restoration Plan (PWA 1996) and the SFPUC's 2002 Peninsula Watershed Management Plan (EDAW 2002), as well as database sources such as the California Wildlife Habitat Relationship System (CWHR) and the California Natural Diversity Database (CNDDB) (CNDDB 2007). Information from the online version of the California Native Plant Society's Inventory of Rare and Endangered Plants of California was used in conjunction with CNDDB to evaluate potential occurrences of special-status plant species within the watershed. The minimum mapping unit of vegetation data in the SFPUC's 2002 Peninsula Watershed Management Plan was approximately 0.10 acre (EDAW 2002). Riparian habitat in the Restoration Plan (PWA 1996) was mapped using aerial orthophotos at 1:400 scale and three days of reconnaissance between July and September 1995 on property where access was granted (PWA 1996). Vegetation data from CWHR is derived from Landsat Thematic Mapper satellite imagery, high altitude color infrared photography and ground surveys resulting in a minimum mapping unit of approximately 250 acres.

5.2 DISTRIBUTION AND COMPOSITION OF NATIVE PLANT ASSOCIATIONS

A wide range of vegetation types occur within the Pilarcitos Creek Watershed varying with elevation, aspect, soil types, disturbance regimes, and previous land use (Figure 32). The predominant vegetation community throughout the watershed is a mosaic of coastal scrub and annual grassland (CWHR 2005). Agricultural cropland and urban areas dominate the lower elevations adjacent to Pilarcitos Creek, while in the upper watershed patches of coniferous forest comprised of Douglas fir (*Pseudotsuga menziesii*) and coast redwood (*Sequoia sempervirens*) as well as areas of mixed chaparral are present (CHWR 2005, EDAW 2002). These upland plant communities provide important habitat components for special-status wildlife in the watershed, and some include rare plant species and community types. However, in accordance with the H.T.H.'s scope of work, this assessment is primarily focused on the vegetation within the riparian corridors of the Pilarcitos Creek Watershed.

Riparian vegetation in the Pilarcitos varies between the upper and lower portions of the watershed. Arroyo willow (*Salix lasiolepis*) and red alder (*Alnus rubra*) are the dominant trees in the riparian corridors of the watershed. However, the upper watershed also includes a few additional closely associated habitats along the riparian corridor; these include the coastal scrub, chaparral, and Douglas fir forest. The riparian plant communities in the watershed have previously been classified by various sources within different parts of the watershed (PWA 1996, EDAW 2002). Riparian areas in the lower watershed have been classified into five categories according to the dominant tree species: Willow Riparian Forest, Willow-Alder Riparian Forest, Willow-Mixed Riparian Forest, Eucalyptus-Alder Riparian Forest, or Eucalyptus Grove (Figure 33 and Figure 34) (PWA 1996).

The tree canopy of Willow Riparian Forest areas consists of arroyo willow and yellow willow (*Salix lutea*). This habitat is found along Pilarcitos Creek west of Highway 1 and along the lower reaches of Corinda Los Trancos Creek. Scattered red alder, Monterey pine and blue gum eucalyptus trees also occur within the lower reaches of Pilarcitos Creek. Dominant understory shrubs typically include California blackberry (*Rubus ursinus*), poison oak (*Toxicodendron diversilobum*), and red elderberry (*Sambucus racemosa*). The herbaceous understory in this riparian habitat is dominated by non-native invasive species, particularly Cape ivy (*Delairea odorata*) and poison hemlock (*Conium maculatum*).

Red alder (*Alnus rubra*), arroyo willow (*Salix lasiolepis*), and yellow willow (*Salix lutea*) dominate the upper canopy of Willow-Alder Riparian Forest. Examples of this type of riparian forest occur along the lower reaches of Apanolio Creek, Madonna Creek, upper Arroyo Leon, and Mills Creek (Figure 33 and Figure 34). In addition to the dominant tree species, California buckeye (*Aesculus californicus*), blue gum eucalyptus (*Eucalyptus globulus*), Monterey cypress (*Cupressus macrocarpa*), and Douglas fir occur in scattered locations. The shrub layer is dominated by California blackberry, poison oak, and coast elderberry. Additional shrub species that are present include coffeeberry (*Rhamnus californica*), snowberry (*Symphoricarpos albus var. laevigatus*), thimbleberry (*Rubus parviflorus*), and creek dogwood (*Cornus sericea*). Dominant plant species in the herbaceous understory include stinging nettle (*Urtica dioica*), sword fern (*Polystichum munitum*), and hedge nettle (*Stachys bullata*). Non-native invasive species such as Cape ivy and poison hemlock are also prevalent in the herbaceous understory.

Where arroyo willow and yellow willow are equally dominant with a number of other species in the upper canopy layer, the riparian habitat was classified as Willow-Mixed Riparian Forest. Examples of this habitat occur along lower reaches of Arroyo Leon and Pilarcitos Creeks (Figure 33). Here, associated dominant tree species include red alder, Monterey pine (*Pinus radiata*), and blue gum eucalyptus. The shrub layer is dominated by California blackberry and poison oak with some red elderberry and coyote bush (*Baccharis pilularis*) present. The herbaceous understory is primarily composed of non-native invasive species (see below); however a few native understory species are present including, mugwort (*Artemisia douglasiana*), bedstraw (*Galium sp*.), wild cucumber (*Marah fabaceus*), and hedge nettle (*Stachys palustris arenicola*).

In riparian areas where eucalyptus has invaded and is out-competing native riparian tree species, the corridor was previously classified as either Eucalyptus-Alder Riparian Forest, or simply as a Eucalyptus grove (PWA 1996). Examples of this forest type occur along portions of the lower reaches of all seven creeks in the watershed (Figure 33 and Figure 34). Examples of extensively invaded corridors are evident at the junction of Nuff Creek, Pilarcitos Creek, and along sections of Mills Creek. Although this riparian forest type presently represents a unique forest composition and structure that provides certain wildlife habitat functions, it may be better to consider it as an invaded type of the previous three historic riparian habitat types (i.e. Willow Riparian, Willow-Alder Riparian, or Willow-Mixed Riparian Forest). According to this approach, Eucalyptus-Alder Riparian Forest would represent an example along the continuum from Willow Riparian Forest to pure Eucalyptus Grove. Considering the riparian habitat this way may be helpful in assessing the restoration potential of a given patch of riparian forest, whereby the least invaded areas may be the most cost-effective to restore to a willow or willow-alder type of riparian forest.

Sites along low gradient reaches of the tributaries of the Pilarcitos with access to shallow groundwater or that experience frequent flooding represent good candidate sites to restore Willow or Willow-Alder Riparian Forest. One example that could serve as a reference site for restoration planning purposes can be found upstream of the ponds at Higgins Rd. on Arroyo Leon Creek (Go Native 2002). Tall red alder and yellow willow dominate the tree canopy in this location. The tall shrubs in this area include arroyo willow, creek dogwood, and red elderberry. Additional shrubs include thimbleberry and California blackberry. The herbaceous understory includes western sword fern, California bee plant (*Scrophularia californica*), hedge nettle, and stinging nettle. Above the riparian corridor begins the coastal scrub community, which includes coyote bush, twinberry (*Lonicera involucrata*), coffee berry, sticky monkey flower (*Mimulus aurantiacus*), lizard tail (*Eriophyllum staechadifolium*), yerba buena (*Satureja douglasii*), coast madia (*Madia sativa*), mugwort (*Artemisia vulgaris*), and pink flowering current (*Ribes sanguineum*).

Riparian forest in Upper Pilarcitos, above the junction with Nuff Creek and Pilarcitos Creek, has mostly been classified according to two types of dominant species: arroyo willow or red alder (EDAW 2002). The understory of the red alder dominated areas includes salmonberry (*Rubus spectabilis*) and red elderberry in the shrub layer. Riparian areas with significant amounts of white alder (*Alnus rhombifolia*) also occur between Stone Dam and Pilarcitos Reservoir. In addition, the main channel of Pilarcitos Creek is shown bisecting a patch of old growth Douglas fir / redwood forest as well as running through coastal scrub and chaparral near the headwaters. These upland plant communities within the upper watershed occur in close proximity to the narrow riparian corridor and may be influenced by riparian conditions. Some riparian reaches in the upper watershed include California bay (*Umbellularia californica*), big leaf maple (*Acer macrophyllum*), and Douglas fir in the tree canopy with hazel (*Corylus cornuta*) in the understory shrub layer. Similarly, coast live oak (*Quercus agrifolia*) woodlands grow close to the riparian community near the headwaters of Pilarcitos Creek and side tributaries above Pilarcitos Reservoir. Where coastal scrub grows close to the riparian corridor in Upper Pilarcitos, it can consist of coyote brush, coffeeberry, and thimbleberry.

5.3 INVASIVE PLANT SPECIES

Invasive non-native species are present in all seven tributaries of Lower Pilarcitos, frequently occurring with high percent cover (PWA 1996). Blue gum eucalyptus and Cape ivy appear to be the most pervasive and cover the greatest surface area (Figure 35 and Figure 36). Additional invasive species that occur in the watershed include: poison hemlock, bristly ox-tongue (*Picris echioides*), black mustard (*Hirschfeldia incana*), Italian thistle (*Carduus pycnocephalus*), milk thistle (*Silybum marianum*), periwinkle (*Vinca major*), garden nasturtium (*Tropaeolum majus*), pampas grass (*Cortaderia spp.*), French broom (*Genista monspessulana*), and small-leaf spiderwort (*Tradescantia fluminensis*) (Figure 35 and Figure 36). The most highly invaded areas appear to be along lower Nuff Creek near the confluence with Pilarcitos Creek, Mills Creek, and the lower reaches of Pilarcitos Creek. Detailed information about the amount and location of invasive species are not available for the upper watershed.

5.4 SENSITIVE PLANT COMMUNITIES

Riparian corridors and wetland habitats are considered high priority habitats by the CDFG CNDDB and are subject to federal, state, and county regulations. Freshwater wetland habitat does exist in the watershed; however, it has not been mapped in detail for the majority of the watershed. For example, freshwater wetland habitat occurs at the upstream end of Pilarcitos Reservoir, behind Stone Dam, and in numerous locations along riparian floodplains. Vegetation removal and stream alteration are subject to permits according to Section 1600 of the California Fish and Game Code and Section 404 of the federal Clean Water Act. In addition, these habitats are considered sensitive according to the San Mateo County General Plan (DEP 1986) and Local Coastal Program (LCP) (ESASM 1998) and are accorded consideration within the County grading ordinance. The LCP defines riparian corridors according to the limit of riparian vegetation. According to this definition, riparian vegetation must include at least 50 percent cover of any of the following plant species: red alder, jaumea (*Jaumea carnosa*), pickleweed (*Salicornia spp*.), big-leaf maple, narrow-leaf cattail (*Typha angustifolia*), arroyo willow, broad-leaf cattail (*Typha latifolia*), horsetail (*Equisetum spp*.), creek dogwood, black cottonwood (*Populus balsamifera trichocarpa*), and box elder (*Acer negundo*) (Figure 37).

5.5 SPECIAL-STATUS PLANT SPECIES

A search was conducted to determine whether any special-status plant species might occur within riparian habitats within the watershed. A query of CNDDB records for the three USGS quadrangles that cover the watershed (Montara Mountain, Woodside, and Half Moon Bay) revealed a total of 36 plant species that have historically occurred within these three quadrangles. Many of these species occur outside of riparian habitats in the serpentine grassland and maritime chaparral located in the upper watershed. A cross-reference using the CNPS inventory showed that only five of these species occur within riparian habitats such as those that occur within the Pilarcitos Watershed (CNPS 2007) (Table 12). All five species are included on List 1B by CNPS indicating that they are rare and endangered in California and elsewhere. However, due to the way that coastal scrub, chaparral and Douglas fir forest intergrade with the riparian corridor, especially in the upper watershed, some additional species may occur in close proximity to the riparian corridor that were not detected by this method. Many of the species known to occur in this vicinity are said to occur in coastal prairie, coastal scrub, or Valley and foothill grasslands, habitats that occur closely adjacent to the riparian corridor. For example, fragrant fritillary (*Fritillaria liliacea*) has been reported as occurring, “near the headwaters of Pilarcitos Creek,” even though it is not listed as occurring in riparian habitats according to the CNPS inventory (PWA 1996). One recorded occurrence for western leatherwood (*Dirca occidentalis*) lists associated species as coyote bush, poison oak, hollyleaf cherry (*Prunus ilicifolia*), Pacific black snakeroot (*Sanicula crassicaulis*), and wild cucumber, and a second record lists the associated species as Douglas fir, coffeeberry, and mountain mahogany (*Cercocarpus betuloides*) (CNDDB 2007). These lists of associated species are not comprised of typical obligate riparian species. This suggests caution when considering riparian habitat requirements too narrowly for special-species plant species within the watershed since many are known to occur within both riparian and adjacent habitats, such as coastal scrub. Table 12 shows each species’ rarity status and their associated habitats.

Among the five special-status plant species known to occur in riparian habitats within the vicinity of the watershed, only Hickman's cinquefoil (*Potentilla hickmanii*), western leatherwood, and fragrant fritillary have been reconfirmed in recent years (Table 12). Hickman’s cinquefoil is known to occur just outside the watershed near the town of Montara (Figure 38). A population of Hickman’s cinquefoil was found at this location as recently as 2002. Western leatherwood is known to occur within the watershed and has been reconfirmed in 2001 (Table 12 and Figure 38). Davidson's bush mallow (*Malacothamnus* *davidsonii*), Parry's tarplant (*Centromadia parryi ssp. Parryi*), and coastal marsh milk-vetch (*Astragalus pycnostachyus var. pycnostachyus*) have not been reconfirmed since prior to the early 1920s, though CNDDB records still consider them to be extant. Among these three species, only Davidson's bush mallow has been recorded as ever occurring within the Pilarcitos Watershed, while the other two species were recorded outside the watershed, along the coast, northwest of the watershed boundary. Field notes in the CNDDB record state that recent surveys for coastal marsh milk vetch were limited and that the species needs further study to confirm its presence and extent in the vicinity (CNDDB 2007).

Table 12. Conservation Status, Habitat Information, and Occurrence Records of Special-Status Plant Species Reported from the Vicinity of the Pilarcitos Creek Watershed within Riparian Habitats

Common	Scientific	Family	Life Form	Rarity Status	Habitat	Elevation	Confirmed Status	Bloom Period	Quad
coastal marsh milk-vetch	*Astragalus pycnostachyus var. pycnostachyus*	Fabaceae	perennial herb	List 1B.2 S2.2 G2T2	Coastal dunes, Coastal scrub, Marshes and swamps (coastal salt, streamsides)	0 - 30 m	1902 outside watershed, Pillar Point vicinity	Apr-Oct	Half Moon Bay
Parry's tarplant	*Centromadia parryi ssp. parryi*	Asteraceae	annual herb	List 1B.2 S2.2 G4T2	Chaparral, Coastal prairie, Meadows and seeps, Marshes and swamps (coastal salt), Valley and foothill grassland, Vernally mesic, often alkaline sites	2 - 420 m	1921, exact location uncertain, northwest of watershed near Pacifica	May-Nov	Montara Mountain

Common	Scientific	Family	Life Form	Rarity Status	Habitat	Elevation	Confirmed Status	Bloom Period	Quad
western leatherwood	*Dirca occidentalis*	Thymelaeaceae	deciduous shrub	List 1B.2 S2S3 G2G3	Broadleaved upland forest, closed-cone coniferous forest, Chaparral, Cismontane woodland, North Coast coniferous forest, Riparian forest in mesic brushy slopes, mesic sites, mostly mixed evergreen & foothill woodland communities	50 - 395 m	1954 & 1975 in upper watershed 2001 in upper watershed	Jan-Mar	Montara Mountain
Davidson's bush mallow	*Malacothamnus davidsonii*	Malvaceae	deciduous shrub	List 1B.2 S2.2 G2	Chaparral, Cismontane woodland, Coastal scrub, Riparian woodland in sandy washes	15-355 m	1901 in upper watershed	Apr-Sept	Woodside

Common	Scientific	Family	Life Form	Rarity Status	Habitat	Elevation	Confirmed Status	Bloom Period	Quad
Hickman's cinquefoil	*Potentilla hickmanii*	Rosaceae	perennial herb	List 1B.1 S1.1 G1 SE & FE	Coastal bluff scrub, Closed-cone coniferous forest, Meadows and seeps (vernally mesic), Marshes and swamps (freshwater) freshwater marshes seeps, small streams in open or forested areas along coast	10-135 m	1933 near Half Moon Bay 1996-2002 outside of watershed, north of Montara	Apr-Aug	Montara Mountain
fragrant fritillary	*Fritillaria liliacea*	Liliaceae	bulbiferous herb	List 1B.2 S2.2 G2	Cismontane woodland, Coastal prairie, Coastal scrub, Valley and foothill grassland/often serpentinite	3-410 m	2003 in upper watershed	Feb-Apr	Woodside

Key to Table

CNPS List Definitions
List 1A=Plants presumed to be extinct in California
List 1B= Plants rare and endangered in California and elsewhere
List 2= Plants rare and endangered in California, more common elsewhere
List 3= Plants about which more information is needed, review list
List 4= Plants of limited distribution, watch list

0.1-Seriously threatened in California (high degree/immediacy of threat)
0.2-Fairly threatened in California (moderate degree/immediacy of threat)
0.3-Not very threatened in California (low degree/immediacy of threats or no current threats known)

State and Federal Listing
FE=Federally Endangered
SE=State Endangered

Global Ranking The global rank (G-rank) is a reflection of the overall condition of an element throughout its global range.
G1 =Less than 6 viable element occurrences (EOs) OR less than 1,000 individuals OR less than 2,000 acres.
G2 = 6-20 EOs OR 1,000-3,000 individuals OR 2,000-10,000 acres.
G3 = 21-80 EOs OR 3,000-10,000 individuals OR 10,000-50,000 acres.
G4 =Apparently secure; but factors exist to cause some concern; i.e., there is some threat, or somewhat narrow habitat.
G5 =Population or stand demonstrably secure to ineradicable due to being commonly found in the world.

State Ranking The state rank (S-rank) is assigned much the same way as the global rank, except state ranks in California often also contain a threat designation attached to the S-rank.
S1 = Less than 6 EOs OR less than 1,000 individuals OR less than 2,000 acres
S2 = 6-20 EOs OR 1,000-3,000 individuals OR 2,000-10,000 acres
S3 = 21-80 EOs or 3,000-10,000 individuals OR 10,000-50,000 acres
S4 = Apparently secure within California; this rank is clearly lower than S3 but factors exist to cause some concern; i.e. there is some threat, or somewhat narrow habitat
S5 = Demonstrably secure to ineradicable in California

6. WILDLIFE HABITAT

This section describes habitat conditions for special-status wildlife species within the Pilarcitos watershed. Species of interest include steelhead (*Oncorhynchus mykiss*), San Francisco garter snake, California red-legged frog, western pond turtle, riparian-associated bird species, and marbled murrelet.

6.1 DATA SOURCES AND METHODS

In order to determine the existing conditions of special-status wildlife species within the watershed, we conducted literature and database searches to identify known locations of species occurrences and reviewed aerial photographs to map potential aquatic habitat for special-status reptiles and amphibians.

Habitat assessments and electrofisher sampling of juvenile steelhead were performed in a portion of the watershed in 1995 to rate habitat conditions for steelhead and suggest restoration actions for the Restoration Plan. Since then, additional fisheries studies have been conducted that improve our understanding of previously sampled reaches and/or provide information on areas not previously investigated. In addition, barrier modification and other actions have been taken that modified conditions compared to 1996; details of these actions are provided in a subsequent section.

Because San Francisco garter snake, California red-legged frog, and western pond turtle rely upon aquatic and wetland habitats, we quantified the distribution of ponded environments within the watershed. USDA National Agricultural Imagery Program Aerial photographs taken in the spring of 2005 were used to assess potential aquatic breeding sites (e.g. areas that pond water); ponds were digitized using ArcGIS 9.1. Aerial photographs taken in 2005 were chosen because ponding of water at potential aquatic habitat for these species is more evident in the spring or early summer during a year of at least average rainfall; rainfall was above average in 2005. We felt it necessary to identify pond habitats throughout the watershed, as this habitat type was not explicitly quantified, or discussed, in the Restoration Plan (PWA 1996) and represents important breeding and/or foraging habitat for California red-legged frogs, San Francisco garter snakes, and western pond turtles.

Information on special-status riparian-associated birds was derived from previous reports, the CNDDB, and the San Mateo County Breeding Bird Atlas (Sequoia Audubon Society 2001). Marbled Murrelet occurrences in the Pilarcitos Watershed were obtained from previous reports on murrelet surveys on SFPUC lands (Albion Environmental 1998, CDM and Merritt Environmental Consulting 2003, URS Corporation 2004, Avocet Research Associates 2005, 2006).

6.2 STEELHEAD

Steelhead habitat requirements change as they go through different life phases. Adult steelhead need to have access to their natal streams. This means that streams must be free of barriers to migration, as the majority of spawning often occurs in the upper reaches of tributaries. Adults also need access to spawning gravel in areas free of heavy sedimentation with adequate flow and cool, clear water. For spawning, steelhead utilize gravel that is between 0.5 to six inches in diameter, dominated by two to three inch gravel. Escape cover such as logs, undercut banks, and deep pools for spawning adults is also important.

For steelhead eggs and pre-emergent fry, the most important consideration in terms of habitat is clean gravels and cool water with adequate dissolved oxygen. Fine sediment will smother developing eggs, so the area must not have excessive fine silt or sand. During their first summer, juvenile steelhead are typically found in a variety of habitats, including pools and also shallower riffle and run areas with cobble and boulder bottoms. Juvenile steelhead prefer areas with escape cover, including boulders, undercut banks and woody debris such as logs or tree roots. Cover structures and deep pools are even more important for summer rearing of larger juveniles and to allow fish to survive the high flows of winter. The best pools for habitat are those with abundant escape cover in the form of large woody debris, undercut banks, root masses, and large boulders.

Cool, clean water is essential for the survival of steelhead during all portions of their life cycle. Elevated water temperatures (>70° F) can greatly impair growth rates of juvenile steelhead if adequate food is not available.

This section summarizes available steelhead abundance and habitat information for the Pilarcitos watershed. The first three sub-sections describe significant factors limiting steelhead habitat, and the final sub-section summarizes habitat conditions in the Pilarcitos stream system by reach.

6.2.1 Flow Diversions

As described above, the Pilarcitos Reservoir and Stone Dam complex divert substantial amounts of winter and spring flow to San Andreas Reservoir and Upper Crystal Springs Reservoir (SFPUC) and through a pipeline to CCWD. The winter diversions probably reduce passage conditions for adult steelhead migrating in Pilarcitos Creek, especially upstream of tributaries closest to Stone Dam (ENTRIX 2006b). The CCWD wells may also reduce winter and spring flows in Upper Pilarcitos (Kennedy/Jenks 2006). Reduced spring flows and lack of early summer bypass flows at Stone Dam hinder smolt out-migration in spring and the growth of juvenile steelhead in spring and early summer.

The effects from Pilarcitos Reservoir and Stone Dam could be mitigated with improvements to the diversion and with a change in how the diversions are managed. The City and County of San Francisco and the SFPUC are reviewing the operations of Pilarcitos Reservoir and Stone Dam as part of their Program Environmental Impact Report for Water Systems Improvements.

Numerous smaller diversions on Apanolio and Pilarcitos Creeks and on Arroyo Leon also affect spring and summer stream flows and smolt out-migration and juvenile rearing growth and density. Lower Pilarcitos Creek and Arroyo Leon are normally dry by September in average to dry years due to several appropriative and numerous riparian water diversions. Diversion dams are also potential impediments to adult steelhead spawning access and may also affect smolt out-migration. The diversion on Apanolio

Creek (barrier 1) normally blocks adult access to all potential spawning and the best rearing habitat on that stream. The timing of closure of the dam/pond on Apanolio Creek (barrier 2) is a potential smolt and adult passage issue. The timing of closure at the two ponds (the Johnson Ranch or Guisti Ponds) on Arroyo Leon was a smolt passage issue and a major factor in eliminating their operation.

6.2.2 Culverts and Fish Passage

Culverts are potentially important barriers to adult steelhead migrating upstream. Even when originally constructed at channel grade level, down cutting frequently occurs at the downstream ends of culverts, especially in sandy-bedded streams like those within the Pilarcitos Creek watershed. This produces "perched" culverts. A private culvert on Arroyo Leon and an historical bridge on Mills Creek were modified in 1997-1998 for adult passage following recommendations in PWA (1996). However, the (vortex) boulder weirs used to remediate the culverts were also subject to channel down-cutting and still posed difficulties to steelhead passage in 2007 (Alley 2007b). A private culvert (barrier 3) on Apanolio Creek was modified in 2007 for fish passage with boulder weirs that may be subject to down cutting in the future (Alley 2007a). Modest partial barriers to adult steelhead movement exist at Highway 92 on Pilarcitos Creek (planned for modification by CalTrans) and at Higgins-Purisima Road on Arroyo Leon.

Most importantly, stream culverts can block or impede upstream access for adult steelhead, preventing seeding of upstream habitats. In response to density induced competition, juvenile steelhead generally disperse downstream in late spring and summer and saturate downstream habitats, including reaches where spawning conditions are poor. However, in some cases, barriers can also have effects by blocking juvenile fish from upstream movements. These movements are probably only ecologically significant (limiting to steelhead smolt production) where lower reaches become too warm for rearing or where fish move upstream to or from winter high flow refuges. Even when lower reaches dry up, it appears that fish generally concentrate in deep pools (which also later dry up), rather than move upstream. The apparently low relative significance of juvenile movement in many cases is an important issue, since providing passage for large, high-jumping adults can often be accomplished relatively easily and cheaply compared to providing passage for juvenile fish.

6.2.3 Rearing Habitat

Production of young-of-year (YOY) steelhead in the watershed is probably most affected by the lack of adult spawning access to habitats by made-made barriers and by the quality of spawning habitat, with the best habitat concentrated in upstream reaches. However, steelhead must grow to at least five to six inches in length before smolting and entering the ocean to grow and mature to adulthood, and smaller smolts have much lower marine survival than larger smolts (Bond, 2006). Production of these larger juveniles is more important than production of smaller YOY fish in terms of producing returning adults.

For most habitats within the Pilarcitos Creek watershed (and most other central coast streams (Smith 2006)) juvenile steelhead must spend two years rearing in stream habitat to reach smolt size. That also means that they must survive two winters, and overwintering habitat, in the form of large, complex pools with large instream wood, backwaters and cobble and boulder substrate, is scarce. Yearling and older steelhead are scarce compared to YOY steelhead throughout stream habitat in the Pilarcitos watershed (and many other central coast watersheds), and the shortage of high quality habitat for them limits smolt and adult abundance (Smith 2006).

Where stream habitat is more productive for aquatic invertebrates and summer stream flows are higher (to allow feeding on drifting insects), YOY steelhead can reach smolt size in a single summer. This occurs in high summer stream flow sections of the lower San Lorenzo River and Soquel Creek watersheds (Alley 2007c) and where summer stream flows are augmented downstream of reservoirs, like in Uvas Creek in Santa Clara County (Smith and Li 1983). Lagoons can also provide for fast steelhead growth by providing relatively warm, but extremely productive rearing habitat with abundant food sources (Smith 1990, Bond 2006). Nearly all YOY steelhead rearing in Central Coast lagoons reach smolt size in one summer.

Lagoons/estuaries provide important spring and summer rearing habitat and saltwater transition habitat for smolting steelhead in many coastal watersheds (Smith 1990, Bond 2006, Alley 2007d). For Pilarcitos Creek, the lack of summer stream flow to the mouth prevents the development of a lagoon in all but the wettest years. Even in systems where summer water is available, the beach configuration and sandbar dynamics are major factors in the quality of a lagoon for steelhead rearing in spring and summer. Where scour objects (cliffs, meanders, bridge abutments) are present, the stream tends to scour deep pools that provide residual habitat when the sandbar is open in late winter and spring. These pools provide habitat for feeding by smolts migrating to the ocean and may provide a substantial spring growth increment to improve ocean survival. In addition, the deep pockets, or ponding behind early partial sandbars, trap heavier salt water on the bottom during high tides and provide habitat where smolts (especially smaller ones) can gradually adjust to salt water (by going up and down in the water column). This salt-water acclamation improves their survival upon ocean entry (Smith 1990). Sandbar dynamics are also a factor in lagoon ecology, with early summer sandbar formation damming up inflow and producing productive, mixed, (but often relatively warm) freshwater lagoons (Smith 1990, Bond 2006). Not only does Pilarcitos Creek normally lack a summer lagoon, due to lack or scarcity of inflows, it does not provide a spring feeding or salt water transition habitat for smolts because of a lack of residual depth when the sandbar is not in place; small smolts produced in upstream portions of the watershed probably have minimal transition habitat and low ocean survival (Bond 2006).

In some systems, early sandbar closure in spring can block smolt out-migration, and delayed opening in the winter of drought years can delay adult upstream access. In addition, a broad, shallow open lagoon mouth may restrict successful fish passage to extreme high tide periods. At Pilarcitos Creek, the lagoon is small and relatively small stream flows from Pilarcitos Creek (and Frenchmen's Creek) help to keep the sandbar opened. However, passage through the shallow open lagoon and across the broad lagoon mouth may often be a problem for migrating fish; predation in such a shallow system is an additional threat.

In the Pilarcitos Creek watershed, stream flows are low, fine sediment is abundant and insect production is generally low. No lagoon is usually present. The only habitat that provided for abundant fast-growing steelhead was the two on-channel ponds on Arroyo Leon (the Johnson Ranch or Guisiti Ponds), which acted like productive “upstream lagoons.” Sunlight penetrating these ponds produced algae and an abundance of invertebrate food that allowed YOY and yearling steelhead to grow to large size, despite the higher metabolic cost of living in warmer water (Smith 2001, 2002). The unusually large size of the fish produced in these ponds means that they would have a high probability of returning as adults (Bond 2006). Large size is also especially important in order to survive the transition to salt water in a system like Pilarcitos Creek, where no brackish estuary exists in spring to aid the transition to salt water. If the regulatory issues surrounding operation of these ponds could be resolved, these important habitats might again contribute substantially to steelhead production in the watershed. Depending upon how it is operated, the on-channel pond on Apanolio Creek also has the potential to produce numerous large juvenile steelhead.

6.2.4 Stream Habitat Summary

The Restoration Plan concluded that the most limiting factor to steelhead population was low streamflow resulting from water diversion, which hinders adult spawning migration, smolt out-migration, and juvenile rearing conditions. Although the fishery assessments reported in the Restoration Plan were performed in a wet year (1995), summer stream flows were still low enough to limit steelhead abundance throughout the watershed. Fine sediment throughout the watershed also substantially limited spawning and rearing habitat quality.

Water quality is normally not a major issue for fisheries for most of the watershed. In the running streams, water temperatures are relatively cool, dissolved oxygen is rarely a problem due to mixing in riffles, algae is controlled by shading and limited availability of hard substrates (rather than nutrient levels), and rooted aquatic plants such as watercress provide important habitat for fish and aquatic invertebrates as long as open water exists. Turbidity from road runoff during winter and spring storms is a problem for Albert Canyon and Pilarcitos Creek downstream of the Highway 92 crossing (Smith 1998, 1999).

Water quality is a potential problem in ponded systems such as the ponds on the Arroyo Leon (Smith 2001 and 2002), the pond on Apanolio Creek, and when a lagoon is present at the mouth. In those habitats growth of algae can produce dissolved oxygen depression during extended periods of fog due to algal respiration and a lack of photosynthesis (Smith 2001 and 2002). However, the abundance of algae in those habitats is major reason for their abundance of invertebrates and the rapid growth of steelhead.

“First flush” and other runoff from the town of Half Moon Bay would affect only the lowermost reaches of Arroyo Leon and Pilarcitos Creek; these reaches have low stream flow or are often dry in summer and rear few or no steelhead in most years. However, the issue could be much more important if stream flows in lower Pilarcitos Creek, including to the lagoon, are increased in the future.

Table 13 summarizes the habitat ratings from the 1996 Restoration Plan and subsequent studies. On the Pilarcitos mainstem, stream habitat quality and fish abundance generally increased upstream. Twelve of 17 spawning habitat reach ratings within the watershed were poor, and only three were rated as fair. However, with additional investigations of four upstream reaches since, spawning on upper Pilarcitos

Creek, upper Arroyo Leon and Albert Canyon are rated as fair or better (Table 13). In 1996 rearing habitat was rated fair-good in only three reaches out of 17, but three additional reaches investigated since are rated as fair-good or better (Table 13). The Bongard pond above the second barrier in Apanolio Creek and the two ponds on Arroyo Leon provided, and still potentially could provide, the only “good” or better rearing habitat for juvenile steelhead. The ratings in 1996, and the updated ratings here, “are graded on a curve” because habitat quality in the Pilarcitos Creek watershed is generally poorer than that of other central coast streams.

Table 13. Existing Steelhead Rearing, Spawning and Migration Conditions for Stream Reaches in Pilarcitos Creek Watershed

New information since PWA 1996 is shown in **bold**. Includes source of new information and primary limiting factors (in approximate order of importance). Ratings are "on a curve," as conditions within the watershed are relatively poor (low stream flow, high sediment levels) compared to most other central coast watersheds.

Stream Reach	Up Migration	Spawning	Rearing	Down Migration	New Info Sources	Limiting Factors
<u>Pilarcitos Creek</u>						
Reach 1 (upstream of Half Moon Bay)	fair-good	none	poor	fair		flow, fine sediment, spawning, pool dev.
Reach 2 upstream to Corinda Los Trancos Creek	Good	poor-fair	poor-fair	fair-good		flow, fine sediment, spawning, pool dev.
Reach 3 upstream to Hwy 92	Good	fair	fair	fair-good	**Smith 1998, 1999**	fine sediment pool development
Reach 4 upstream to Stone Dam	fair-good	fair-good	fair-good	good	**Smith 1996, 1998, 1999** **Trihey 1995, 1996** **ENTRIX 2006a,b**	fine sediment, pool development (overwintering habitat)
Reach 5 upstream to Pilarcitos Lake	None	fair	fair	**N/A**	**ENTRIX 2006a,b**	access, fine sediment, flow

Stream Reach	Up Migration	Spawning	Rearing	Down Migration	New Info Sources	Limiting Factors
Arroyo Leon Creek						
Reach 1 Below dams	good	poor	poor	fair-good		flow, fine sediment
Reach 2 Former ponds site	good	poor-fair	stream: poor-fair	fair-good	**Smith 2001, 2002**	flow, fine sediment, pool-development
Reach 3 upstream to drop structure	good	fair	poor-fair	fair-good	**Smith 2001-2002**	flow, fine sediment
Reach 4 upstream to Higgins Rd.	fair— barrier modified but partially failed	poor-fair	fair?	fair-good	**Alley 2007b**	flow, fine sediment
Reach 5 upstream of Higgins Rd.	fair-good?	fair?	fair?	fair-good	**Smith 2006 (limited)**	fine sediment? flow?
Mills Creek						
Reach 1 upstream to historic	good	poor-fair	fair-good	fair-good		fine sediment, flow

Stream Reach	Up Migration	Spawning	Rearing	Down Migration	New Info Sources	Limiting Factors
bridge						
Reach 2 Bridge upstream to gradient increase & small dam	poor- bridge barrier modified, but failing	fair	fair-good	fair-good	**Alley 2007b**	flow, sediment
Reach 3 upstream	good- barriers modified	fair-poor	poor-fair	fair-good	**Alley 2007b**	flow, sediment
<u>Madonna Creek</u>						
Reach 1 upstream to barrier	fair	poor	poor	fair-good		sediment, flow
Reach 2	none	poor	poor-good?	fair		sediment, flow
<u>Apanolio Creek</u>						
Reach 1 upstream to diversion dam	good	poor?	fair?	fair-good		sediment, flow

Stream Reach	Up Migration	Spawning	Rearing	Down Migration	New Info Sources	Limiting Factors
Reach 2 upstream to pond	none-poor	poor?	fair?	fair-good		access, sediment, flow
Reach 3 Pond to flashboard dam apron below BFI boundary	good at present	poor-fair	stream: fair	poor-good	**Alley 2007a**	access, sediment flow
			pond: very good?			pond open/close operations
Reach 4 flashboard dam apron upstream 1.1 miles	none-poor	fair	poor	poor-good	**Alley 2007a**	access, sediment, pool development, flow
<u>Nuff Creek</u>						
Reach 1 upstream to quarry barrier	?	poor	poor	fair		sediment, pool development
Reach 2	none	poor	poor	fair		access, sediment pool development

Stream Reach	Up Migration	Spawning	Rearing	Down Migration	New Info Sources	Limiting Factors
<u>Albert Canyon</u>						
Reach 1 ½ mile to falls	fair-good	good	poor-fair	good	**Smith 1998, 1999**	flow, fine sediment from Hwy 92, turbidity
Reach 2	none	fair	poor-fair (no fish present)	**N/A**		access, flow

Note: Revision of Table 10 from PWA 1996

The following sub-sections summarize steelhead habitat conditions for each stream reach in the Pilarcitos watershed.

6.2.4.1 Lower & Middle Pilarcitos Creek

CDFG conducted a survey of Pilarcitos Creek from Stone Dam to the ocean in 1977 during a severe drought. Continuous surface flow existed only in approximately the ½ mile downstream of Stone Dam. The mainstem was intermittent to channel mile four and was completely dry downstream (Zatkin 2002). Even in recent average years, the creek is normally dry near Highway 1 by late summer. A CDFG survey by seasonal aide Judi Ford upstream to above the Sare property in 1985 found the channel dominated by sand, dewatering by diversions at temporary dams common, and riparian vegetation removal occurring (Zatkin 2002). Conditions were similar in 1995 (PWA 1996) and at the present time. Streamflows are generally highest upstream, and immediately below the Apanolio Creek confluence. Substrate conditions are best immediately downstream of Albert Canyon, but even there habitat conditions are not good. Most of the steelhead habitat downstream of Albert Canyon on Pilarcitos is dominated by shallow glides or runs (Smith 1999). Pools are scarce. During even small storms, this reach received turbid runoff from Albert Canyon. Substrate is predominantly sand with the addition of larger gravels and cobbles from Albert Canyon.

6.2.4.2 Lower Arroyo Leon

Steelhead were common during a CDFG survey of Arroyo Leon in the fall of 1958. On-channel reservoirs (Johnson Ranch or Guisti Ponds) were in place, and angling use was assumed to be heavy in lower reaches and assumed to be planted with hatchery fish (Zatkin 2002). A CDFG Survey of Arroyo Leon in 1992 (Jennifer Nelson) found rainbow trout, steelhead, and frogs (*Rana* sp.) above the impoundments (Zatkin 2002). A large Eucalyptus logjam 100 ft long was observed above the impoundments, and lower reaches were used as an urban dumpsite. In 2000 and 2001, a partial logjam was present at the upper end of the upper pond, at an abandoned flashboard dam.

The two on-channel impoundments provided the best habitat conditions for steelhead in the Pilarcitos watershed in 2000 and 2001 (Smith 2002). Fish reared in the impoundments were large (145-244 mm Standard Length). Almost all captured fish had silvery coloration, lacked parr marks, and had deciduous scales and black edges to their caudal fins. These strong smolt characteristics probably indicated that fast growth in the reservoirs, and cooling conditions in November triggered early preparation for smoltification. Smith (2002) noted early smoltification in fast-growing lagoon fish in previous lagoon studies, allowing them to emigrate to the ocean within a month of sandbar breaching. Reservoir densities were much higher than in stream habitat immediately upstream of them, producing 10 times the number of smolts (and much bigger fish) as an equivalent length of stream habitat in 2001. Relatively few 2-year old smolts were trapped in the reservoirs. About 2,000 steelhead of smolt size were estimated from 0.3 miles of reservoir in the year 2000 compared to 35 smolt-sized fish captured in 0.1 miles of nearby stream. Anglers were commonly seen at the upper reservoir during water quality sampling. These reservoirs could account for the majority of smolt production in Arroyo Leon subwatershed in years like 2000.

These ponds have not been operated since 2001, due to regulatory restrictions (see Section 7).

6.2.4.3 Mills Creek

A CDFG survey of Mills Creek in the fall of 1995 indicated excellent spawning gravel without confirming data (Zatkin 2002). Steelhead/rainbow trout were also observed. Streambed conditions in 1995 (PWA 1996) and 2007 (Alley 2007b) were dominated by sand. Spawning habitat was judged to be at best fair, but improved somewhat upstream. A severe barrier at the historical bridge was modified in 1997 and 1998 (see Section 7); modification partially failed by 2007 (Alley 2007b), and the site remains a significant impediment to adult steelhead movement.

6.2.4.4 Upper Arroyo Leon

A severe culvert barrier to fish passage existed in Arroyo Leon above the mouth of Mills Creek. It was modified in 1998 for passage and was assessed in 2007 (see Section 7). Despite partial failure of the modifications (see Section 4), passage is now suitable for adult steelhead during high winter storms. The culvert at Purisima-Higgins Road required a jump to enter in 1995, but was at grade in 2006, and easily passable in winter. With both barriers passable, adult steelhead can access habitat in Upper Arroyo Leon. Rearing and spawning were rated as “fair” in the Restoration Plan (PWA 1996), based only upon conditions observed immediately up and downstream of the two barriers.

6.2.4.5 Apanolio Creek

Apanolio Creek has higher summer streamflow than other portions of the watershed, because of the sandy granite geology of the upper watershed. However, the stream channel is dominated by sand and the channel is relatively small. The first recent survey of the upper portion of the stream on BFI property was conducted in November and December 2007 (Alley 2007a). Alley found the channel to be sandy, narrow (mostly three to5 feet wide in fall) and incised, with poor pool development (average depths of 0.6 feet and maximum depths averaging only 0.9 feet). Densities of resident rainbow trout were low, with fish inhabiting mostly small pools that constituted only about 30 percent of the habitat in one sampled segment and 10 percent in another. An impassable bedrock falls would block fish migration about one mile upstream on the BFI property, but 2 man-made drop structures that were judged potentially significant steelhead passage impediments are also present in the reach. Three fish passage barriers were identified in this subwatershed downstream of the BFI property in 1995 (PWA 1996) and are described below in Section 4. The upper barrier was modified for fish passage in 2007, but will not be reachable by migrating steelhead until the lowermost barrier is modified. An additional barrier, a perched apron for a flashboard dam, was discovered by Alley (2007a). The barrier, immediately downstream of the BFI property, was at grade in 1995, but the channel has since downcut about five feet on the downstream side. It would now probably be impassable to migrating steelhead except during extreme floods.

Based upon the high densities of juvenile steelhead and rapid growth rates in the Arroyo Leon ponds (Smith 2002), the best potential steelhead rearing habitat in the Apanolio Creek watershed would be in the Bongard on-channel pond, if it were operated in a “fish-friendly” manner (regulated timing of opening and closure, to insure adult and smolt passage) and if the downstream barrier 1 were modified to allow steelhead passage to the pond.

6.2.4.6 Corinda Los Trancos, Nuff & Madonna Creeks

In the PWA (1996) report, Madonna, Corinda Los Trancos, and Nuff creeks were discounted as steelhead resources but contributed summer streamflow and were significant sediment sources. Corinda Los Trancos had very poor habitat conditions. Nuff Creek is relatively small and ditch-like. The small size of the channel is apparently due to attenuated winter storm flows, due to the quarry upstream. There was a concrete/wood dam 0.3 miles up Madonna Creek. It had very limited steelhead habitat because of its very low streamflow. It was intermittent even in the wet year of 1995.

6.2.4.7 Albert Canyon

Albert Canyon contains a small tributary along the uphill portion of Highway 92. Sites immediately up- and downstream from Albert Canyon, were sampled for CalTrans in November 1998 and 1999 (Smith 1998, 1999). Steelhead may access only about ½ mile of Albert Canyon Creek, downstream of a boulder falls. However, because of the shale and sandstone geology of the watershed, this tributary has abundant gravels and cobbles and relatively good spawning habitat. Fine sediment in runoff from Highway 92 is a problem for winter turbidity levels and for fine sediment within spawning gravels. The tributary is probably a very important spawning site that seeds much of the rearing habitat downstream in Pilarcitos Creek. Gravels, cobbles and suitable spawning gravels were common, unlike in most of Pilarcitos Creek. In the very wet first sampling year (1998) juvenile steelhead densities were relatively high in this small stream due to relatively good pool and escape cover development. In 1999 (an average rainfall year), fish density was about two-thirds less, reflecting the effect of low summer stream flows that are typical of the creek.

6.2.4.8 Pilarcitos Creek Between Highway 92 and Stone Dam

An apron and drop structure under Highway 92 are a significant partial barrier to adult fish passage. They will apparently be modified by CalTrans to improve fish passage (see Section 7).

In November 1992 CDFG biologist Jennifer Nelson surveyed the reach between Stone Dam and Pilarcitos Reservoir. Pools were very shallow; the deepest being 1.5 feet deep and most averaging about nine inches. The streambed consisted of sand and was not conducive to spawning or food production. Only four rainbow trout were observed.

Access to CCWD property was not available to the PWA team in 1995, but three sites were sampled by electrofisher by Smith (1996) and reported as Appendix C to the Restoration Plan. The CCWD property on Pilarcitos Creek provided some of the best steelhead spawning and rearing habitat in the watershed (Smith 1996). There was relatively good substrate that would produce good insect abundance if flows were increased. There was good pool development and the streambanks and channel were stable, unlike most other incised reaches in the watershed. Rearing conditions were fair to good. Spawning was fair-to-good. Migration was good for adults and fair-to-good for smolts. Juvenile steelhead densities were between 12 and 23 smolt-sized juveniles/ 100 ft.

Balance (1997) summarized results from PWA (1996) and Smith (1996) in their report, but did no additional fish sampling. Trihey and Associates, under contract with the SFPUC, conducted habitat and electrofishing sampling on CCWD and SFPUC properties, downstream of Stone Dam in 1995 and 1996 (Trihey 1995 and 1996). A qualitative habitat assessment conducted August 4, 1995 by Trihey & Associates (1995), identified habitat conditions consisting of mostly shallow run with probably less than 20 percent pool habitat in a well-developed riparian corridor. They surveyed 1.5 miles of habitat including three 100 ft segments that were electro-fished. Most fish captured were YOY's, 37-97 mm fork length. Older fish were 114-179 mm fork length. They estimated that approximately 2,500 fish/mile inhabited the property with 3,700 juvenile trout estimated. Riffles contained gravels and some cobbles. Fine textured streambed probably made aquatic insect production low. Several small pools were observed at one to 1.5 feet in depth (did not specify maximum depth or average depth). Trihey & Associates (1995) concluded that other than fine sediment, there was good to very good habitat for juvenile trout, although their observations do not seem to support this conclusion.

Trihey & Associates (1995) recommended several habitat improvements, including:

- periodic channel maintenance/flushing flows
- flow augmentation in dry years
- better roadway drainage and road maintenance with graveling
- placement of Douglas fir logs across the stream to cause scour pools
- gravel augmentation (addition of imported, rounded river gravels) to increase spawning gravel
- acquisition of a stream conservation easement downstream of the CCWD property in order to restore the riparian corridor

These studies were in general agreement between years and with Smith (1996) that spawning and rearing conditions in the reach were somewhat better than further downstream on Pilarcitos Creek. However, low summer stream flows and abundant fine sediment (granitic sand) limited rearing habitat. Substrate conditions were best (more gravels, cobble and boulders) in the first mile downstream of Stone Dam, where gradient was higher and sediment input was reduced by sediment retention at Stone Dam. However, this portion of the reach had the lowest summer stream flows because seepage flow past the dam was minimal and west bank tributary inputs were further downstream. Smith (1998, 1999) sampled a site at the bottom of the reach (immediately upstream of Albert Canyon Creek on the Sare property) in

1998 and 1999, finding habitat sandier and fish scarcer than further upstream during previous sampling in the 1995 and 1996.

Habitat conditions were investigated and an evaluation of the relationship of flow to rearing habitat, spawning habitat and passage downstream of Stone Dam was conducted in 2004 by ENTRIX (2006a, 2006b), as Appendices A and B in the 2006 Kennedy/Jenks report. These studies indicated that an increase in summer stream flow would substantially improve rearing habitat conditions for steelhead. However, the quantitative results of the flow study should be considered preliminary because of questionable methods associated with: choosing cross-section locations to model, the low number of cross-sections modeled, selection of the reference grade conditions, assumptions made for habitat suitability and passage criteria, and the exclusion of escape cover as factor to be modeled for rearing habitat as a function of streamflow.

6.2.4.9 Pilarcitos Creek Upstream of Stone Dam

ENTRIX (2006a) evaluated habitat conditions and sampled fish (resident rainbow trout) in 2004 in the reach between Stone Dam and Pilarcitos Reservoir. They concluded that spawning and rearing habitat and existing fish populations were generally similar to those downstream of Stone Dam. Low stream flows and fine sediment limited rearing habitat quality. Pools were relatively scarce and shallow, but escape cover (in the form of overhanging riparian vegetation) was common. The report concluded that an additional 2.3 miles of stream could be provided for steelhead above Stone Dam, which would add 27 percent to the total length of Pilarcitos Creek mainstem accessible to steelhead. No upstream passage at Stone Dam presently exists, but options for providing passage were evaluated in Kennedy/Jenks (2006). An environmental constraint in laddering Stone Dam is that if too much bypass flow is required to provide up- and downstream steelhead passage over the dam in winter and spring, there will be insufficient bypass flows available for rearing habitat below the dam in summer and fall. Without these bypass flows, Pilarcitos Creek may become intermittent between the dam and the CCWD well field during the dry season.

6.3 HERPETOFAUNA

Riparian habitat supports a diverse assemblage of flora and fauna and is considered one of the most important wildlife habitats in North America. Riparian corridors are used by a wide variety of wildlife for breeding, foraging, and dispersal. The Restoration Plan (PWA 1996) focused on riparian conditions and highlighted potential restoration and management strategies for the tributaries and associated vegetation communities throughout the watershed. Non-fish, special-status wildlife species that were identified in the plan as known to occur within, or in close proximity to, the watershed included San Francisco garter snakes, California red-legged frogs, and western pond turtles; however, the plan included relatively little information on these species. Furthermore, although the riparian corridor represents important habitat for all of the aforementioned species (especially for foraging and dispersal), ponded and slow moving backwater pools are considered the primary habitats for these species. Incised channels, dense forest cover, and/or high winter and spring flows that are common along creeks within the watershed provide marginal to poor habitat for this group of herpetofauna. Rather, ponded environments, deep slow moving waterways, and off-channel pools represent very important habitat for these species. In addition to suitable aquatic habitat, appropriate upland habitat is also an important component of maintaining viable populations of these species.

6.3.1 California Red-legged Frog

(Rana aurora draytonii).
Federal Status: Threatened;
State Status: Species of Special Concern

The California red-legged frog is a member of the family Ranidae within the order Anura, and is one of two subspecies of the red-legged frog (*Rana aurora*). The *draytonii* subspecies was included as a Category 1 candidate species in the U.S. Fish and Wildlife Service's Annual Notice of Review in November 21, 1991. On June 24, 1996, the California red-legged frog was officially listed as a Threatened species under the auspices of the Federal Endangered Species Act (FESA) (USFWS 1996) based largely on a significant range reduction and continued threats to surviving populations. Factors related to declines in populations of red-legged frogs include the degradation or loss of habitat attributed to agricultural practices, introduced plants and animals, livestock grazing, mining, water diversions and impoundments, water quality, recreation activities, timber harvesting, and urbanization.

California red-legged frogs utilize a wide variety of aquatic and terrestrial habitats throughout their historic range. Larvae, juveniles, and adult frogs occur in natural lagoons, dune ponds, pools in or next to streams, streams, marshlands, sag ponds, and springs, as well as human-created stock ponds, secondary and tertiary sewage treatment ponds, wells, canals, golf course ponds, irrigation ponds, sand and gravel pits containing water, and large reservoirs.

California red-legged frogs are typically associated with perennial, or near perennial, water and the general lack of introduced aquatic predators such as crayfish (*Pacifastacus leniusculus* and *Procambarus clarkii*), bullfrogs (*Rana catesbeiana*), and centrarchid fishes such as green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), and largemouth bass (*Micropterus salmoides*). The stream habitats observed to contain the largest densities of red-legged frogs are associated with pools at least 27 inches deep with overhanging willows and an intermixed fringe of cattails (*Typha* spp.), tules or sedges, though adults are commonly found in shallower pools with vegetative cover, and young-of-the-year metamorphs are commonly found in shallow runs and riffles. In addition, red-legged frogs are sometimes found in high densities in stock ponds lacking in vegetation around their margins. The continued persistence of red-legged frog populations may depend largely on the existence of ponds, springs or pools that are apart from perennial streams. Such habitats provide the continued basis for successful reproduction and recruitment into nearby drainages that may lose frog populations due to stochastic events such as extreme flooding or droughts. During wet periods, especially in the winter and early spring, red-legged frogs can move a mile or more between aquatic habitats. This movement often occurs across seemingly inhospitable frog habitat like roads, open fields, and croplands. This type of movement, which is best documented in mesic coastal areas, may result in frogs occupying aquatic habitats isolated from known frog populations.

Locations of Known Occurrence of California Red-legged Frog in the Watershed

There were five CNDDB records and five anecdotal accounts (Swaim Biological 2006, PWA 1996) of California red-legged frogs occurring within the Pilarcitos Creek Watershed at specific locations (Figure 39). Field notes from CDFG surveys conducted over the last 70 years included several accounts as well; however, specific locality data was not included and several of the accounts simply listed "frogs" (Zatkin 2002). Therefore, these accounts were not included in the species maps. Adult and recently metamorphosed California red-legged frogs were observed in artificial, in-stream ponds on Arroyo Leon at Johnson Ranch (Smith 2002) as well as ponded water above Stone Dam (Swaim Biological 2006) indicating these sites are likely being used for breeding. Both of these sites are artificial impoundments and their hydrology can be changed by different management strategies. The Arroyo Leon ponds have historically been open for the majority of the year and were closed during the late spring in order to pond water during the summer months (Jerry Smith, pers. comm.). The fact that water was not ponded prior to late spring in these ponds suggests that California red-legged frogs may have been breeding later than normal (California red-legged frogs typically breed in the late winter and spring). These ponds also supported a large number of steelhead smolt (Smith 2002). If California red-legged frogs are indeed breeding in these ponds, continued closure of the dams will enhance breeding and foraging habitat for this species.

We reviewed the Seymour and Westphal 2000 study on amphibians in the Midpeninsula Regional Open Space District Preserves in the Santa Cruz Mountains for the presence of California red-legged frog occurrences in the Pilarcitos watershed (Seymour and Westphal 2000). Their study area just barely extended into the focal area for the Pilarcitos Watershed Assessment (where the extreme edge of Purisima Creek Redwoods OSP extends into the Arroyo Leon watershed), and they reported no California red-legged frogs in this area.

6.3.2 San Francisco Garter Snake

(Thamnophis sirtalis tetrataenia).
Federal Status: Endangered;
State Status: Endangered

The San Francisco garter snake was one of the first reptiles to be listed under the FESA by the USFWS in 1967. The San Francisco garter snake was also listed under the state Endangered Species Act in 1971 and is fully protected species under the state Fish and Game Code. San Francisco garter snakes remain threatened by continued habitat loss and degradation, as well as illegal collecting by reptile fanciers. San Francisco garter snakes have been observed in a number of aquatic and terrestrial habitats throughout their historic range, such as ponds, pools in or next to streams, streams, lakes and reservoirs. The presence of adjacent upland areas with abundant small mammal burrows is also important as hibernation sites for snakes during the winter. They prefer a dense cover of vegetation such as willows, bulrushes, cattails, and tules. Adults mate during the spring and fall and young are usually born alive during late July to early August. San Francisco garter snakes depend on frogs, particularly the threatened California red-legged frog, for food. The San Francisco garter snake is restricted to San Mateo County and northern Santa Cruz County, and has been found in creeks in Half Moon Bay.

Locations of Known Occurrence of San Francisco Garter Snake in the Pilarcitos Creek Watershed
There were two CNDDB records and one anecdotal account (Swaim Biological 2006) of San Francisco garter snakes occurring within the Pilarcitos Watershed (Figure 39). CNDDB records were along lower Pilarcitos Creek, one near the mouth (recorded in 1988) and another in a weedy field between the creek and Highway 92 approximately 0.15 miles east of Highway 1 (recorded in 2004). The only account higher in the watershed is at the northeastern boundary of the eastern finger of Pilarcitos Reservoir (Swaim Biological 2006). This area contains a relatively large area of freshwater marsh habitat that may be suitable to support populations of San Francisco garter snake (Swaim Biological 2006).

6.3.3 Western Pond Turtle

(Emys marmorata).
Federal Status: None;
State Status: Species of Special Concern.

The western pond turtle is a medium-sized brown or olive-colored aquatic turtle, and is found west of the Sierra Nevada crest and deserts and south to northern Baja California. Western pond turtles have disappeared from a significant portion of their range due to habitat loss from agriculture, urbanization, water development projects, and the introduction of non-native aquatic predators (i.e. fishes and bullfrogs).

Pond turtles are normally found in and along riparian areas, although gravid females have been reported up to a mile away from water in search of appropriate nest sites. The preferred habitat for these turtles includes ponds or slow-moving water with numerous basking sites (logs, rocks, etc.), food sources (plants, aquatic invertebrates, and carrion), and few predators (raccoons [*Procyon lotor*], introduced fishes, and bullfrogs). Juvenile and adult turtles are commonly seen basking in the sun at appropriate sites, although they are extremely wary animals and often dive into the water at any perception of danger. Pond turtles have been known to colonize isolated stock ponds, and thus some long-distance overland dispersal occurs. During the summer, they may aestivate in leaf duff, well away from riparian areas. Adults breed in the spring and early summer (March - July). Typically, the female excavates a nest in hard-packed clay soil in open habitats (usually on south-facing slopes) within a few hundred yards of a watercourse; however, nests have been located up to 0.4 miles from water. The female then lays one to - 15 eggs, which are left to incubate for three to four months.

Locations of Known Occurrence of Western Pond Turtle in the Watershed
There are no CNDDB records of western pond turtles within the Pilarcitos Watershed and only one anecdotal account. The anecdotal account was from Jerry Smith who reported seeing several turtles at the

reservoirs in Arroyo Leon Creek (pers. comm. J. Smith 2007). There are CNDDB records of western pond turtles to the south and immediately east of the watershed.

6.3.4 Discussion of Herpetofauna

Review of 2005 aerial imagery resulted in a detection of 41 off-channel ponds within the Pilarcitos Watershed (Figure 39). These ponds represent potential breeding and aquatic foraging habitat for California red-legged frogs, and aquatic/wetland foraging habitat for San Francisco garter snakes and western pond turtles. The majority of ponds occurred in the floodplain along lower Pilarcitos Creek and in the foothills throughout the southwestern region of the watershed. Nearly all of the ponded areas appear to have been created as a result of anthropogenic activities (e.g., having earthen and concrete dams). It is important to note that while this method (i.e., review of aerial photos) does allow for detection of ponds over a broad spatial scale, other ponds distributed throughout the watershed (especially in heavily forested regions) could be missed. The suitability of these off-channel ponds as habitat for these three special-status species has not been assessed in detail, and site-specific conditions (e.g., predator abundance) likely influence suitability. Nevertheless, many or most of these ponds should be considered potential habitat for one or more of these species.

California red-legged frogs, San Francisco garter snakes, and western pond turtles are known to occur within the Pilarcitos Watershed. With the exception of the pond behind Stone Dam and fringe wetland habitat flanking the northeastern edges of Pilarcitos Reservoir, there is very little suitable breeding habitat for California red-legged frogs in the northern watershed (region north of Pilarcitos Creek). This area consists of incised creeks with dense riparian canopies and steep terrain. California red-legged frogs require ponded or slow moving water devoid of predators, habitat that is uncommon in the northern Pilarcitos Watershed. San Francisco garter snakes also require ponded or slow moving water and rely heavily upon California red-legged frogs as their prey base. Thus, while there is suitable dispersal habitat (e.g., riparian corridors) for California red-legged frogs and San Francisco garter snakes, there are very few high quality breeding areas in this part of the watershed. However, the lowland areas in the lower watershed, and throughout the southwestern portion of the watershed from Pilarcitos Creek to Arroyo Leon Creek, contain numerous ponds and low-gradient creeks (Figure 39). These areas likely provide higher-quality habitat for California red-legged frogs and San Francisco garter snakes, and, in the ponded areas, western pond turtles.

6.4 BIRD SPECIES

Two special-status, riparian/wetland-associated birds are known to breed within the riparian corridors of the San Mateo Coast: the Saltmarsh Common Yellowthroat (*Geothlypis trichas sinuosa*) and Yellow Warbler (*Dendroica petechia brewsteri*). Despite its common name, the Saltmarsh Common Yellowthroat (a state species of special concern) actually breeds primarily in freshwater and brackish marshes, using salt marsh habitats more during winter. This species has been confirmed breeding in a number of areas in coastal San Mateo County (Sequoia Audubon Society 2001). It is expected to nest in weedy riparian habitats and emergent vegetation along the lower portion of Pilarcitos Creek, and more sparingly in such habitats (e.g., around ponds and in other areas providing emergent vegetation) farther upstream. It is absent from the majority of the upper portion of the watershed due to the paucity of such habitats; for example, it was not recorded during bird surveys at Stone Dam Reservoir, 2004-2006, despite the presence of some emergent vegetation there (URS Corporation 2004, Avocet Research Associates 2005, 2006).

The Yellow Warbler, a state species of special concern, is a riparian-associated bird species throughout much of its California range. This species often breeds in riparian habitats dominated by cottonwoods (*Populus* spp.) and willows (*Salix* spp.), but also uses riparian habitats dominated by alders (*Alnus* spp.), western sycamores (*Platanus racemosa*), and other species. Although it is one of the most abundant migrant warblers through the study area, it is much scarcer as a breeder, and it was not confirmed breeding along Pilarcitos Creek during the San Mateo County Breeding Bird Atlas Project (Sequoia Audubon Society 2001). Nevertheless, this species was recorded as a “probable” breeder in the atlas blocks that included lower Pilarcitos Creek, and there is some potential for Yellow Warblers to nest in the willow-dominated habitats in the lower portions of the watershed.

In addition, two raptors that are designated state species of special concern, the Cooper’s Hawk (*Accipiter cooperii*) and Sharp-shinned Hawk (*Accipiter striatus*), could potentially breed in riparian habitat along Pilarcitos Creek. Sharp-shinned Hawks were recorded in the Pilarcitos Creek area during the San Mateo County Breeding Bird Atlas Project (Sequoia Audubon Society 2001), though breeding was not confirmed in the watershed. A Sharp-shinned Hawk was recorded near Stone Dam Reservoir during a breeding-season bird survey in 2005 (Avocet Research Associates 2005), and this species likely nests at low densities in the watershed. San Mateo County Breeding Bird Atlas results suggest that Cooper’s Hawks were unrecorded at least in the lower portion of the watershed during the Atlas Project (Sequoia Audubon Society 2001). However, this species’ Bay Area populations have continued to increase in recent years, and it is possible that this species nests in the study area at low densities, particularly in the lower portion of the watershed.

The riparian habitats within the Pilarcitos Watershed support very high densities of breeding, wintering, and migrant songbirds. Breeding species for which riparian habitats are particularly important include Neotropical migrants such as the Warbling Vireo (*Vireo gilvus*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Swainson’s Thrush (*Catharus ustulatus*), Pacific-slope Flycatcher (*Empidonax difficilis*), Wilson’s Warbler (*Wilsonia pusilla*), and Orange-crowned Warbler (*Vermivora celata*), as well as permanent resident species such as the Winter Wren (*Troglodytes troglodytes*), American Dipper (*Cinclus mexicanus*), Song Sparrow (*Melospiza melodia*), American Robin (*Turdus migratorius*), and American Goldfinch (*Carduelis tristis*). During migration, large flocks of migrants occur in the riparian habitats along Pilarcitos Creek.

6.4.1 Marbled Murrelet

(Brachyramphus marmoratus).
Federal Status: Threatened;
State Status: Endangered

The Marbled Murrelet is a small seabird that feeds in coastal oceanic waters and nests inland in mature (often old-growth) forests dominated by conifers such as coast redwood and Douglas fir. This species nests from the Aleutian Islands in Alaska south along the Pacific Coast to Santa Cruz County, California. Marbled Murrelets spend most of their time foraging in coastal waters, usually within one mile of shore. However, when nesting (and occasionally during other times of the year), this species will fly inland to suitable mature coniferous forest stands. Most nesting areas are fairly close to the sea, though the species has been recorded in appropriate nesting habitat as far inland as 50 miles in Washington, 23 miles in northern California, and 11 miles in central California (USFWS 1992).

Marbled Murrelets are semi-colonial, and multiple pairs may nest in a single stand of mature conifers. Potential nesting habitat for Marbled Murrelets consist primarily of mature coniferous forests, or occasionally younger coniferous forests with trees that provide relatively flat "platforms" on limbs high in the crown. Such platforms consist of wide branches, mosses or lichens, mistletoe, or other structures (Avocet Research Associates 2005). A single egg is laid on the platform. The loss of old-growth forests to logging has been the primary cause of this species' population declines.

The Pilarcitos Watershed occurs near (approximately 31 miles north of) the southern terminus of the species' range. The center of this species' distribution at the southern end of its range has historically been the Big Basin State Park area in Santa Cruz County, although numbers at this location have declined precipitously in recent years (D. Suddjian, pers. comm.).

Designated Critical Habitat for the Marbled Murrelet includes an approximately 947-acre tract of land owned by the City of San Francisco in Upper Pilarcitos (USFWS 1996). This area is located on the southwest side of the creek between Pilarcitos Reservoir and Stone Dam Reservoir (Figure 40). Critical Habitat for this species has been re-proposed, but the proposed Critical Habitat unit within the Pilarcitos Creek Watershed would remain unchanged (USFWS 2006).

Locations of Known Occurrence of Marbled Murrelet in the Watershed
Although the Marbled Murrelet is regularly seen along the coast in the vicinity of Pilarcitos Creek, it was not recorded inland within the watershed until 1998. In that year, a survey for this species along Cahill Ridge, which forms the northeastern boundary of the watershed in the area downstream from Pilarcitos Reservoir, recorded a single detection (Albion Environmental 1998). A follow-up survey in 2003 recorded two detections within the Pilarcitos Creek Canyon in the general vicinity of Stone Dam Reservoir (CDM and Merritt Smith Consulting 2003a). A Marbled Murrelet monitoring plan for the Pilarcitos Creek watershed between Pilarcitos Reservoir and Stone Dam Reservoir was developed by

CDM and Merritt Smith Consulting (2003b), and more intensive surveys were then conducted according to this plan, and USFWS protocols, in 2004, 2005, and 2006.

No murrelets were recorded during the 2004 surveys (URS Corporation 2004). However, surveys in 2005 recorded a number of Marbled Murrelet detections (Avocet Research Associates 2005). Based on a maximum count of four to eight individuals, Avocet Research Associates (2005) estimated that two to four pairs of Marbled Murrelets were nesting in a pure stand of mature Douglas fir west of Stone Dam Reservoir in 2005. Flight behavior of these birds, which included birds flying within the crown of the trees in this stand, was consistent with locally nesting birds. Although approximately 30 percent of known nests of this species in North America have been from Douglas fir trees, most such nests are in association with coast redwoods (Ralph et al. 1995). Avocet Research Associates (2005) noted that the forest stand with which the Pilarcitos Creek birds were associated was thus possibly unique, at least in California, for consisting purely of Douglas fir.

Surveys in 2006 again detected murrelets in Upper Pilarcitos Watershed, with a minimum estimate of three pairs (Avocet Research Associates 2006). Flight behaviors suggested that murrelets were nesting in the same general portion of the watershed (i.e., the area southwest of the creek between Pilarcitos Reservoir and Stone Dam Reservoir), but not in the same Douglas fir stand that was used in 2005. A reconnaissance of the east-facing slope along the southwest side of the creek, and a review of aerial photographs, by Avocet Research Associates (2006) indicated that potential nesting habitat was fairly extensive. The approximate area mapped by Avocet Research Associates (2006) as providing potential nesting habitat for Marbled Murrelets is shown on Figure 40.

Based on the locations and flight directions of murrelets detected in 2006, Avocet Research Associates (2006) concluded that murrelets commuting between the upper Pilarcitos Creek watershed and the ocean likely followed the creek during their commute flights.

7. IMPLEMENTATION STATUS AND PROGRESS SUMMARY: 1996 RESTORATION PLAN

Opportunities and constraints were identified in the 1996 Restoration Plan. Constraints included low streamflows resulting from surface diversions, near-channel wells and agricultural ponds. Other constraints were sandy substrate that limited spawning and rearing habitat and fish barriers that restricted or prevented steelhead migration to upper stream sections. Opportunities included increase streamflow through voluntary agreements, modification of fish barriers, stabilizing streambanks and hillslopes, removing exotic vegetation and replanting with natives, promoting setback and riparian buffers by purchasing land or obtaining conservation easements.

PWA (1996) recommended alternatives for each sub-watershed. To summarize the implementation status of these alternatives, we identified certain recommendations as common to all subwatersheds, specifically removal and replacement of exotic plant species with native plant species, bank stabilization, and maintenance of unpaved roads. Alternative recommendations targeted for specific locations within a particular sub-watershed were kept separate. A summary of the current status of the alternative recommendations can be found in Table 14 followed by a brief description of each of the ongoing and completed alternatives.

Table 14. Status Summary of Recommended Alternatives from 1996 Restoration Plan

Tributary	Alternative	Status	Summary
All	Provide resources for workshops	Ongoing	PCAC Forum on Restoration Projects in Watershed (2/26/06)
	Maintain unpaved roads	Ongoing	California State Parks - San Mateo State Parks Road-Related Erosion Prevention Planning Project
	Remove exotic plants and replace with native species	Ongoing	Half Moon Bay Riparian Restoration Project - San Mateo County Natural History Association
	Stabilize failing banks	Unknown	
Mills Creek and Arroyo Leon	Modify Irrigation Ponds	Ongoing	Preliminary plans developed for modification of dams. Ponds presently not in operation due to regulatory restrictions. Alternative plans developed for off channel ponds with diversion from the stream.
	Modify barrier and stabilize banks at Historic Bridge on Mills Creek	Completed, but requires remedial work to function properly	Fish Passage Design by Clearwater Hydrology and Watershed Science. Vortex weirs installed in 1997, but failed in winter 1997-8. Reinstalled in 1998. Based upon November 2007 assessment, most weirs have failed from dislodged boulders, and fish passage is severely restricted.
	Modify Barrier 2 miles upstream on Mills Creek	Completed.	Modified in 1998. Based upon November 2007 assessment, still functioning properly
	Modify barrier at Arroyo Leon culvert	Completed, but requires remedial work to function properly	Fish Passage Design and Riparian Restoration by Fall Creek Engineering (FCE) with Swanson Hydrology and Geomorphology, JGA and HES. Based upon November 2007 assessment, lower weir under driveway bridge requires remedial work due to dislodged boulders, and channel down-cutting below it requires action to provide easy fish passage. Substantial hillslope erosion and landsliding upstream of driveway bridge.
	Stabilize gullies	Unknown	

Tributary	Alternative	Status	Summary
Apanolio Creek	Modify lower fish passage barrier and stabilize banks	Ongoing	Fish Passage Design by Fall Creek Engineering. Future funding and permits for implementation required.
	Modify middle fish passage barrier and stabilize banks	Ongoing	Plans developed, but future funding and permits required.
	Modify upper fish passage barrier and stabilize banks	Completed. May require future remedial action.	Modified with ungrouted boulder weirs and bridge in 2007. Based upon November 2007 observations of similar structures on Arroyo Leon and Mills Creek, will likely fail in first wet year (boulder movement likely, channel down-cutting likely below downstream weir).
Pilarcitos Creek	Increase instream flow below Stone Dam to CCWD Wells	Ongoing - Pilarcitos IWMP	Kennedy/Jenks Final Operations Report - Feasibility Study
	Increase instream flow from CCWD Wells to Half Moon Bay	Ongoing - Pilarcitos IWMP	Kennedy/Jenks Final Operations Report - Feasibility Study
	Install Vortex Weirs as a test of potential for pool improvement. Install Vortex weirs to replace drop structure at Highway 92	Indirectly tested by fish passage projects Partially Complete	Ungrouted Vortex Weirs appear to have limited potential for pool development in the watershed. Fish Passage and Culvert Design by WRECO
	Modify Fish Barrier at Stone Dam	Ongoing - Pilarcitos IWMP	Kennedy/Jenks Final Operations Report - Feasibility Study
Estuary	Reduce disturbance by constructing new horse bridge	Unknown	
	Increase instream flow to estuary	Ongoing	Would require study of possible use of reclaimed wastewater.

7.1 MAINTAIN UNPAVED ROADS

California Department of Parks and Recreation - Bay Area District was awarded approximately $70,780 for the San Mateo State Parks Road-Related Erosion Prevention Planning Project in 2003. The goal of the project was to produce an erosion-prevention plan for a 66-mile network of active surfaced and un-surfaced roads and legacy roads. This project is an ongoing effort, and we were unable to find any reports on the progress.

7.2 REMOVE EXOTIC PLANTS AND REPLACE WITH NATIVE SPECIES

Half Moon Bay State Beach, part of State Parks, receives grant funding from the San Mateo County Natural History Association, the San Mateo Countywide Stormwater Pollution Prevention Program (STOPP), the California State Park Foundation, and the California Coastal Conservancy (CCC) to restore riparian areas of lower Pilarcitos Creek, lower Frenchman's Creek, and the ponds of Venice Beach by removing non-native vegetation, planting willows and other riparian plants along with native coastal scrub, and removing trash. Members of the public can volunteer on a weekly basis to plant Beach Burr, Beach Sagewort, Beach Primrose, Coast Buckwheat, Yarrow, Coyote Bush, Lizard Tail, Yellow Bush Lupine, Evening Primrose, Figwort, Gum Plant, and Seaside Daisy. Education occurs through volunteer recruitment publicity and training, interpretation display at the Half Moon Bay State Beach Visitor Center, and post-project publicity and maintenance.

The major concern about exotic plants was with the extensive, expanding groves of Eucalyptus, which reduce stream flow and suppress riparian native species more likely to control stream-bank erosion, provide wildlife and fish habitat and provide edible leaves to support aquatic invertebrates. Discussions did take place with companies that harvest trees for firewood. The hope was that removal could be done for free as part of firewood harvest. However, stump treatment to kill cut trees and revegetation efforts would still result in substantial cost of Eucalyptus removal.

7.3 MODIFY BARRIER AND STABILIZE BANKS AT HISTORIC BRIDGE ON MILLS CREEK

A drop structure at a perched historic bridge on Mills Creek was identified as a barrier in the Restoration Plan (PWA, 1996). The SWRCB and CDFG contracted Clearwater Hydrology and Watershed Science to conduct geomorphic assessment and hydrologic and hydraulic analyses to document existing channel conditions and to assess stable channel design characteristics at the historic bridge.

A series of step-pools with cascade regions from below the downstream end of the historic bridge to roughly 85 ft. downstream were constructed to correct a severe grade drop (nine ft.) produced by scour below the historical bridge (USACE 1997). The step-pools were constructed through the use of six boulder weirs. Because of permitting delays, partial construction took place in the fall of 1997. Storms in the winter 1997-1998 damaged most of the weirs in the sandy (bank and bed) channel. The project was completed in the summer of 1998 incorporating flow data from the 1997 flood.

Alley (2007b) evaluated the project for fish passage conditions, and PWA (2007a) performed a brief engineering and geomorphic evaluation at the site. The bridge has provided grade control for the upper reaches of Mill Creek, stabilizing it at a slope of roughly one percent. The step structures are providing a fair amount of heterogeneity in the channel between weirs 4 through 2, where the drop heights are roughly one to 1.5 ft. There appear to be jump barriers to adult steelhead at weirs 6, 5, 4 and 1. Fish passage onto and through the culvert under the historic bridge also is extremely difficult and probably limited to a narrow range of high flows.

The primary mechanism preventing passage was the transport of crest boulders into downstream pools, which lowered the effective weir heights and created jump barriers at weirs 6, 5, 4, and 1. Hydraulic transport of the crest boulders propagated downstream from weir 1 because it lowered the effective weir height increasing the gradient of the water surface downstream. We noted several keystone boulders in RCD construction photos that were displaced into pools and transported at least 150 feet downstream. We identified the re-located members by the color of the rocks and the presence of grout on the surface of the boulders. Given the slope of the reach upstream of the bridge, transport rates also may be relatively high and the supply of large coarse material (greater than one-foot diameter) in this sand-bed stream may be too low to sustain a cascade or step-pool system with movable keystone members.

For weirs and step-pools, a critical depth is necessary over the step, followed by a free-falling jet or waterfall that can result in a hydraulic jump and/ or roller. For steps made of boulders to be stable, it is often recommended to design structures for high flow events that do not coincide with fish migration flows. Assuming a 1.4 ft. drop in a 13-foot wide channel sloped at five percent using a discharge of 500 cfs, we would expect a free-falling jet length of roughly 25 feet. The distance between weirs 5 and 4 (step spacing or pool length) is approximately 11 ft.; based on our observations, this length is inadequate for higher design discharges.

Inadequate spacing also prohibits weir packing, as hydraulic forces on the next downstream step can cause flow through the downstream weir (piping). Weir packing is a technique recommended by CDFG in which variable gradations of sediments are packed into interstitial voids of the step, ideally as keystone boulders are placed. The intent is to “seal” the weirs such that water does not flow through them, but over them. Piping was observed at weir 3 under the flow conditions during our field visit and during the reconnaissance of Alley (2007b).

The primary site constraint is the difference in elevation (~nine ft.) necessary to overcome the incision below the historic bridge over such a short distance. The weirs were designed and constructed to fit this constraint, though with the design limitations noted above. Additionally, depths within the historical bridge may be too shallow or to fast for adult passage without baffles.

Alley (2007b) made recommendations that could provide short-term fish passage. Grout is not a viable alternative with such short step spacing due to extreme hydraulic forces on downstream steps at high flows. Several grouted boulder specimens were observed downstream of the project area, demonstrating that this approach may not be effective.

A comprehensive hydrologic and hydraulic analysis should be undertaken to determine adequate fish passage remedies relative to site constraints. Possible solutions to remediate the conditions at the historical bridge site include:

- Fill in all pools with large material to create a “roughened channel.” This may not be supported by permitting agencies and design depths and velocities for fish passage flows may not be able to be met.
- Raise height of step 5. Fill in pool below step 5 and construct a short riffle of tightly interlocked material. Construct a riffle below step 1 using large boulders with a wide gradation of gravel and angular rock.
- Build additional weir(s) downstream of weir 6 to lessen overall relief. Repair existing weir crests with a minimum of one-ton rock.
- Remove weirs 5, 4, and 2 and redistribute steps further downstream to increase step spacing.

7.4 MODIFY BARRIER AND STABILIZE BANKS AT DIVERSION DAM

A small flashboard dam/domestic diversion structure further upstream was identified as a barrier to fish passage in the Restoration Plan (PWA 1996). The SWRCB and CDFG contracted Clearwater Hydrology and Watershed Science to conduct a geomorphic assessment and hydrologic and hydraulic analyses to document existing channel conditions and to assess stable channel design characteristics at the flashboard dam. The flashboard dam was subsequently removed in 1998, an infiltration gallery was built to provide domestic water, and boulder weirs were installed to stabilize the channel. An assessment in November 2007 (Alley 2007b) found the weirs to still be functioning properly.

7.5 MODIFY FISH PASSAGE BARRIERS AND STABILIZE BANKS ON APANOLIO CREEK

Final design plans have been completed for two barriers identified in the Restoration Plan (PWA 1996) on Apanolio Creek, and one barrier was modified in 2007. The lowermost (barrier 1, the Bongard diversion dam) and uppermost (barrier 3, a perched culvert) were probably impassable under most conditions. The middle barrier, an on-channel pond, is a partial barrier (apron and inclined culvert) when the dam is open. The RCD was awarded a grant from the SWRCB to remove the uppermost barrier and improve riparian habitat on Apanolio Creek (RCD 2007a), and this project was completed in September 2007. The goal of this project was to restore steelhead trout passage in Apanolio Creek by removing an existing migration barrier protecting existing species and habitat, and improving in-stream and riparian habitat in reaches directly affected by the project while maintaining access to private property. However, steelhead are very unlikely to reach the site of the former barrier until Barrier 1 is modified for fish passage.

The barrier was a perched culvert associated with an unpaved road that prevented upstream fish passage due to its height above the streambed. The culvert was removed and replaced with a three-sided free-span bridge. The stream was re-graded with a boulder step-pool sequence. The RCD and landowner selected these recommended alternatives after field surveys as well as discussions and site visits with representatives of the National Marine Fisheries Service (NMFS), CDFG, RWQCB, and the PCAC (RCD 2007b). However, based upon assessments in November 2007 (Alley 2007a) of similar structures installed in 1997-1998 on Mills Creek and Arroyo Leon, the boulder weirs are likely to fail during large storms. Boulders will probably move, leaving gaps in the weirs, and down cutting will probably occur at the downstream weir, because of the sandy channel bed and banks. Grouting the boulders together may be necessary to prevent or correct failures after boulders move. Additional weirs may be required downstream of the recent project to remediate future down cutting.

The RCD sought additional funds from the City of San Mateo Wastewater Treatment Plan (SMWTP) to meet the construction and permitting costs, which have increased since the inception of the project. SMWTP awarded the funds to the RCD, who will continue to be responsible for managing the Apanolio Canyon Fish Passage Enhancement Project including all compliance schedules set forth by the RWQCB. Plans have been developed for barriers 1 and 2, but no funds are presently available for implementation and new permits for modifying the barriers are required.

7.6 INSTALL VORTEX WEIRS ON PILARCITOS CREEK

Water Resources Engineering Company (WRECO) is designing a fish passage restoration at Pilarcitos Creek in San Mateo County as a part of an ongoing Hydraulic On-call Services to CalTrans District 4 (WRECO 2007). The fish passage project is required for the mitigation of two CalTrans Highway 92 improvement projects. The proposed project will remove a five-foot concrete drop structure at Highway 92 and replace it by five-step rock vortex weirs. The design efforts were coordinated with NMFS and CDFG.

The original proposal in PWA (1996) was to install some vortex weirs as a test to see if they could be used to provide improved pool habitat. However, because of the high expense and failure rate of ungrouted weirs used for passage improvement in the sandy channel beds of the watershed (Alley 2007b), no use of boulder weirs for rearing habitat improvement seems desirable.

7.7 INCREASE INSTREAM FLOW TO ESTUARY

Additional summer stream flow for lower Pilarcitos Creek and the lagoon may require either the use of reclaimed wastewater or the substitution of reclaimed wastewater for stream diversions or well use. No feasibility studies have been done. When the Pilarcitos Creek lagoon configuration is pushed far to the north, Frenchman’s Creek also discharges to the lagoon. Like most small lagoons on the central coast, there is almost no residual depth in the Pilarcitos Creek lagoon when the sandbar is open. When the sandbar is closed, sufficient inflows (in excess of sandbar seepage) are needed to raise the lagoon level to provide usable habitat for steelhead rearing.

7.8 FISH BARRIER MODIFICATION OR REMOVAL ON ARROYO LEON

PWA (1996) noted three barriers on Arroyo Leon (2 large on-channel dams and a severe culvert barrier).

7.8.1 Severe Culvert Barrier Upstream of the Mouth of Mills Creek

The barrier on Arroyo Leon upstream of the mouth of Mills Creek was a drop at a failed culvert/road crossing. It was modified in 1997 with a bridge and a series of boulder weirs/step pools. The step pools provided access to Arroyo Leon upstream of Mills Creek. An assessment in November 2007 (Alley 2007b) found that boulders within the downstream weir had moved, and channel down cutting had occurred at the lower weir. Presently, fish passage by upstream migrating adult steelhead is likely restricted to higher winter flows of 50-75+ cfs. However, unless the boulders are grouted together, additional boulder movement is likely to occur. The channel down cutting in the sandy bed and banked channel may require installation of another weir (any additional weir may also result in down cutting). Only one weir (under the driveway bridge) was visible in 2007; the others were apparently buried under sand from an eroding hillslope and attempted bank repair on the right (north bank), upstream of the bridge.

7.8.2 Johnson Ranch ("Giusti Farms") Dams and On-Channel Ponds

The Restoration Plan (PWA, 1996) report recognized that steelhead rearing of unknown extent took place in these two on-channel seasonal ponds operated for agricultural water supply. The ponds are on land owned by the Peninsula Open Space Trust (POST) and leased to Guisti Farms for agricultural use. Several potential problems with operation were suspected. First, in spring, when steelhead smolts were migrating downstream, the ponds could block migration by: 1) early installation (prior to June); 2) not providing for fish passage over the dams (a thin sheet of water over the spillway); and 3) not providing adequate bypass flows for passage downstream of the dams during filling and subsequent operation. In addition, the old slide gates that closed the dams could not be opened until most of the water had been drained from the reservoirs; draining through the small pipes near the bottom could take three or more weeks to drain. This meant that after the irrigation season was over (late October) the reservoirs were regularly drained down and opened, so that the first big rains did not occur with inoperable reservoir gates. These actions would often drain the ponds (and stop rearing) prior to sufficient rains to sustain flows downstream of the dams and could result in killing many of the fish reared in the ponds in some years. Finally, although the ponds were regularly illegally fished for "catchable-sized" trout, the population size and growth rates of steelhead in the ponds were unknown and might be affected by high water temperatures or dissolved oxygen problems in the ponds.

In 2000 and 2001 installation of the dams was delayed until mid May and passage over the upper dam was provided (notched weir) under restrictions in a CDFG streambed alteration agreement. The lower dam was closed about 2 weeks later, but no downstream fish passage was provided at the lower dam (after late May) in either year because the reservoir never filled to the point of spilling. Studies of the ponds (Smith 2001 and 2002) showed that relatively few smolts (2 year olds) from the upper watershed were apparently trapped by the closure. Studies also showed that large numbers (estimated at 1984 fish in 2000) of fast-growing young-of-year and yearling steelhead reared in the two ponds in both years.

The ponds were often over five m deep and stratified with warmer water on/near the surface and cooler water below, and with lower dissolved oxygen levels in the lower half of the water column. Water temperatures (based upon temperature array recorders and periodic water column profiles) were generally cool (< 20 degrees C) in the upper pond, but surface temperatures were often higher in the lower pond (22-24 degrees C). Temperature and dissolved oxygen conditions in the ponds were driven by weather (sunny versus overcast days) rather than by seasonal changes from June to September. Overcast days brought cooler water but reduced oxygen concentrations. Since algae (phytoplankton and filamentous) were common in the ponds, dissolved oxygen levels declined due to plant respiration and limited photosynthesis during persistent overcast periods.

In the second year, water fern (*Azolla*) coated much of the surface of the lower pond in late summer, reducing wind-driven mixing and reducing water column dissolved oxygen. Despite some water quality problems, the steelhead that reared in the ponds showed very high growth rates and the fish in the lower pond (with warmer water in both years and some dissolved oxygen problems in 2001) were larger than those in the upper pond in both years. Young-of-year fish in the ponds were generally much larger by fall than yearlings produced in 2 years of rearing in upstream habitats, and yearlings rearing in the ponds during their second year were 150-250+ mm standard length (six-10 inches long) by November.

Conditions in the ponds were similar to the warmer, but highly productive, conditions that provide for rearing large smolt-sized fish in lagoons at the mouths of many central coast streams (Smith 1990; Bond 2006; Alley 2007d). In addition, the studies by Bond (2006) demonstrated that the very large fish produced in Scott Creek lagoon (similar to the sizes in the Guisti ponds) made up a disproportionately large portion of the returning adults in that watershed, because smaller smolts rearing in upstream habitats had very low ocean survival. In Arroyo Leon, the ponds in both years produced more than 10 times the smolts as an equivalent amount of stream habitat (based upon sampling in the shaded, sandy, low-flow habitat upstream of the ponds) (Smith 2001 and 2002). In addition, because of their larger size and much higher likelihood of ocean survival (Bond 2006), the number of returning adults produced by the ponds was probably 100 times that of an equivalent length of Arroyo Leon stream habitat (and may have accounted for a majority of returning adult steelhead in the entire Pilarcitos watershed).

Preliminary (concept) plans were developed for modifying the dams (with new slide gates and drainage valves) to allow bypass flows during filling, fish passage over full ponds, and to allow rapid draining immediately prior (or during) the first large rains in fall (or winter). These modifications would eliminate most of the fish passage and other problems associated with operation of the ponds. However, the ponds have not been used since 2001 due to lack of a streambed alteration agreement with the CDFG and a decision by NMFS that “take” (adverse effects) on steelhead at the dams/ponds required an “incidental take agreement” (either a section 7/consultation (if a federal nexus was involved) or section 10/Habitat Conservation Plan) that demonstrated a net beneficial effect on steelhead of operating the ponds. In the years since the ponds have ceased operation, few steelhead have apparently reared at the site of the ponds, since the streambed is normally dry or intermittent by September of all but the wettest years (Tim Frahm and Keith Mangold, pers. comm.).

Although operating one or both of the ponds in a “fish-friendly” manner is preferable for watershed steelhead production, because of the regulatory restrictions on the use of the ponds, POST is developing a feasibility study to remove the two impoundments. Agricultural land owners have relied on the reservoirs created behind these impoundments for irrigation during the dry season and are now faced with water supply losses that in many cases will put them out of business. POST aims to develop a solution that replaces the ponds with in-stream habitat and provides an agricultural water supply. The solution will replace the ponds with approximately 1/2 mile of typically non-perennial, low quality stream habitat, eliminate any restriction by the dams to in-stream spawning and rearing habitat above the dams, and provide a long-term off-stream supply of water for irrigation.

8. REFERENCES

Albion Environmental. 1998. San Francisco Bay Area Ridge Trail Marbled Murrelet and Spotted Owl survey findings.

Alley, D. W. 2007a. Apanolio Creek fishery assessment December. Prepared for this project.

Alley, D. W. 2007b. Evaluation of present condition of past fish passage improvement projects on Arroyo Leon and Mills Creeks. Prepared for this project.

Alley, D. W. 2007c. Comparisons of 2006 juvenile steelhead densities in drainages of the San Lorenzo, Soquel, Aptos and Corralitos watersheds in Santa Cruz County, California. Prepared for Santa Cruz County Environmental Health Department.

Alley, D.W. 2007d. Soquel Creek Lagoon Monitoring Report, 2006. Prepared for the City of Capitola.

Avocet Research Associates. 2005. Protocol-level surveys for Marbled Murrelet (*Brachyrampus marmoratus marmoratus*) at Cahill Ridge and the Upper Pilarcitos Creek Watershed San Mateo County, California: 2005. Prepared for Tetra Tech, Inc. and the San Francisco Public Utilities Commission.

Avocet Research Associates. 2006. Protocol-level surveys for Marbled Murrelet (*Brachyrampus marmoratus marmoratus*) at Cahill Ridge and the Upper Pilarcitos Creek Watershed San Mateo County, California: 2006. Prepared for the San Francisco Public Utilities Commission.

Balance (Balance Hydrologics, Inc.) (with Schaaf & Wheeler and EIP Associates). 1997. Pilarcitos Creek alternative point of CCWD diversion study. Prepared for Coastside County Water District.

Balance (Balance Hydrologics, Inc.). 2001. Sediment-Transport Reconnaissance of the Pilarcitos Creek Watershed, San Mateo County, California – Water Year 2000. Prepared for Pilarcitos Creek Advisory Committee and San Mateo County Resource Conservation District.

Balance (Balance Hydrologics, Inc.). 2003a. Hydrologic analysis of streamflow parameters for Arroyo Leon at Giusti Farm: Half Moon Bay, San Mateo County, California. Prepared for EDAW, Hagar Environmental Science, and Peninsula Open Space Trust.

Balance (Balance Hydrologics, Inc.). 2003b. Catalog of Active Sediment Sources and Control Opportunities, Apanolio Creek, Half Moon Bay, San Mateo County, California. Prepared for San Mateo County Resource Conservation District, Pilarcitos Creek Advisory Committee.

Bell, D.T. and Williams, J.E. 1997. Eucalypt ecophysiology. In: J.E. Williams and J.C.Z. Woinarski (Editors), Eucalpytus ecology: individuals to ecosystems. The Press Syndicate of the University of Cambridge, Cambridge, UK, pp. 168-196.

Benda, L. E. and T. W. Cundy. 1990. "Predicting deposition of debris flows in mountain channels." Canada Geotechnical Journal **27**: 409-417.

Bond, M. H. 2006. The importance of estuarine rearing to Central California steelhead (Oncorhynchus mykiss) growth and marine survival. M. A. Thesis. University of California, Santa Cruz.

Brabb, E.E. et al. 1998. Geology of the onshore part of San Mateo County, California: A Digital Database. Derived from USGS Pamphlet OF98-137.

CCC (California Coastal Conservancy). 2006. Frenchman's Creek Fish Passage File No. 06-033. Project Manager Janet Diehl.

CCWD (Coastside County Water District). 2006. Water Supply Evaluation Report Calendar Year 2005, March.

CDM and Merritt Smith Consulting. 2003a. San Francisco garter snake and red-legged frog survey report and Marbled Murrelet survey report. Prepared for the San Francisco Public Utilities Commission.

CDM and Merritt Smith Consulting. 2003b. Marbled Murrelet monitoring plan. Prepared for the San Francisco Public Utilities Commission.

CNDDB (California Natural Diversity Database). 2007. Rarefind. California Department of Fish and Game.

CNPS (California Native Plant Society). 2007. Inventory of Rare and Endangered Plants of California (6^{th} edition). Rare Plant Scientific Advisory Committee, David P. Tibor, Convening Editor. http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi

CWHR (California Wildlife Habitat Relationships System). 2005. Geographic Information Systems Shape Files of Vegetation Types. Prepared by the California Department of Fish and Game and California Interagency Wildlife Task Group.

DEP (Department of Environmental Management), San Mateo County, California. 1986. General Plan.

Dietrich, W. E., S. L. Reneau, et al. 1987. Overview: "Zero-order basins" and problems of drainage density, sediment transport and hillslope morphology. Erosion and Sedimentation in the Pacific Rim, Corvallis, OR, IAHS.

Dietrich, W. E., and Dunne, T. 1978. "Sediment Budget for a small catchment in mountainous terrain." Zeitschrift Für Geomorphologie 29: 191-206.

Doerr, S.H. 1998. On standardizing the 'water drop penetration time' and the 'molarity of an ethanol droplet' techniques to classify soil hydrophobicity: a case study using medium textured soils. Earth Surface Processes and Landforms 23: 663-668.

Doerr, S.H. et al. 2005. Effects of contrasting wildfire severity on soil wettability in Australian eucalypt catchments. Journal of Hydrology In Press.

EDAW, Inc. et al. 2002. Peninsula Watershed Management Plan. Prepared for the San Francisco Public Utilities Commission.

Ellen, S.D., Mark, R.K., Wieczorek, G.F., Wentworth, C.M., Ramsey, D.W., and May, T.E. 1997. Map Showing Principal Debris-Flow Source Areas in the San Francisco Bay Region, California. US Geological Survey Open File Report 97-745e. 8pp.

Environmental Services Agency – County of San Mateo (ESA-SM). 1998. Local Coastal Program.

ENTRIX. 2006a. Pilarcitos Creek aquatic habitat and fish population survey, September 2004. Prepared for City of San Francisco Public Utilities Commission. Appendix A in Kennedy/Jenks Consultants 2006. Final Pilarcitos Operations Report. Prepared for San Francisco Public Utilities Commission.

ENTRIX. 2006b. Evaluation of flow-habitat relationships in Pilarcitos Creek downstream of Stone Dam. Prepared for City of San Francisco Public Utilities Commission. Appendix B in Kennedy/Jenks Consultants 2006. Final Pilarcitos Operations Report. Prepared for San Francisco Public Utilities Commission.

EOA. 1990. Country of San Mateo Feasibility Study for the Pilarcitos Creek Watershed Restoration Program.

Ferriera, A.J.D. et al. 2000. Hydrological implications of soil water-repellency in Eucalyptus globulus forests, north-central Portugal. Journal of Hydrology 231-232: 165-177.

Flosi, G. et al. 1998. California Salmonid Stream Habitat Restoration Manual, 3rd Edition. CA Department of Fish and Game, Inland Fisheries Division.

Frahm, Tim. 2002-2007. Personal Communication. Pilarcitos watershed resident and stakeholder.

Freeman, J.R.. 1912. The Hetch Hetchy Water Supply for San Francisco. Prepared for James Rolph, Jr., Mayor of San Francisco and Percy V. Long, City Attorney.

Go Native Nursery LLC. 2002. Johnson Ranch/Arroyo Leon Vegetation Survey. Prepared for the Peninsula Open Space Trust.

HTB (Heal the Bay). 2004. 14th Annual Beach Report Card for 2003-2004.

HTB (Heal the Bay). 2007. 17th Annual Beach Report Card for 2006-2007.

Leighton-Boyce, G. et al. 2005. Temporal dynamics of water repellency and soil moisture in eucalyptus plantations, Portugal. Australian Journal of Soil Research 43(3): 269-280.

Kennedy/Jenks Consultants. 2006. Final Pilarcitos Operations Report. Prepared for San Francisco Public Utilities Commission.

Mangold, Keith. 2002-2007. Personal Communication. Pilarcitos watershed resident and stakeholder.

Marston, D. 1993. Sediment assessment report. Pilarcitos Creek, San Mateo County. CDFG Report, January.

Montgomery and Buffington. 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin*. 109: 596-611.

Natural Resources Conservation Service, United States Department of Agriculture (SSURGO). Soil Survey Geographic Database). For *San Mateo County, California* http://soildatamart.nrcs.usda.gov

NCDC (National Climatic Data Center). 2007. Western Regional Climate Center archive for the Half Moon Bay National Weather Service Station Report 043714-4.

Nelson, E.A. 1997. Phase I of Lower Pilarcitos Creek Groundwater Investigation, Half Moon Bay, California. Prepared for the Coastside County Water District.

Nelson, E.A. 1998. Phase II of Lower Pilarcitos Creek Groundwater Investigation, Half Moon Bay, California. Prepared for the Coastside County Water District.

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2000. Snapshot Day 2000. http://www.coastal-watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2001. Snapshot Day 2001. http://www.coastal-watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2003. First Flush Event Summary, October 31st and November 3rd, 2003. http://www.coastal-watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2004a. Snapshot Day 2004. http://www.coastal-watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2004b. Dry Weather Monitoring September 26th, 2004 & First Flush Monitoring Report October 16th and 17th, 2004. http://www.coastal watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2005a. Snapshot Day 2005. http://www.coastal-watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2005b. 2005 Dry Run & First Flush Monitoring Report. http://www.coastal watershed.org/CWC_Library/index.htm

Network (Monterey Bay Sanctuary Citizen Watershed Monitoring Network). 2006. Snapshot Day 2006. http://www.coastal-watershed.org/CWC_Library/index.htm

Pryor, L.D. 1976. The biology of eucalypts. Edward Arnold United, London, UK.

PWA (Philip Williams & Associates, Ltd.) (with Habitat Restoration Group, Prunuske Chatham and Callander Associates). 1996. Pilarcitos Creek Restoration Plan. Prepared for Regional Water Quality Control Board and California Department of Fish and Game. Report no. 1021.

Ralph, C.J., G.L.Hunt, M. G. Raphael, and J. F. Piatt. 1995. Ecology and Conservation of the Marbled Murrelet. USDA Forest Service Gen. Tech. Rep. PSW-152. 1995.

Ramirez, Tim. 2007. Personal Communication. SFPUC staffmember. Pilarcitos IWMP Workgroup Meeting May 9.

RCD (San Mateo County Resource Conservation District). 2007a. Apanolio Canyon Fish Passage Enhancement Project – Project Description. [http://www.swrcb.ca.gov/rwqcb2/Agenda/04-11-07/6/SEP%20San%20Mateo.pdf]

RCD (San Mateo County Resource Conservation District). 2007b. Memorandum of Understanding January 25.

RWQCB (Regional Water Quality Control Board), San Francisco Region. 2006. Order no. R2-2006-0040: Updated Waste Discharge Requirements for Browning-Ferris Industries, Inc., Ox Mountain Class III Waste Management Facility, Half Moon Bay, San Mateo County.

SMCPHEPD (San Mateo County Public Health and Environmental Protection Division). 2006. Fecal bacteria source study for Pilarcitos and Gazos Creek Watersheds.

Sciaromi, Hank. 2007. Personal Communication. Operates nursery along Pilarcitos Creek.

Scott, D.F. and Lesch, W. 1997. Streamflow responses to afforestation with Eucalyptus grandis and Pinus patula and to felling in the Mokobulaan experimental catchments, South Africa. Journal of Hydrology 199: 360-377.

Sequoia Audubon Society. 2001. San Mateo County Breeding Bird Atlas.

Seymour R. and M. Westphal. 2000. Results of a one-year survey for amphibians on lands managed by the Midpeninsula Regional Open Space District in the Santa Cruz Mountains of California. Prepared for Midpeninsula Regional Open Space District.

Shakesby, R.A., Doerr, S.H. and Walsh, R.P.D. 2000. The erosional impact of soil hydrophobicity: current problems and future research directions. Journal of Hydrology 231-232: 178-191.

Smith, Jerry, 2007. Personal Communication. Fisheries biologist and member of the consultant team.

Smith, J. J. 1996. Appendix C: 1996 evaluations for Arroyo Leon and upper Pilarcitos Creek.

Smith, J. J. 1998. The effect of the CalTrans project to remove gabions and repair the Highway 92 road culvert upon habitat and fisheries of Albert Canyon. Report to CalTrans.

Smith, J. J. 1999. Steelhead abundance in Albert Canyon and Pilarcitos Creek upstream and downstream of Highway 92 in November 1999. Report to CalTrans.

Smith, J. J. 1990. The effects of sandbar formation and inflow on aquatic habitat and fish utilization in Pescadero, San Gregorio, Waddell and Pomponio creek estuary/lagoon systems 1985-1989. Report to California Department of Parks and Recreation.

Smith, J. J. 2001. Progress report: 2000 studies of habitat conditions and steelhead in the Arroyo Leon seasonal reservoirs.

Smith, J. J. 2002. Habitat conditions and steelhead in the Arroyo Leon seasonal reservoirs and adjacent stream in 2001.

Smith, J. J. 2006. Distribution and abundance of juvenile coho and steelhead in Gazos, Waddell and Scott creeks in 2006.

Smith, J.J. and H.W. Li. 1983. Energetic factors influencing foraging tactics of juvenile steelhead trout Salmo gairdneri. D.L.G. Noakes, et al. (eds.). Predators and Prey in Fishes. Dr. W. Junk Publishers, the Hague. pp. 173-180.

Suddjian, D. 2007. Personal Communication. Biologist.

Swaim Biological. 2006. Results of the 2005 surveys for the San Francisco garter snake and California red-legged frog at Mud Dam 1, Mud Dam 2, Skyline Quarry, and Stone Dam San Mateo County, California. Report to Tetra Tech.

Teter. J. 2002. Preliminary Report on Estimated Cost of Water Production from the Proposed Lower Pilarcitos Creek Groundwater Project.

Thompson, A. 2006. Soil Water Repellency and Eucalyptus globulus in Coastal California. San Francisco State University, pp. 20.

Todd Engineers. 2003. Lower Pilarcitos Creek Groundwater Basin Study. Prepared for the Coastside County Water District.

Trihey and Associates. 1995. An assessment of habitat conditions for juvenile trout in the portion of Pilarcitos Creek on CCWD property. Prepared for Coastside County Water District.

Trihey and Associates. 1996. Fishery survey on Pilarcitos Creek. Prepared for San Francisco Water Department.

URS Corporation. 2004. Peninsula watershed Marbled Murrelet survey report. Prepared for the San Francisco Public Utilities Commission.

USACE (US Army Corps of Engineers). 1997. Pre-construction notification for Mills Creek stable channel design and fish passage barrier removal project. File no.: 22820S.

US Interagency Advisory Committee on Water Data. 1982. Guidelines for determining flood flow frequency, Bulletin 17-B of the Hydrology Subcommittee: Reston, Virginia, U.S. Geological Survey, Office of Water Data Coordination, [183 pp.]. [Available from National Technical Information Service, Springfield VA 22161 as report no. PB 86 157 278 or from FEMA on the World-Wide Web at http://www.fema.gov/mit/tsd/dl_flow.htm

USDA (US Department of Agriculture) National Agriculture Imagery Project (NAIP). 2006. http://datagateway.nrcs.usda.gov/GatewayHome.html

USFWS (US Fish and Wildlife Service). 1992. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Washington, Oregon, and California Population of the Marbled Murrelet. Federal Register 57(191):45328-45337.

USFWS (US Fish and Wildlife Service). 1996. Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for the Marbled Murrelet. Federal Register 61(102):26256-26320.

USFWS (US Fish and Wildlife Service). 2006. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Marbled Murrelet. Federal Register 71(176):53838-53951.

WRECO (Water Resources Engineering Company). 2007. Project description for Pilarcitos Creek Fish Passage Restoration Project. http://www.wreco.com/projects/restoration/coastal.html#pilarcitos

Zatkin, R. 2002. San Mateo County Coastal Streams, Apanolio Creek, Arroyo Leon, Corinda Los Trancos, Mills Creek, Nuff Creek, Pilarcitos Creek. A compendium of information from the California Department of Fish and Game, two volume manuscript at Water Resources Center Archives.

9. LIST OF PREPARERS

This report was prepared by the following PWA staff:

Adam Parris, Project Manager
Setenay Bozkurt, Fluvial Geomorphologist
Elizabeth Andrews, PE, Project Director
Catherine Lee, Production Manager

With:

Mike Liquori, Senior Plan Writer/Geomorphologist, Sound Watershed Consulting
Max Busnardo, Restoration Ecologist, H. T. Harvey and Associates
Matthew Ramsay, Restoration Ecologist, H. T. Harvey and Associates
Don Alley, Fisheries Biologist, D.W. ALLEY & Associates
Jerry Smith, PhD, Fisheries Biologist, D.W. ALLEY & Associates
Joe Hayes, Hydrogeologist, Weber-Hayes and Associates

10. FIGURES

Figure 40. Marbled Murrelet Habitat / Occurrences

Appendix A
Geospatial Map Inventory

Appendix B
Interviews with Selected Stakeholders