Gold Ridge Resource Conservation District

Upper Green Valley Creek Watershed Plan

A Living Document to Facilitate the Restoration of Coho Salmon and Preservation of Sustainable Agriculture

June 30, 2010

The Upper Green Valley Creek

Watershed Management Plan

Phase 1, June 2010

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Executive Summary

The Upper Green Valley (UGV) watershed is located in the Russian River Hydrologic Unit in western Sonoma County, California and has been identified by state and federal government as priority recovery habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). The UGV Watershed Management Plan (Plan) provides a description of existing watershed conditions, identifies data gaps, identifies and prioritizes sediment reduction and other projects for immediate implementation and provides recommendations for management practices to support agricultural and environmental sustainability.

The UGV Creek watershed is a sub-basin of the Atascadero-Green Valley watershed, a tributary of the Russian River. Terrain in the watershed is varied, with gently rolling hills in the east and steep forested slopes in the west. It has a Mediterranean climate, with hot dry summers and cool wet winters. The watershed is composed of Franciscan Complex, Wilson Grove Formation, and Great Valley Complex geology. Much of the watershed, in particular steep slopes underlain by Franciscan Complex, is highly susceptible to erosion. Soils in the watershed are composed mostly of Gold Ridge sandy loam with Hugo and Josephine loams present in the steep, forested areas of the UGV Creek watershed (USDA 2008).

The watershed has been inhabited for roughly six thousand years, first by the Southern Pomo, and more recently by European and American settlers. With the arrival of Euro-Americans, land use in the watershed changed drastically with natural resource extraction occurring at scales previously unencountered – redwood forests were cleared for timber, and riparian forests, woodlands, and grasslands were cleared and utilized for agriculture. Orchards were the primary crop in the early 20th century, giving way to vineyards in the early 21st century. The UGV watershed is almost completely privately owned. Primary land uses in 2010 include apple and pear orchards, vineyards, livestock pasture, and rural residential development. Twenty-two cultural resources from both prehistoric and historic times have been recorded in the watershed.

Water supply is governed by a series of Water Rights Decisions and Water Rights Orders by the State Water Resources Control Board. Surface water in the watershed is fully appropriated between June 15 and October 31 yearly (SWRCB 1998). The greatest demand for surface water is for residential and agricultural needs; many ponds and surface diversions have been created. Currently, several entities have formed a partnership to investigate alternatives for water supply.

Water quality has been monitored by Gold Ridge Resource Conservation District (GRRCD) for the past eighteen months (Chapter II, Section B). During this time, monitoring locations have gone dry, water temperature has exceeded preferred temperatures for salmonids, and dissolved oxygen levels have dropped below optimal levels – all during the summer months. During winter months, several instances of turbidity higher than the threshold value for physiological effects to salmonids were recorded. Purrington Creek most often met standards conducive to salmon, however, elsewhere in the watershed, the low flows during summer months likely limits salmonid survival.

An analysis of hydrology and instream flow found that rainfall amounts substantially exceed human water use in the watershed; however, the timing of supply and demand is out of sync (Chapter II, Section C). Rainwater catchment and reservoirs are suggested as a means to capture and store surplus winter rains for summer use. To ensure sufficient water supply for environmental water needs, an analysis of cumulative effects on streamflow from capture and storage is recommended.

An analysis of sediment sources and impacts indicate that channel incision, surface erosion, and gullying are factors in sedimentation of Upper Green Valley and Purrington Creeks (Chapter II, Section E). Road assessments conducted over the past few years found private unpaved roads were insufficiently constructed with regard to preventing or controlling erosion, with poorly constructed stream crossings and inadequate road drainage. Impacts to aquatic habitat include higher peak stream discharge, reduced infiltration, and aggradation, which contributes to lower summer baseflows. UGV Creek has aggraded dramatically throughout the lower reach, potentially contributing to flooding and potential fish stranding in the Green Valley Road / Korbel Vineyard area. Assessment of watershed and reach-scale geomorphic processes and an expanded assessment of erosion and sediment delivery are recommended to provide a more complete picture of watershed geomorphology, erosion processes, and impacts of erosion. Development of a program to arrest channel incision in lower Purrington Creek and the reduction of anthropogenic erosion and sediment delivery are recommended to reduce sediment load in streams throughout the watershed.

The UGV watershed supports a diverse assemblage of biological resources including several native vegetation communities and numerous wildlife species (Chapter II, Section G). Of particular importance are instream and riparian habitats, which support several special status species including coho salmon, steelhead trout, and California red-legged frogs. The value of these habitats for wildlife has been compromised by land use practices such as logging, grazing, agriculture, and rural development. Recommendations to protect and enhance biological resources include protection and enhancement of the riparian corridor, improvement of instream habitat, management of sediment delivery, increasing summer base flows, monitoring and improving water quality, protection and enhancement of upland habitats, monitoring and enhancement of salmonid and other wildlife habitat and collaboration with the agricultural community to promote on-farm enhancement projects.

Management actions to improve watershed conditions include the promotion of agricultural sustainability and responsible rural residential stewardship. Sustainability in agriculture was officially defined by the U.S. Congress in the 1990 Farm Bill, which characterized it as "an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- Satisfy human food and fiber needs;
- Enhance environmental quality and the natural resource base upon which the agricultural economy depends;
- Make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- Sustain the economic viability of farm operations;
- Enhance the quality of life for farmers and society as a whole."

The definition describes a broad-scale, integrated approach which provides roles and benefits for the producer, consumer, and community, and necessitates involvement from policy makers, researchers, landowners, farm workers, retailers, and others. While the word "sustainable" has in recent years become synonymous with ecological concerns, its true definition must equally consider social and economic aspects.

Rural residential development is the primary land use in the UGV watershed, comprising about 45% of total land cover. Rural residential development leads to similar land use issues resulting from urbanization – runoff, flood control, groundskeeping/chemical control, and onsite wastewater treatment systems. An aspect not commonly found in urban areas is the construction, use, and maintenance of unpaved access roads. Sources for BMPs from federal, state, and local agencies are provided to assist rural residents in determining appropriate stewardship practices.

Climate change has become an increasingly important concern with Northern California expected to experience increased temperatures and greater extremes in weather events. Sea level is expected to rise, exacerbating effects of winter storms. Native vegetation and crops are expected to be affected through changes to phenology, possible disruption of pollination processes, and proliferation of pathogens and parasites. Salmonid habitat is expected to experience changes including decreased instream flow and changes to ocean habitat. Additional impacts of climate change include increased electricity demand, reduced water quality, increased air pollution and airborne allergens, and climate-sensitive infectious diseases.

Recommendations for the Plan were developed to contribute towards coho recovery and agricultural sustainability. Some of the conditions which have been documented as limiting the recovery of salmonids include: (and are described in greater detail in Chapter II, Section G)

- High turbidity and sediment loads from roads and riparian and gully erosion;
- Low streamflow during dry summer months and late spring throughout critical frost protection times;
- Poor instream habitat from lack of channel complexity; and
- High summer water temperatures from lack of adequate canopy cover.

An active group of landowners in the Green Valley Creek Watershed help to contribute to Plan goals

However, the technical team has reached the preliminary conclusion that the Upper Green Valley Watershed ecosystem can be considered healthy and functioning if we achieve the following goals and have the ability to measure results. Due to the constraints of the planning process, these goals are a work in progress and will be reviewed and adapted as the next phase of the Plan moves forward.

Upper Green Valley Watershed Management Plan Goals

Goal 1: **Wild populations of Coho salmon and steelhead trout return to the Upper Green Valley Watershed**

Goal 2: **Water Quality should meet or exceed all regulatory targets**

Goal 3: **Stream flows and water quality support fish and other aquatic organisms at all life stages.**

Goal 4: **Surface water and groundwater supplies within the watershed are managed to support resident's quality of life, agriculture, and ecosystem needs**

Goal 5: **Aquatic and riparian habitats are assessed, protected and restored**

Goal 6: **Upland habitats are resilient and biologically diverse with intact ecosystems**

Goal 7: **Agricultural producers are supported in their efforts to sustainably grow crops and/or produce food**

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I. Introduction

A. Overview and Purpose

Located in western Sonoma County, California, Upper Green Valley Creek and its main tributary, Purrington Creek are considered important salmonid streams in the Lower Russian River basin (*Map 1, Atascadero Green Valley Watershed Location*). These creeks are located within the greater Atascadero-Green Valley (AGV) watershed, which has been identified by the California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) as priority recovery habitat for endangered coho salmon (*Oncorhynchus kisutch*). Atascadero-Green Valley is a focus watershed for both CDFG's coho recovery program and the Russian River Coho Salmon Captive Broodstock Program. Upper Green Valley and Purrington Creeks contain critical salmonid habitat; however, CDFG has documented a decline in salmonid habitat conditions in the Upper Green Valley system, and this decline has been accompanied by a collapse in both coho and steelhead trout (*O. mykiss*) populations.

Over the years, several studies evaluating habitat impairments and potential limiting factors to salmonid survival have indicated a general decline in habitat quality in Upper Green Valley and Purrington creeks (CDFG 1995, 2006, Laurel Marcus and Associates 2002, Merritt Smith 2003). This decline in local habitat quality occurs at a time when coho salmon populations in the region are in danger of extinction (Weitkamp et al. 1995), with the Russian River system experiencing a "catastrophic reduction in coho salmon distribution (CDFG 2002)." Timely action to improve habitat conditions is necessary to increase salmonid populations: Purrington Creek watershed is one of several "core areas" for implementation of priority recovery actions identified in National Marine Fisheries Service's (NMFS) recently released *Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon* (2010).

Historic timber harvest and removal of riparian vegetation, conversion of native habitat and agricultural lands to rural residential, development of timber, agricultural, and rural access roads, and other land use practices have resulted in significant cumulative changes to watershed processes and characteristics. Land uses that potentially contribute to increased sedimentation in the watershed include improperly designed and/or maintained unpaved rural residential and agricultural roads, agricultural and other development practices, and slope instabilities resulting from historic logging practices. Factors that may be contributing to low stream flow in the watershed include agricultural and residential use; periods of increased demand for both residential landscapes and agriculture coincide with periods of increased environmental demand. Additionally, some reaches may be impacted by excessive aggradation, which can also contribute to low stream flow.

The Upper Green Valley watershed is almost completely privately owned; primary land uses are agricultural and rural residential. If instream and riparian habitat is to be preserved and enhanced, then cooperation and participation of landowners is vital. By implementing a variety of best management practices (BMPs) known to reduce sedimentation, conserve water, and improve habitat, landowners can not only help to protect wildlife habitat and fisheries resources, but also increase economic opportunities in the watershed. Implementation of sustainable practices yields social, environmental, and economic benefits – these are described in detail in *Chapter III, Management Considerations*.

This Upper Green Valley Watershed Management Plan (UGVWMP) provides a description of existing conditions in the watershed and identifies data gaps, identifies and prioritizes sediment reduction and other coho habitat improvement projects (instream and/or riparian) for immediate implementation, and provides recommendations for management practices to support agricultural and environmental sustainability. Goals and objectives identified below represent the most recent watershed-specific information; as more data is gathered and effects of management actions become better understood, goals of this plan may change. The Upper Green Valley Watershed Management Plan is intended as a living document, setting a framework for community cooperation for mutual benefit.

Table 1. Upper Green Valley Watershed Management Plan Goals & Objectives

Goal	**Indicator**	**Potential Source of Impact**	**Management Objective**
Restore coho and steelhead populations to Upper Green Valley and Purrington Creeks	Population counts; fish trap counts	Low flow during summer months, lack of riparian cover in some reaches due to legacy timber and agricultural practices; lack of instream habitat complexity; summer agricultural and landscape uses of instream water and near-stream groundwater withdrawals	Restore instream habitat complexity; restore hydrologic connectivity of stream channel and floodplain; implement water conservation measures; conjunctive uses (possibility for offstream storage); implement prioritized sediment reduction projects.
Meet water quality standards for temperature	Temperature	Lack of riparian cover due to legacy timber and agricultural practices; pool filling due to excessive sedimentation; summer agricultural and landscape uses of instream water and near-stream groundwater withdrawals	Restore native riparian vegetation (those not host for Pierce's disease); implement water conservation measures; conjunctive uses (possibility for offstream storage); implement prioritized sediment reduction projects.

Goal	Indicator	Potential Source of Impact	Management Objective
Meet water quality standards for dissolved oxygen	Dissolved oxygen	Low flow during summer months	Implement water conservation measures; conjunctive uses (possibility for offstream storage).
Support agricultural sustainability efforts	Implementation of sustainable management practices	Competitive markets; environmental regulations	Provide technical and funding assistance.
Assess, protect & enhance riparian habitat	Extent and condition of riparian plant communities, habitat connectivity; bird species diversity and richness	Streambank and upland erosion and habitat fragmentation	Map and assess riparian function and condition; improve agricultural management, grazing practices, and rural residential landscaping activities; identify areas for conservation easements or restoration.
Restore aquatic habitat	Riparian vegetation; instream habitat structure	Historic riparian vegetation removal, upland erosion and delivery, historic channel alteration (including large wood removal), fish passage barriers	Reduce sedimentation from roads and other sources; improve aquatic habitat through streambank stabilization and native riparian revegetation (those not host for Pierce's disease); conduct stream habitat typing; remove fish passage barriers; and increase instream habitat structure and complexity.
Promote native biodiversity in upland habitats	Extent and condition of native plant communities	Historic and current land use practices; invasive species	Map highly invasive species (broom, arundo) and develop eradication plans.

Gold Ridge RCD & Watershed Planning in the Upper Green Valley Watershed

Since the 1940s, the Gold Ridge Resource Conservation District (GRRCD) has supported many conservation-oriented projects and programs to enhance and protect lands in the district. Through decades of cooperative collaboration, GRRCD has formed productive, long-standing relationships with the agricultural community in the Green Valley Watershed. Given GRRCD's proven commitment to protecting both the ecological integrity and economic productivity of the watershed's natural resources, we felt well positioned to produce this document and to facilitate the cooperative planning process on which it is based.

This Upper Green Valley Watershed Management Plan has been under development since 2008. The State Coastal Conservancy (SCC) provided funding to:

- Collect existing information and field data and synthesize into existing conditions report
- Continue to gather support in the watershed for fisheries restoration
- Identify and prioritize sediment reduction and other projects for immediate implementation
- Provide recommendations for improved management practices to support agricultural, environmental, and social sustainability.

In late 2008, funding for the project was frozen because of a state budget shortfall and the planning effort, which had begun to gain momentum, was cut short. However, GRRCD continued to monitor water quality at selected locations within the watershed. In August 2009, the SCC indicated that the project could move forward at a significantly reduced funding amount and with a revised deadline of December 31, 2009. This deadline was extended first to April 30, 2010 and later to June 30th, 2010 and funding was partially reinstated, which allowed for a geomorphic and hydrologic characterization of Purrington Creek, a water supply analysis, and some limited public participation and review.

Public input has been less than desired in this process due to the work stoppage and short time frames upon resumption of planning. A public meeting was held on October 8, 2009 to provide information about the plan and take public comment. Additionally, a stakeholder meeting was held on October 15, 2009 with members of the Atascadero/Green Valley Watershed Council (AGVWC). AVGWC members also attended a Technical Advisory Committee meeting on March 25, 2010. The UGVWMP was provided to the public in May 2010 and comments to the plan and GRRCD responses are provided in Appendix 1. Given a longer time frame and full funding, greater emphasis would have been placed on stakeholder outreach, potentially resulting in increased land owner participation in road and stream surveys. Additionally, more stakeholder input would have allowed for individualized solutions for specific problems. When this plan is seen as a living document however, refinement of management practices and ongoing dialogue with stakeholders becomes a part of the adaptive planning process. The limits to stakeholder communication experienced during this phase of plan development are not likely to continue – the next iteration of the plan has been identified for funding by the California Department of Fish and Game (CDFG). The CDFG grant is scheduled to begin in June 2010, and has a three-year duration, providing ample time for stakeholder outreach. Additionally, as projects identified in this plan are implemented and as related planning efforts get underway (see below), stakeholder inclusion and participation are expected to increase greatly.

Related Efforts

The Upper Green Valley Watershed Management Plan (UGVWMP) represents the first phase of a long-term planning effort that will include instream habitat and riparian restoration, water conservation and supply enhancement practices, enhanced water quality monitoring, and implementation of ecologically appropriate and economically profitable land management practices. As a living document, this plan is intended to provide a framework for future project prioritization and implementation and to complement and contribute to other local and regional planning efforts.

This plan is expected to dovetail with the Russian River Coho Water Resources Partnership (Partnership), a multi-stakeholder effort to ensure sufficient water supply in the Russian River basin to support coho salmon and other aquatic organisms. The Partnership identified Green Valley Creek as one of 5 first priority streams important for salmonid recovery in the Russian River basin. The Partnership's guiding principle is that careful planning and water supply management can provide water for human uses and coho salmon (Sotoyome RCD 2010). GRRCD and their partners in the Partnership are developing streamflow augmentation and water storage; implementation of these projects will begin in 2011.

By implementing the actions recommended in this plan to improve local watershed conditions, stakeholders in the Upper Green Valley Creek watershed are also contributing toward improved regional conditions and attainment of state and local goals. The Russian River Watershed Adaptive Management Plan is currently in development by the Russian River Watershed Council with funding from the Army Corps of Engineers, with the goal of promoting ecological health and sustainability within the Russian River watershed (RRIIS 2006). The UGVWMP, with its existing conditions report, roads analysis, creek characterization, and recommendations can provide a fine level of detail about an important sub-watershed in the Lower Russian River while identifying projects that support the goals of the larger plan. This plan also implements goals of the North Coast Integrated Regional Water Management Plan – salmonid population enhancement and implementation of state goals, such as Total Maximum Daily Loads (TMDL), the SWRCB's Watershed Management Initiative, and the CDFG Coho Recovery Strategy.

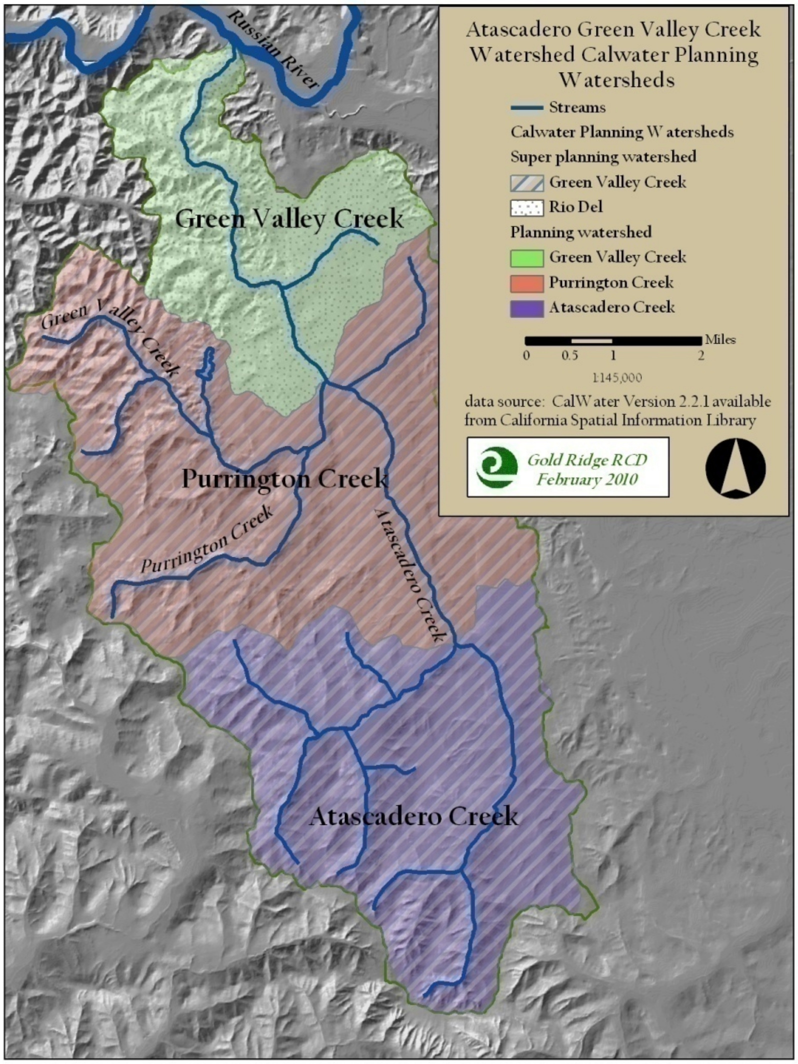
The implementation of the UGVWMP will contribute to the attainment of state goals and objectives. Projects identified and management practices implemented through this plan directly support attainment of TMDL goals for sediment and temperature in the Russian River. This plan also supports goals outlined in the North Coast Regional Water Quality Control Board's Watershed Management Initiative Chapter of the SWRCB's Watershed Management Initiative to protect and maintain groundwater quality and quantity and protect and enhance coldwater fisheries. Likewise, this plan supports CDFG Coho Recovery Strategy Task RR-GU-09, which addresses changes to water diversions in Green Valley Creek. The UGVWMP also supports implementation of the recently released National Marine Fisheries Service (NMFS) *Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon* (2010). The Recovery Plan calls for implementation of priority recovery actions in the Purrington Creek watershed; the UGVWMP implements a recommended action by promoting the use of BMPs for roads and other land use activities. Additionally, road surveys – both those completed to date and future efforts – work toward reducing both erosion and hydrologic impacts from roads, a high priority for habitat restoration (NMFS 2010).

II. Watershed Description

A. Regional Setting

Watershed Location

The Atascadero/Green Valley (AGV) watershed encompasses about 38 square miles in the Lower Russian River Hydrologic Area[1] in Sonoma County, California (*Map 1: Atascadero/Green Valley Watershed Location*). The AGV watershed is part of the Guerneville hydrologic subarea (HSA) and contains almost all of Graton, a significant part of Forestville, and the westernmost part of the City of Sebastopol. Green Valley Creek's primary tributary streams are Atascadero, Jonive, and Purrington Creeks, and it flows into the Russian River near Forestville. The AGV watershed contains the Green Valley Creek, Purrington Creek, and Atascadero Creek Calwater Planning watersheds (*Map 2, AGV CalWater Planning Watersheds).* A legal description of the location and CalWater Planning Watershed numbers is provided (Appendix 2).

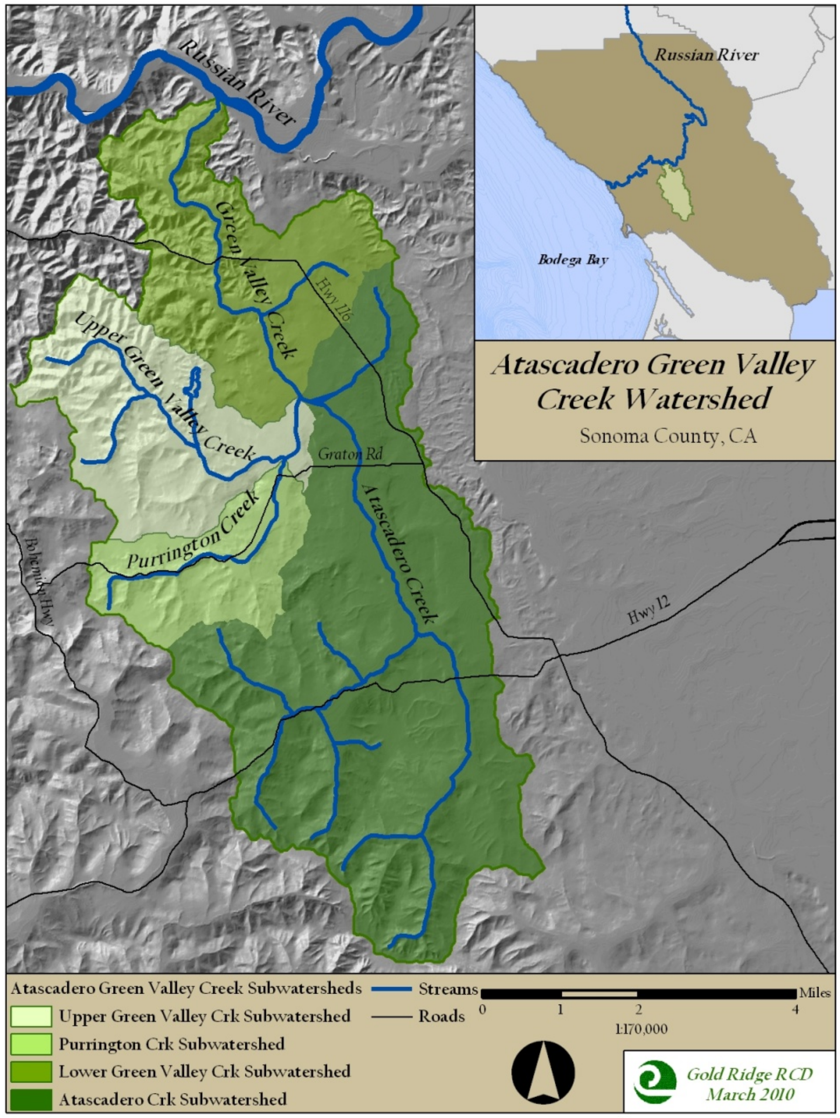


Map 1. Atascadero-Green Valley Creek Watershed Location

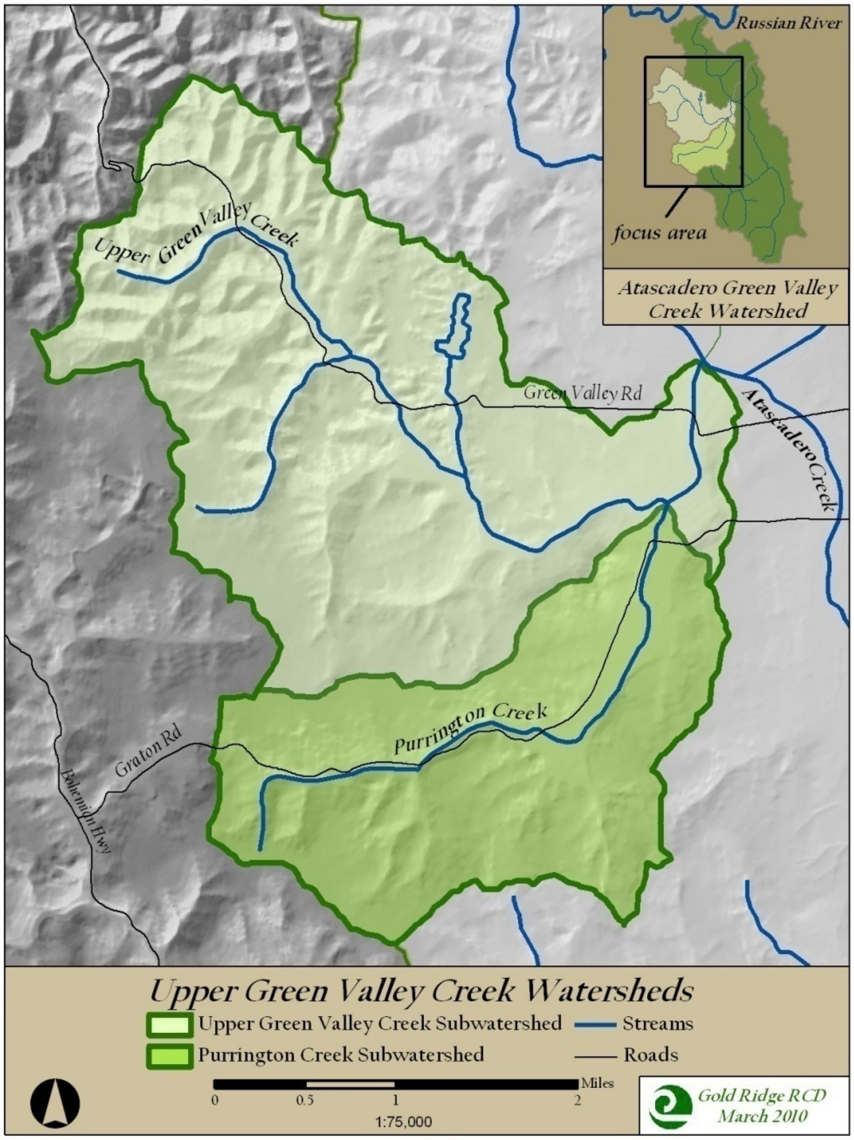
[1] Hydrologic Units are geographic divisions based on drainage patterns utilized by CALWATER, the watershed mapping system used by the State of California. The CALWATER classification includes, from largest to smallest, hydrologic regions, hydrologic units (HUs), hydrologic areas (HAs), hydrologic subareas (HSAs) and planning watersheds.

Geographic Focus of the Upper Green Valley Watershed Management Plan

The geographic focus of this watershed plan is the Upper Green Valley (UGV) watershed, which is defined as the watershed of Green Valley Creek upstream of its confluence with Atascadero Creek (*Map 3, UGV Watershed*). The UGV watershed is comprised of the Upper Green Valley and Purrington Creek subwatersheds. The creeks in these subwatersheds have been identified by the California Department of Fish and Game (CDFG) as optimal coho spawning and rearing habitat in the Atascadero-Green Valley Creek watershed. Green Valley Creek was one of only three Russian River tributaries in which coho salmon were recorded during the early 21st century (2000 to 2002) (CDFG 2004). In the Russian River Fisheries Restoration Plan (Coey et al. 2002), Green Valley Creek was identified as "the only known stream in the Russian River basin that continues to harbor a recorded, consistent coho run." Stream survey reports (CDFG 2006a, b) recommend management of Green Valley and Purrington Creeks as anadromous, natural production streams. Green Valley Creek has been stocked with coho yearly since 2006; steelhead were stocked in 1970 and 1984 (Obedzinski et al. 2006, CDFG 2006a, b). Salmonids will be discussed in detail in *Section F: Biological Resources*.



Map 2. Atascadero-Green Valley Creek Planning Watersheds



Map 3. Upper Green Valley Creek and Purrington Creek Subwatersheds

The California Central Coast Coho Salmon Recovery Plan (produced by the National Marine Fisheries Service) identifies Green Valley Creek as a Phase I Priority area (NMFS 2010), with a goal for near-term population recovery. The Recovery Strategy for California Coho Salmon (CDFG 2004) identifies the Guerneville HSA as having the greatest coho salmon restoration and management potential in the Central California Coastal Coho Evolutionary Significant Unit (ESU). Upper Green Valley and Purrington Creeks contain spawning and rearing habitat, greater canopy shading and has many opportunities and alternatives for habitat improvement, especially projects that increase pool frequency, volume, and shelter (CDFG 2006a, b).

Geography

The Upper Green Valley Creek watershed is a 6,420-acre sub-basin of the Atascadero-Green Valley watershed and includes the drainages of Purrington, Harrison and Upper Green Valley Creeks. The terrain is varied, with gently rolling hills in the lower elevation areas to the east, and steep, forested slopes to the west. Elevation ranges from approximately 100 feet at the confluence of Upper Green Valley and Atascadero Creeks to 700 feet in the western hills, outside the town of Occidental. Streams rise in the steep upper valleys, where hillslope gradients frequently exceed 80%, and drain to broad, low-gradient alluvial valleys in the lower watershed.

The climate of the Upper Green Valley Creek watershed is characterized by dry, mild-to-warm summers and cool winters with periods of intense rainfall. Average annual temperature is about 53 to 55 degrees F., although temperatures can reach into the 90s and low 100s in the lower watershed during the hotter months of July through September, and these same areas can drop below freezing during December through April. Occasional freezing events occur annually with lows occasionally dropping into the teens (February 1989, December 1990) (NOAA 2004). Because of the proximity of the Pacific Ocean, the forested uplands experience a more moderate climate, with cooler temperatures and fog during the summer and slightly warmer temperatures during the winter. Most precipitation occurs between November and April; average annual precipitation is between 40 (southeast) and 50 (northwest) inches with a range from 25 – 70 inches (see Chapter II, Section C). The higher elevations to the west typically see more rain (up to 85 inches), while the lower elevations to the east are drier.

Geology

The Upper Green Valley Creek watershed lies in a geologic region that has been subjected to a range of tectonic forces and processes, and consequently the geology is locally very complex, with geologic units that are highly sheared, faulted and deformed. The watershed is dominated by two formations: the variety of rocks associated with the Franciscan Complex, and the sedimentary rocks of the Wilson Grove Formation, with a number of other units occupying smaller areas (Blake et al, 2002).

The Upper Green Valley Creek subwatershed (excluding Purrington Creek) is underlain predominantly by rocks of the Franciscan Complex. This complex is part of an accreted terrane – rocks that formed elsewhere and were transported to their present location by tectonic processes. Consequently, they are highly variable and complex. Franciscan Complex geology in Green Valley includes rocks of two units: sandstones and shales, which occupy most of the Upper Green Valley subwatershed, and melange, which outcrops in the northwesternmost portion of the subwatershed. Franciscan Melange is composed of areas of shale and siltstone, grading into a matrix of highly sheared, weathered and erodible mudstone or sandstone. This matrix contains chunks of more coherent sedimentary and metamorphic rocks. Franciscan Melange is also often associated with blocks of serpentinite, a metamorphic rock with unique characteristics. A serpentinite outcrop occurs in the western portion of Upper Green Valley. Smaller areas of Wilson Grove sandstone (described below) also occur in this subwatershed.

The Purrington Creek subwatershed is dominated by the Tertiary sandstone of the Wilson Grove Formation. Geologically younger than the Franciscan Complex, the Wilson Grove is a massive, fine-grained marine sandstone that formed in a shallow coastal embayment between 2 and 10 million years ago. Outcrops of serpentinite and Franciscan Melange also occur along Purrington Creek and its tributaries in the steep area to the west of Green Hill Road. In the headwaters of the stream, a large area of the Great Valley Complex can be found. The Great Valley Complex is of Jurassic age, and consists of a variety of sedimentary, metamorphic and igneous rocks of deep water origin. In Purrington Creek, two units of the Great Valley Complex can be found: the weakly consolidated shales and fine-grained sandstones of the Knoxville Formation, which occurs in the upper valley of Purrington Creek, and a small area of volcanic tuff and breccias. Rocks of the Great Valley Complex were emplaced in the Purrington Creek subwatershed by processes of faulting.

Throughout both Upper Green Valley and Purrington Creeks, valley bottom areas are composed of alluvial and colluvial deposits of Quaternary age. These are mostly gravels and finer sediments eroded in the uplands and deposited and reworked on the valley floors by mass movements and fluvial processes.

The geology of the Upper Green Valley watershed has produced a steep landscape with large areas that are highly susceptible to erosion. This is particularly true of areas underlain by the Franciscan Complex.

Serpentinite has unique properties that affect both runoff generation and erodibility. Serpentinite is low in minerals necessary for plant growth, but high in toxic metals. This combination discourages vegetative cover, resulting in thin soils with sparse and unique vegetation. These areas are highly erodible and generate abundant runoff.

Soils

Gold Ridge sandy loam is the most extensive soil type in the Upper Green Valley watershed, dominating both the Purrington Creek subwatershed and the lower (eastern) portion of the Upper Green Valley Creek subwatershed (from about Bones Road to the confluence with Atascadero Creek). In the UGV watershed, these deep and fertile soils are typically found on moderate to low-gradient slopes underlain by the Wilson Grove Formation, and have been weathered from this weakly consolidated sandstone. Gold Ridge soils are well-drained, and are considered excellent for growing wine grapes.

Hugo and Josephine loams dominate the steeper, forested areas of the Upper Green Valley Creek watershed. These soils contain more clay than the Gold Ridge soils, and are typically found in areas underlain by the Franciscan and Great Valley formations. These soils are well drained and characterized as highly erodible when disturbed on steep slopes (USDA 2008).

History

The entire Russian River Hydrologic Unit has a long history of human habitation. Among the first inhabitants were the Southern Pomo, who migrated to the Russian River about 6 to 7 thousand years ago (Stewart 1985). Their former territorial lands comprised Sonoma County south of the Russian River and east to the southern Santa Rosa area, and they spoke the Southern Pomo language, which is part of the Hokan language stock (McLendon and Oswalt 1978). They were a seasonally nomadic people who hunted and gathered animals, plant materials, salmon, and seafood. The Southern Pomo are renowned for their skilled basketry and are considered expert flint knappers and clamshell bead makers. The Pomo and neighboring peoples developed a relatively stable society composed of small groups linked by geography, lineage, and marriage. They managed the landscape using fire, pruning, weeding, and selective harvest to promote the growth of desirable plants and create conditions favorable for game animals.

The way of life of the Southern Pomo and all Native Americans dramatically changed following contact with European and American settlers in the late 18th and early 19th century. Land use in the Upper Green Valley Creek watershed also changed drastically – natural resource extraction began at scales previously unencountered. Over the next century, redwood forest was harvested for timber; riparian forests, woodlands and grasslands were cleared for grain, orchards, row crops, and hops production; and the area's rich wildlife was massively harvested.

In the Upper Green Valley Creek watershed, forests were intensively harvested in the 1920s and 1950s followed by heavy grazing (CDFG 2006a). A large part of the natural grasslands and meadows was planted to orchards in the early 20th century (PWA 2008). In 1938, the Army Corps of Engineers and the Sonoma County Flood Control and Water Agency recommended channel clearing of the mainstem Russian River and several tributaries, including Green Valley Creek (Coey et al. 2002). By the 1950s, Green Valley Creek had become polluted by apple processing waste: "many of the pools in the area were covered with scum and the water appeared black, with visibility limited to less than 1 inch" (CDFG 2006a). In the early 1970s, the rural beauty coupled with proximity to urban areas led to a sharp increase in residential development (Sonoma County Community & Environmental Services 1978). Additionally, the period between 1969 and 1994 saw an increase in intensive land uses, continued removal of large wood debris jams from streams, and human population increase. By the late 1970s, increasing development had led to concerns about future water supply, with some areas requiring imported water during summer months (ibid.). Since the 1980s, orchards have been increasingly converted to vineyards in the Green Valley watershed.

Archaeological Resources

A records search conducted by the Northwest Information Center indicates the presence of 22 recorded cultural resources in the Upper Green Valley watershed. Of these, 20 are prehistoric resources associated with Native American activities or occupation and two are historic-era resources. The prehistoric resources include habitation debris, lithic debitage (the sharp-edged waste material remaining when a person creates a stone tool), and bedrock mortars. The historical resources consist of the remains of a sawmill and a homestead. The watershed also contains a California bay (*Umbellularia californica*) that has been designated a Heritage tree. About 35% of the watershed has been investigated in 54 archaeological/cultural resource studies; many more resources are likely in the remaining 65%. Native American resources in this part of Sonoma County have been identified in terrace areas, ridgelines, and benches near fresh water – the Upper Green Valley Creek watershed contains all of these features. Additionally, it is highly likely that additional historic resources will be identified since USGS maps (1914, 1942, and 1952) show several buildings and structures throughout the watershed.

Ownership and Land Use

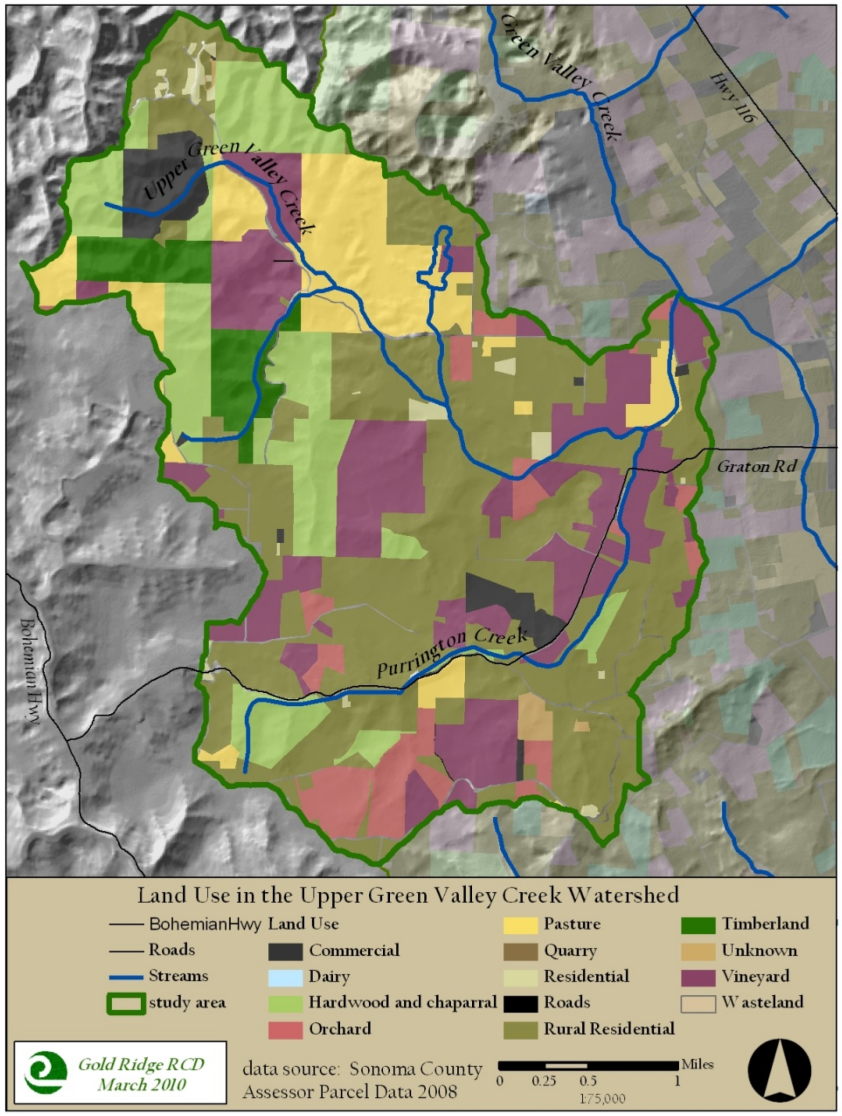
The Upper Green Valley Creek watershed is almost completely privately owned. Primary land uses include apple orchards, vineyards, livestock pasture, and rural residential development. Over the past three decades, an increasing amount of orchard has been converted to vineyard.

Timber harvest, agriculture, rural residential growth and fire suppression activities have led to the development of an extensive rural road network in the watershed. The Upper Green Valley subwatershed has a medium/high frequency of roads on steep slopes and the Purrington subwatershed is categorized as having a high frequency of roads on steep slopes (LMA 2003). Both the Purrington and Upper Green Valley subwatersheds contain less than 10% urban area or impervious surface (LMA 2003).

Although a portion of the headwaters forest in the Upper Green Valley Creek subwatershed has been developed for agriculture, much of it remains undeveloped. Primary land use in the

Upper Green Valley Creek subwatershed is 36% rural residential, 36% agricultural (vineyards, orchards and some pasture) and 24% forest (CDF&FP and USDA FS 2002). Forest/vineyard is identified as the primary land use on steep slopes and land use along creeks mainly includes livestock grazing, vineyard, timber, and roads (LMA 2003). The lower portion of the Upper Green Valley Creek Watershed contains both agricultural and rural residential development (*Map 4, Land Use in the Green Valley and Purrington Subwatersheds*) (CDFG 2006a).

The upper portion of the Purrington Creek subwatershed is also relatively undeveloped with scattered residences, while agriculture and rural residential development comprise the majority of the lower portion. The primary land uses in the Purrington subwatershed are 54% rural residential, 41% agricultural (vineyards, orchards and livestock pasture) and 7% forest (CDF&FP and USDA FS 2002). The primary land use on steep slopes in the Purrington subwatershed is forest/undeveloped, and land uses along creeks consists of roads, vineyard, and forest in this subwatershed (LMA 2003).



Map 4. Upper Green Valley Creek and Purrington Creek Land Use and Land Cover

Green Valley Creek and Purrington Creek are designated "riparian corridors" in the Sonoma County General Plan. Riparian corridor habitat is protected by several county policies intended to protect and enhance riparian areas and functions while balancing the need for agricultural production, urban development, timber and mining operations, and other land uses. The Harrison Grade Road serpentine association is designated "critical habitat" and Green Valley Road is a designated Scenic Corridor.

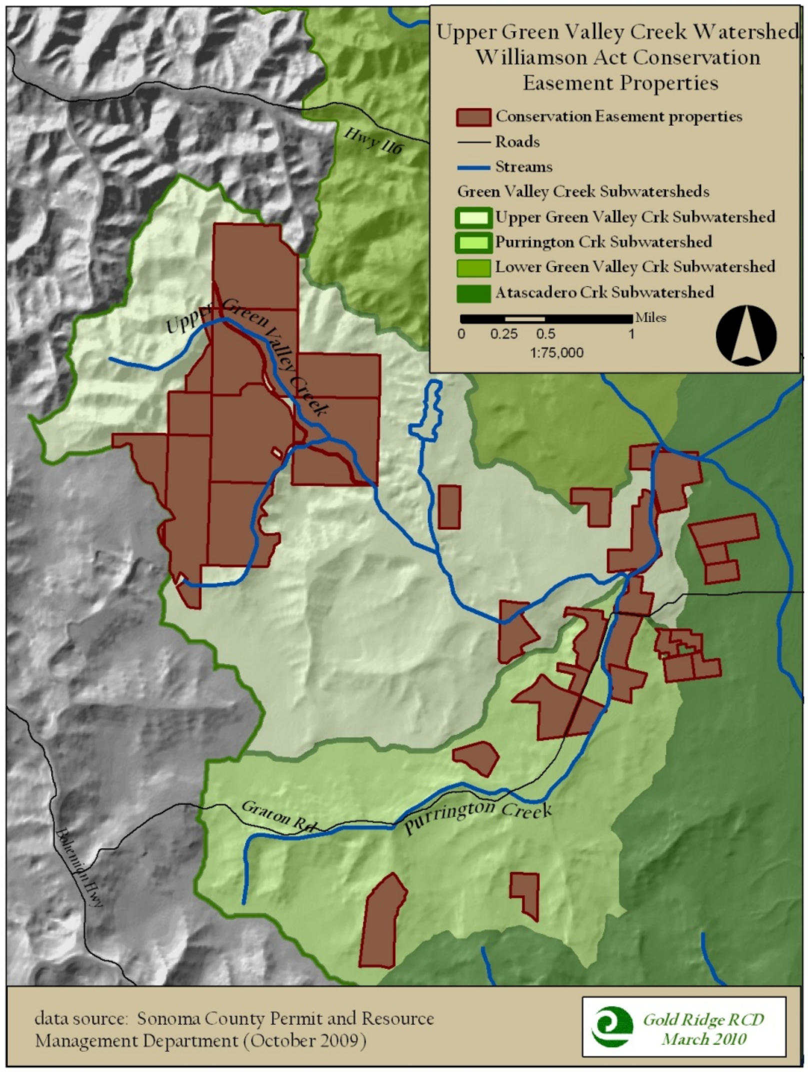
Much of the Upper Green Valley Creek watershed and some parcels along Purrington Creek have land under Type I or Type II Williamson Act Land Contracts; these contracts are an agreement with the landowner to maintain land in agricultural or open space condition for reductions in tax obligations (*Map 5, Land in Williamson Act Land Contracts).*

Table 2. Land Cover in the Upper Green Valley Creek Watershed		
Subwatershed		
Land Cover	Area (acres)	Percentage
Purrington		
Agriculture	961	41.00%
Conifer	567	24.19%
Hardwood	128	5.46%
Herbaceous	161	6.87%
Mix	522	22.27%
Shrub	5	0.21%
	2344	100%
Upper GV		
Agriculture	932	22.20%
Conifer	524	12.48%
Hardwood	369	8.79%
Herbaceous	518	12.34%
Mix	1801	42.89%
Shrub	32	0.76%
Urban	7	0.17%
Water	16	0.38%
	4199	100%

Water Supply

Water supply in the Russian River Hydrologic Unit is governed by a series of Water Rights Decisions (WRD) and Water Rights Orders (WRO) by the State Water Resources Control Board (SWRCB) that regulate instream flows for the Russian River and its tributaries (see SWRCB WRD1030, WRD1610, WRO86-09, and WRO98-08). All of Green Valley Creek and its tributaries upstream from the confluence with the Russian River are fully appropriated between June 15 and October 31 each year (SWRCB 1998). Water rights in the state of California are based on seniority with a "first in time, first in right" principle governing use during times of scarcity – the most junior rights holders must discontinue use first. Riparian rights, which are associated with a parcel of land adjacent to a surface water source, have a higher priority than appropriative rights. Generally, riparian rights holders' priorities are of equal weight and they must share reductions equally during times of shortage (SWRCB 2007).

In the Upper Green Valley and Purrington Creek subwatersheds, recent analysis of water supply and demand indicates that the greatest demand for surface water may be agriculture. However, further studies need to be conducted in order to evaluate the impact that near channel wells and rural residential water use has on water availability. The Upper Green Valley subwatershed contains many diversions and irrigation ponds (LMA 2003). The times of highest agricultural demand – early spring and mid- to late-summer – coincide with critical periods of environmental demand (see *Chapter II, Section F)*, leading to potential conflict between environmental and human uses. During spring 2009, a fish kill on the Russian River occurred due to rapid drawdown of the river caused by the cumulative effect of frost prevention pumping to protect budding grapevines (Roy undated).



Map 5. Upper Green Valley Creek Williamson Act Conservation Easement Properties

The State Water Resources Control Board (SWRCB) recently proposed adding a special regulation to limit diversion of stream water (including "closely connected groundwater") for frost protection between March 15 and June 1. This "Amendment to Division 3 of Title 23 of the California Code of Regulations" states that any diversion of water from the stream system conducted during those dates that the Board determines to be significant shall be considered a violation of Water Code section 100. Water may be diverted if a board-approved water demand management program is in place; such a program would ensure that instantaneous cumulative diversion stayed within amounts that will not harm anadromous fish (DWR 2010).

The Russian River Coho Water Resources Partnership (Partnership), with funding from the National Fish and Wildlife Foundation, has initiated a study investigating the feasibility of utilizing off-stream storage for summer supply in response to concern about agricultural water supply reliability and reductions in instream flow. The Partnership includes the Center for Ecosystem Management and Restoration (CEMAR), the University of California Hopland Research and Extension Center, Trout Unlimited, Occidental Arts and Ecology Center WATER Institute, Sotoyome RCD, and Gold Ridge RCD. The study will initially focus on 5 Lower Russian River subwatersheds – including the Upper Green Valley and Purrington Creek subwatersheds. The Partnership will work with willing landowners and other water users to identify solutions to improve water reliability and flows – from the implementation of water conservation BMPs to increasing water storage capacity (Sotoyome RCD undated). In support of this effort, two flow gauges have been installed in the UGVC watershed – one in each subwatershed. Real-time gauge data is available on the Partnership website: www.cohopartnership.org.

B. Water Quality

Regulatory Context

Water quality affects all beneficial uses of water in a watershed from municipal and agricultural to environmental. According to the US Environmental Protection Agency (US EPA), water quality standards for a watershed must be based on state-designated beneficial uses of its water bodies. These water quality standards are determined by the state and consist of both narrative and numeric water quality objectives. The Guerneville HSA contains twenty beneficial uses identified by the State Water Quality Control Board (NCRWQCB 2007a) (*Table 3, Guerneville HSA Beneficial Uses*).

Table 3. Guerneville HSA Beneficial Uses (* denotes potenttial uses)

Beneficial Uses
Municipal & Domestic Supply
Agricultural Supply
Industrial Service Supply
Industrial Process Supply
Groundwater Recharge
Freshwater Replenishment
Navigation
Hydropower Generation
Water Contact Recreation
Non-Contact Water Recreation
Commercial and Sport Fishing
Warm Freshwater Habitat
Cold Freshwater Habitat
Wildlife Habitat
Rare, Threatened, or Endangered Species
Migration of Aquatic Organisms
Spawning, Reproduction, and/or Early Development
Shellfish Harvesting*
Estuarine Habitat
Aquaculture*

Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify all water bodies that do not meet water quality standards for their designated uses. Identified water bodies are placed on the 303(d) List. The 303(d) list identifies the pollutant(s) or stressor(s) causing the impairment – when known – and establishes a schedule for developing a plan to address the impairment. This plan usually takes the form of a pollution control plan known as a TMDL. TMDLs establish the maximum amount, or "load" that can be discharged into a water body before water quality is impaired. A TMDL is the sum of allowable loads from all contributing natural and anthropogenic inputs. Once allowable loads are determined, all sources of the pollutant in a watershed are identified and loading rates are allocated among existing sources. Acceptable loading rates are generally allocated based on percent reductions for each source. Once the TMDL is established, stakeholders within the watershed must implement management practices and projects that will achieve TMDL targets.

Table 4. Potenial Sources of Sedimentation and Increased Water Temperature (NCRWQCB 2007b)

Pollutant/Stressor	Potential Nonpoint Sources
Sediment/Siltation	Agriculture Irrigated Crop Production Specialty Crop Production Agriculture-storm runoff Agriculture-grazing Silviculture Construction/Land Development Highway/Road/Bridge Construction Land Development Hydromodification Channelization Dam Construction Upstream Impoundment Flow Regulation/Modification Habitat Modification Removal of Riparian Vegetation Streambank Modification/Destabilization Drainage/Filling of Wetlands Channel Erosion Erosion/Siltation
Water Temperature	Hydromodification Upstream Impoundment Flow Regulation/Modification Habitat Modification Removal of Riparian Vegetation Streambank Modification/Destabilization Nonpoint Source

The CWA recognizes two types of water pollution: pollution discharged by *point sources* and pollution discharged by *nonpoint sources*. Point sources include water treatment plants, factories, and other "discernible confined discrete conveyances." Nonpoint source (NPS) pollution is dispersed throughout a watershed and includes pathogens, bacteria, metals, nutrients or pesticides delivered to water bodies in stormwater runoff. NPS pollution also includes sediment discharged to water bodies from roads, streambanks, gullies, and sheet and rill erosion. The insidious nature of nonpoint source pollution is that the individual pollutant contributions may be small, but their combined effects can significantly impact aquatic health.

The portion of a TMDL allocated to a point source of pollution is known as a "waste load allocation;" waste load allocations are enforced through waste discharge requirements (WDRs) inserted into a National Pollutant Discharge Elimination System (NPDES) permit. The portion of a TMDL allocated to nonpoint sources of pollutant (including load estimates from natural sources) is known as "load allocation," and is enforced through the state's NPS management program. Nonpoint source pollution is typically controlled through BMPs.

An agricultural BMP for preventing runoff from land application of manure might require a vegetated buffer strip around farm fields. The US EPA and the U.S. Department of Agriculture (USDA) have developed BMPs for most types of nonpoint source pollution, and have shown that agricultural nonpoint source pollution can be reduced by 20 to 90% through management measures aimed at soil retention and runoff reduction (USDA and NRCS, 1997; US EPA, 2005).

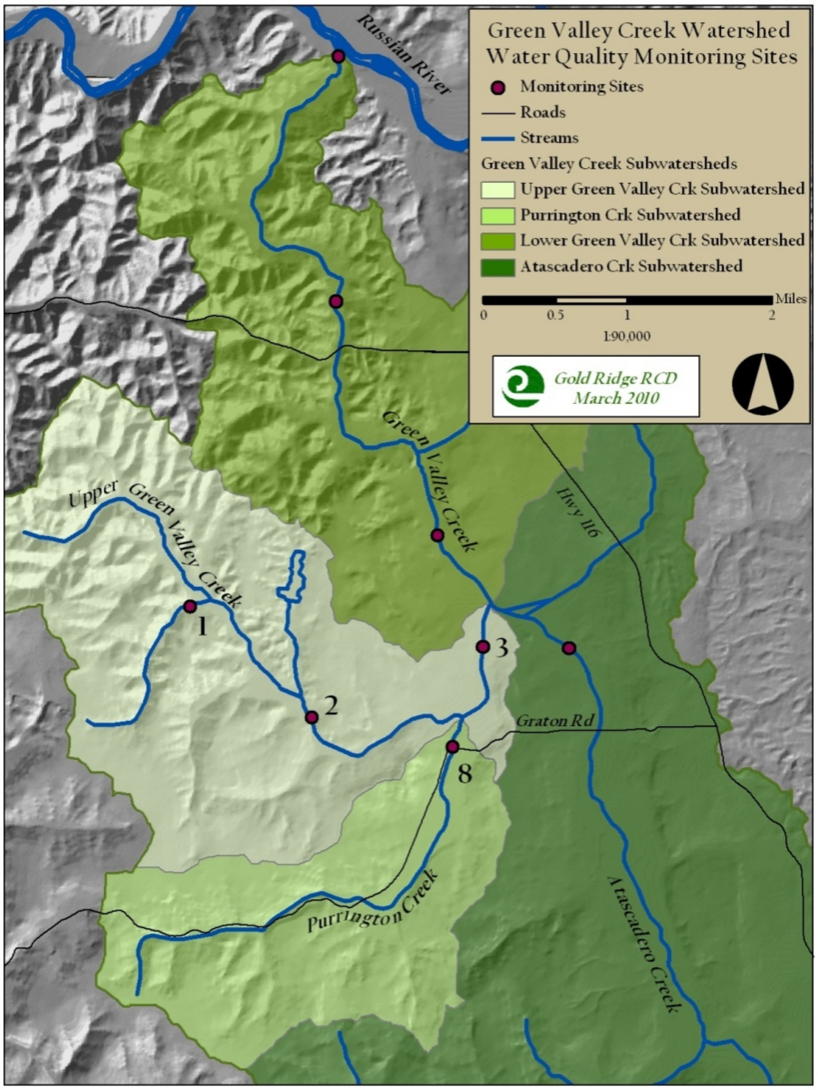
The Guerneville HSA is listed in the 2006 CWA Section 303(d) List of Water Quality Limited Segments for sedimentation/siltation and water temperature. Sediment impacts in tributaries throughout the Russian River HU prompted listing the entire HU for sediment and high water temperatures and have been identified as a major source of impairment of its cold-water fisheries (NCRWQCB 2007b). Potential sources of these impairments are listed in *Table 4, Potential Sources of Sedimentation and Increased Water Temperature.*

The Russian River HU TMDLs for sediment and temperature impairment are scheduled to begin in 2010 (NCRWQCB 2008). Proactive and voluntary measures taken at the watershed scale to reduce nonpoint sources of pollution entering a 303(d) listed water body can potentially eliminate or significantly minimize a mandatory regulatory process. This watershed plan and the planning process on which it is based are designed to help reduce water quality impairments in the watershed through a collaborative, voluntary planning process.

Water Quality in the Upper Green Valley Watershed

Since late 2008, GRRCD has been conducting water quality sampling at select locations within the Atascadero-Green Valley watershed to determine existing conditions (*Map 6, Water Quality Sampling Locations*). Water samples (when available – some locations go dry during the summer) were collected monthly from each monitoring location via grab sample and subsequent chemical analysis. Grab sampling takes a snapshot of the water quality conditions occurring at a specific location at a particular time. Instantaneous temperature, dissolved oxygen (DO), pH, and conductivity were measured directly in the field using a YSI© hand-held water quality measurement and data collection logger. Salinity and turbidity were also measured in the field from grab samples using a Turbidimeter. Separate grab samples were collected and sent to a laboratory for nitrate analysis. Established objectives for the measured parameters are provided in *Appendix 3, Water Quality Objectives by Parameter*.

Salinity levels above zero were not detected at any site in the Upper Green Valley watershed and all nitrate measurements (two sampling events) were below the EPA threshold of < 1.0



Map 6. Water Quality Sampling Locations

mg/l. Water temperature, dissolved oxygen, turbidity, and other monitoring results are discussed in detail below.

Many water quality parameters such as stream temperature, dissolved oxygen percent, pH, conductivity, stream height or stage, can be measured continuously using in situ data loggers.

Continuous stream monitoring tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season. For this reason, continuation of the water quality monitoring program in Green Valley Creek should have a goal of establishing and expanding the use of continuous monitoring for flow and temperature, at a minimum.

Water Temperature

Temperature is an important environmental factor for aquatic habitat and at times is the determining factor for species assemblages; as waterways that were historically cool become warmer, cold water fish can be replaced by species better suited to warmer conditions. Protection and restoration of the Cold Freshwater Habitat beneficial use (see *Table 3, Guerneville HSA Beneficial Uses*) is imperative to restoring coho and steelhead fisheries in the Green Valley watershed. Salmonids are poikilothermic – (cold blooded) – animals, which means that their body temperature is regulated by their environment. Temperature is an important factor in activity level and physiological processes at all stages of the salmonid life cycle; temperature requirements vary depending upon species and developmental stage. Timing of upstream migration is dependent upon flows and temperature; coho salmon enter the Russian River between November and January, with most spawning occurring in December. Steelhead enter the river between December and April, with most spawning occurring from January through March (Coey et al. 2002) (see *Chapter II, Section F* and *Table 5, Water Temperature Criteria for Different Life Stages of Steelhead and Coho*). Summer water temperatures are critical for the survival and health of all salmonid species that occur in the Green Valley Creek watershed. Additionally, temperature affects other aquatic organisms as well as influencing other characteristics of water, including dissolved oxygen (DO), pH, and other physical and chemical characteristics.

Table 5. Water Temperature (°C) Criteria for Different Life Stages of Steelhead and Coho (Thompson and Larsen 2004, Coey et al. 2002, McEwan and Jackson 1996, KRIS Web undated)

Adults				**Juvenile Rearing**		
Species	**Migration**	**Spawning**	**Incubation**	**Preferred**	**Optimum**	**Lethal**
Coho	4.44 – 9.44	4.39 – 9.39	4.39 – 13.28	11.78 – 14.61	9 – 15.6	25.78
Steelhead	7.78 – 11.11	3.89 – 9.39	8.89 – 11.11	7.28 – 15.56	10	24.11

Recorded temperatures in the watershed ranged from a low of 7.15° C in January 2009 in Purrington Creek (GV8) to a high of 17.7° C in June 2009 in Green Valley Creek (GV3) (*Chart 1, Water Temperature*). Water temperatures in the watershed slightly exceeded preferred temperatures for salmonids on most sampling dates except late summer and early fall, but did not reach lethal limits. During late summer and early fall, however, there was another important environmental factor of concern – there was no water at Site 1 beginning in June, and Site 3 was dry in September (no sampling was conducted in August 2009). In October, pools were still connected on Purrington Creek (Site 8), but at Site 2, they were disconnected. Although water had returned to Site 3 in November, Site 1 still had no water.

While measured temperatures were nominally above optimal for several months during the year of monitoring, they never reached lethal limits during the sampling events (see *Chart 1, Water Temperature* and *Table 5, Water Temperature Criteria for Different Life Stages of Steelhead and Coho*). Monitoring locations went dry in the upper watershed beginning in June and by October, the lower reaches were mostly dry, indicating that summer rearing habitat in the watershed may be limited. The Purrington Creek location (Site 8) retained pool connectivity through October; this waterway has been identified by NMFS as priority habitat for coho restoration (NMFS 2010). The Purrington Creek location also had cool water temperatures during most of the sampling events.

Continuous stream monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, should be considered for future monitoring efforts.

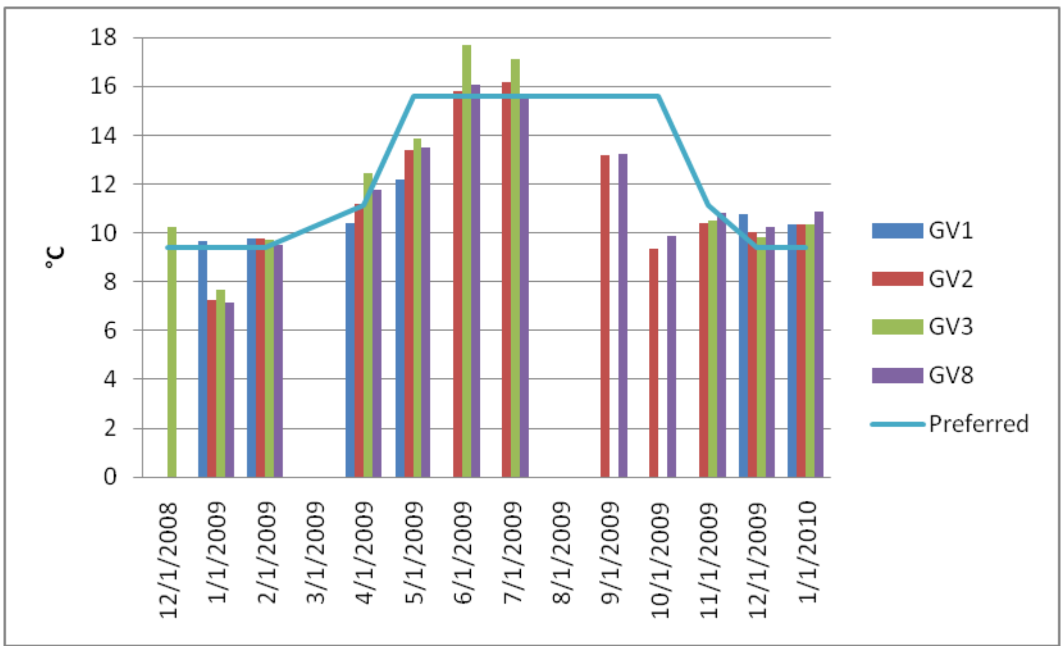


Chart 1. Water Temperature

Factors influencing water temperature in the watershed include heat loading from direct sunlight due to lack of riparian vegetation, high turbidity levels due to high rates of sedimentation, and hydrologic disconnection with cold water inputs such as spring flows and seeps. Sediment deposition can cause pool infilling and channel aggradation, which results in shallower water with warmer temperatures as well as other habitat impacts. Human activities associated with sedimentation are discussed in the next section.

Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates or solids. It is usually measured as the relative amount of light reflecting from a water sample. Turbidity measurements provide the most useful information when describing conditions over a specific time period. Amount of turbidity combined with duration of exposure provides a more robust understanding of potential physiological effects of different turbidity levels (Newcombe and MacDonald 1991).

Turbidity affects aquatic life directly by interfering with feeding success and mobility. Additionally, high concentrations of suspended sediment may delay or divert salmonid spawning runs – especially when the suspended sediment load is greater than 4,000 mg/l (CDFG 2004). The longer an episode of high turbidity persists, the greater the impact to aquatic organisms. Coho juveniles exposed to chronic turbidity were smaller in length and weight and grew more slowly than those exposed to clear conditions in laboratory experiments (Sigler et al. 1984, Redding et al. 1987); however, a study on Mad River tributaries in 2004–2006 did not find substantial negative effects on growth due to turbidity conditions (DeYoung 2007). This discrepancy may be explained by the possibility that juveniles in the wild have the capability to escape into tributaries where turbidity is not as great. Other studies have found that long-term changes in the composition and concentration of suspended solids can have potential cumulative lethal and sublethal effects on aquatic organisms including reduction in foraging capability, gill trauma, reduced disease resistance, increased stress, and interference with orientation cues associated with migration (Bash et al. 2001).

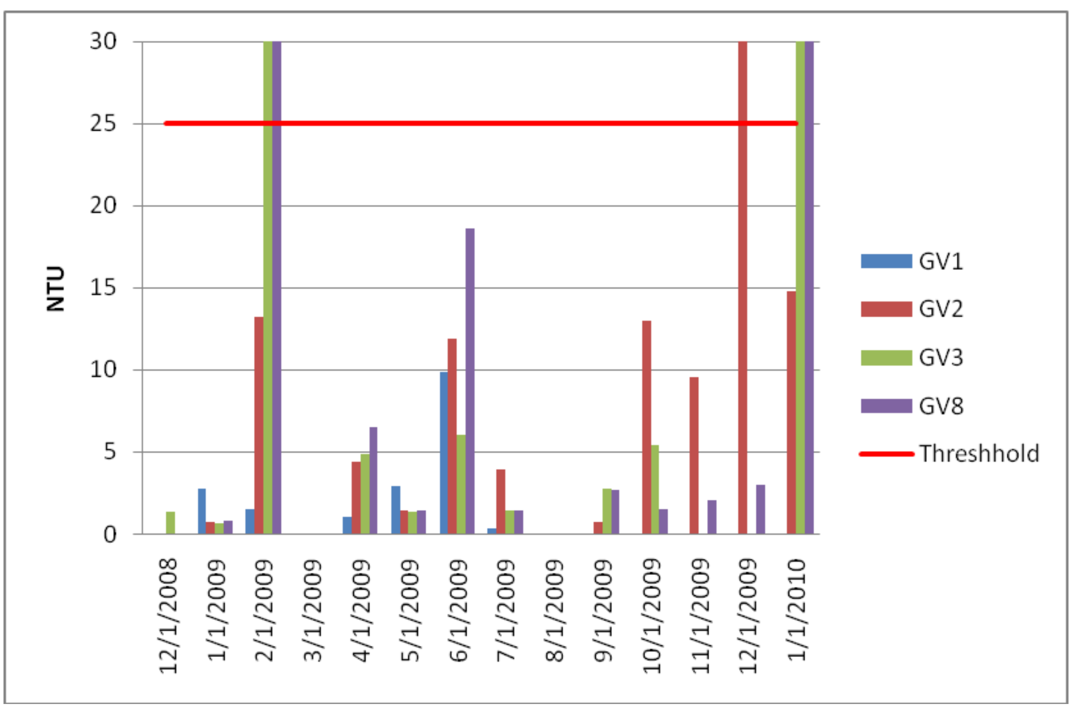


Chart 2. Turbidity

Turbidity can also result in behavioral effects; for example, juveniles in turbid waters were found to be more likely to emigrate (Sigler et al. 1984, DeYoung 2007). Length of exposure, frequency of exposure, water temperature, life stage, size and type of suspended particles, and availability of refugia are some of the factors that influence how turbidity affects salmonids. In addition to the physical effects of suspended solids, Stone and Droppo (1994) suggest suspended solids probably act as the primary transport mechanism for pollutants and nutrients in streams through flocculation, adsorption, and colloidal action (Stone, 1994).

GRRCD, like most resource agencies, measures turbidity in nephelometric turbidity units (NTUs). For this analysis, we conform to the EPA 2006 303(d) list use of Sigler et al.'s (1984) threshold of 25 NTU. During the sampling events over the thirteen months in which the Upper Green Valley Creek watershed has been monitored, turbidity has often been above the 25 NTU suggested by Sigler et al. as a threshold for physiological effects (*Chart 2, Turbidity).* These events occurred during the rainy season and ranged from 33.8 to 75.8 NTU, but duration was not measured. In January 2009, all four monitoring locations were above the threshold; in January, the Upper Green Valley watershed received a large amount of precipitation. During the spring, summer, and fall, turbidity levels are below the threshold for physiological effects. In general, Site 2 has consistently higher turbidity than the other locations; this may be indicative of an ongoing land-based sediment source upstream.

Many factors, both natural and anthropogenic, influence turbidity. In the Green Valley watershed, anthropogenic influences include rural roads, agricultural land use practices associated with vineyards, orchards and livestock pasture, and runoff from rural residential and light commercial development. Natural factors can include the delivery of fine sediment from mass movements (landslides), and natural stream incision related to tectonic processes.

Dissolved Oxygen

Dissolved oxygen (DO) is the amount of oxygen gas present in water and available to aquatic organisms; it provides a good measure of general aquatic health. It is added to water through diffusion from air, turbulence, and photosynthesis of aquatic plants, and removed through respiration of aquatic organisms, decomposition of organic material, and other chemical reactions that use oxygen. Additionally, DO passes from the water to the air in response to changes in atmospheric pressure, temperature, or salinity; more oxygen can dissolve in cold water, under greater pressure, and at lower salinity. DO levels are extremely variable; they can change with time of day, weather, and temperature. Continuous dissolved oxygen monitoring, which tracks the daily and seasonal variations and allows for a more thorough assessment of stream health and how the conditions affect aquatic organisms throughout a season, should be considered for future monitoring efforts, particularly during the summer and fall when temperature tends to be high and streamflow is low.

Dissolved oxygen levels can range from 0 – 18 milligrams per liter (mg/l), but most aquatic ecosystems require at least 5–6 mg/L to support a diverse biological assemblage. When the concentration of DO is greatly reduced, the ability of gills to acquire oxygen for respiration is impaired, potentially leading to chronic effects such as reduced growth, increased susceptibility to disease, or reduced reproductive success. Invertebrate species sensitive to decreasing DO levels include mayfly nymphs, stonefly nymphs, caddisfly and beetle larvae. As DO levels decrease, these organisms are replaced by worms and fly larvae that tolerate water pollution; decreases in DO usually occur after an influx of organic pollutant (Green Media Toolshed and GetActive Software 2005). If DO concentrations fall below 3 to 4 mg/L, fish species such as salmon can experience physiological stress; however, many aquatic organisms can recover from short periods of low DO availability. The optimal DO level for salmon is 9 mg/l with a level of 7-8 mg/l acceptable and 3.5-6 mg/l considered poor. DO levels below 3.5 mg/l are likely to be fatal to salmon; levels below 3 mg/l are stressful to most vertebrates and other forms of aquatic life (Maun and Moulton undated).

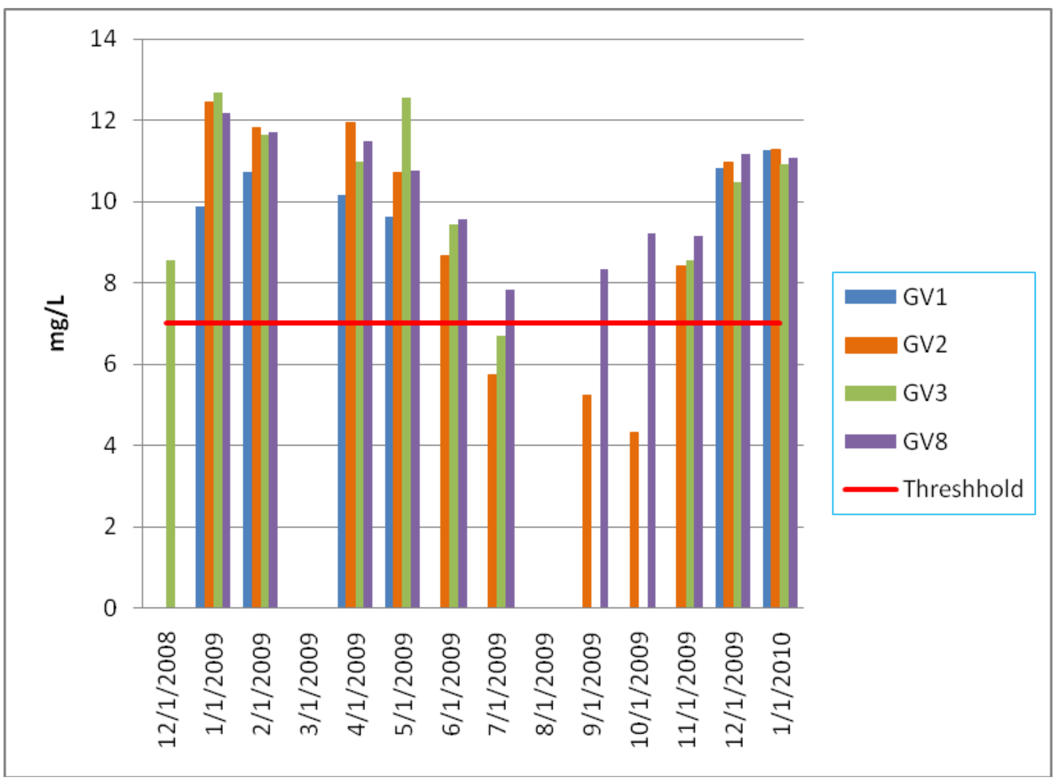


Chart 3. Dissolved Oxygen

Water Quality Objectives from the North Coast Regional Water Quality Control Plan set minimum dissolved oxygen levels at 7.0 mg/l for the Russian River HU with 7.5 monthly mean (90% Lower Limit[i]) and 10.0 monthly mean (50% Lower Limit[ii]) (NCRWQCB 2007a). DO objectives were developed to protect the 5 beneficial uses related to the preservation and enhancement of fish: marine habitat (MAR), inland saline water habitat (SAL), warm freshwater habitat (WARM), cold freshwater habitat (COLD), and spawning, reproduction, and/or early development (SPWN). The Guerneville HSA includes WARM, COLD and SPWN beneficial uses (see *Table 3, Guerneville HSA Beneficial Uses*).

During the fourteen months of water quality monitoring in the Upper Green Valley Watershed, DO measurements in at least one location met or exceeded the 7.0 mg/L minimum during every sampling month (*Chart 3, Dissolved Oxygen*). In general, DO levels were higher through the winter months and dropped off during the summer, reflecting the seasonal increase in water temperature and lower stream flow conditions. Although monthly grab samples only give a snapshot of conditions in the watershed, the data suggests that DO conditions in most of the watershed are generally sufficient for salmonid survival. DO was not monitored in August. DO measurements exceeded the minimum at all locations from January through May 2009. Site 1 contained no water from June through November and Site 3 had no water in September and October. Samples from Site 2 were below the threshold in July and remained low until November. Samples from Purrington Creek (Site 8) were above the minimum throughout the year. In general, DO levels were sufficient during the winter and into early summer, but fell below acceptable levels when flows became low during late summer and early fall.

Factors that may be involved in lower than optimal DO in the watershed include nutrient increases associated with agricultural runoff, increased water temperature, which decreases the ability of water to hold oxygen, or decreased turbulence due to decreases in flow. In stream reaches with excessive algal growth, DO concentrations fluctuate significantly throughout the day – supersaturated conditions occur during the day and lower concentrations around dawn when respiration and other reactions during the dark have consumed oxygen. For areas impacted by algae, early morning sampling should be conducted to evaluate the impacts on DO. The decomposition of algae consumes oxygen, and sampling design should consider capturing this impact. Human activities that draw down the water table, add nutrients, or divert surface water during the summer may contribute to reduced DO during the critical summer months.

pH

pH is a measure of how acidic or basic water is on a scale from 0 to 14, with 7 being neutral. A pH of less than 7 indicates acidic conditions, while above 7 is basic. Most freshwater lakes, streams, and ponds have a natural pH in the range of 6 to 8. Acidity in most streams is controlled by the carbonate buffering system – an equilibrium between calcium, carbonate, bicarbonate, carbon dioxide, and hydrogen ions in the water and carbon dioxide in the atmosphere. Poorly buffered waterways – those most susceptible to acidification – are found in watersheds containing slowly weathering minerals and little limestone or other alkaline materials, like the Upper Green Valley watershed. In poorly buffered surface waters with large aquatic plant populations, pH can show high daily variability – increases of several units during the day and similar decreases during the night are not uncommon. The use of CO_2 by plants during photosynthesis removes carbonic acid from water, which can increase daytime pH dramatically. During the night, pH levels can fall just as drastically because plants are not photosynthesizing and carbonic acid can accumulate (US EPA 2008). However, in the Upper Green Valley Creek watershed, aquatic plant populations are not likely to increase to a population level where this type of oscillation occurs.

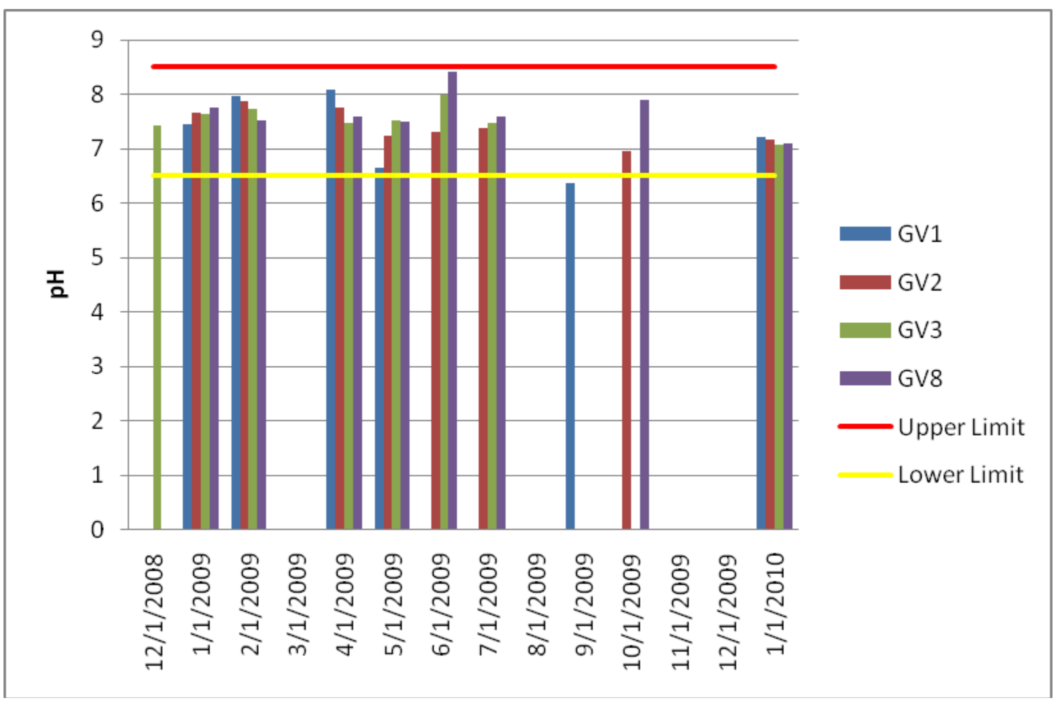


Chart 4. pH

For fish, pH above 9.5 can cause death or damage to outer surfaces like gills, eyes, and skin, and result in an inability to dispose of metabolic wastes. Increased pH can also increase the toxicity of other substances, such as ammonia; the effect of ammonia is 10 times greater at pH 8 than at pH 7. When conditions are more acidic (low pH), plankton and mosses may invade, and some fish populations diminish. Water Quality Objectives from the North Coast Regional Water Quality Control Plan set pH 8.5 as the maximum and 6.5 as the minimum for the Lower Russian River Watershed (NCRWQCB 2007a).

Measurements of pH were within limits set by the NCRWQCB during the monitoring period (*Chart 4, pH*). In August 2009, pH was not monitored and in early winter November and December 2009, the pH meter was malfunctioning. Site 1 pH measurements were somewhat variable from month to month and Site 8 increased markedly in June. Since immature stages of aquatic insects and juvenile fish are sensitive to pH, such changes could be detrimental, and a spike indicates the possibility of a pollutant discharge. Continued testing will help to determine whether such increases are regular phenomena or random fluctuations.

Anthropogenic factors that contribute to extreme pH levels include nutrient loading, which can lead to excessive aquatic plant growth, and runoff or point-source pollution that directly alters stream chemistry. Acid rain can also influence pH levels, but it does not generally occur in the western US.

Conductivity

Conductivity – or specific conductance – measures water's ability to conduct an electric current. It is sensitive to variations in dissolved solids such as mineral salts that dissociate into ions. Each ion's electric charge, ion mobility, and water temperature affect conductivity. Because of its sensitivity the temperature (the warmer the temperature, the higher the conductivity), conductivity is reported as conductivity at 25 degrees Celsius.

In streams, conductivity is affected primarily by the geology of the area through which the water flows – streams that run through areas composed of inert material like granite will have lower conductivity than those that run through areas with clay soils or other rocks that ionize when exposed to water. Discharges to streams can change stream conductivity; failing septic or fertilizer runoff would raise conductivity due to the presence of chloride, phosphate, and nitrate. It is not known how conductivity affects salmonids, but streams that support fisheries usually have a range between 150 and 500 μS/cm (US EPA 2006).

Streams tend to have a relatively constant range of conductivity; once a baseline is established, it can be used as a comparison for ongoing monitoring. Significant changes could indicate discharge of a pollutant. In the North Coast RWQCB Water Quality Control Plan, conductivity is set at 375 micro-Siemens per centimeter (μS/cm) at 25° C (90% Upper Limit[1]) and at 285 (μS/cm) at 25° C (50% Upper Limit[2]) (NCRWQCB 2007a).

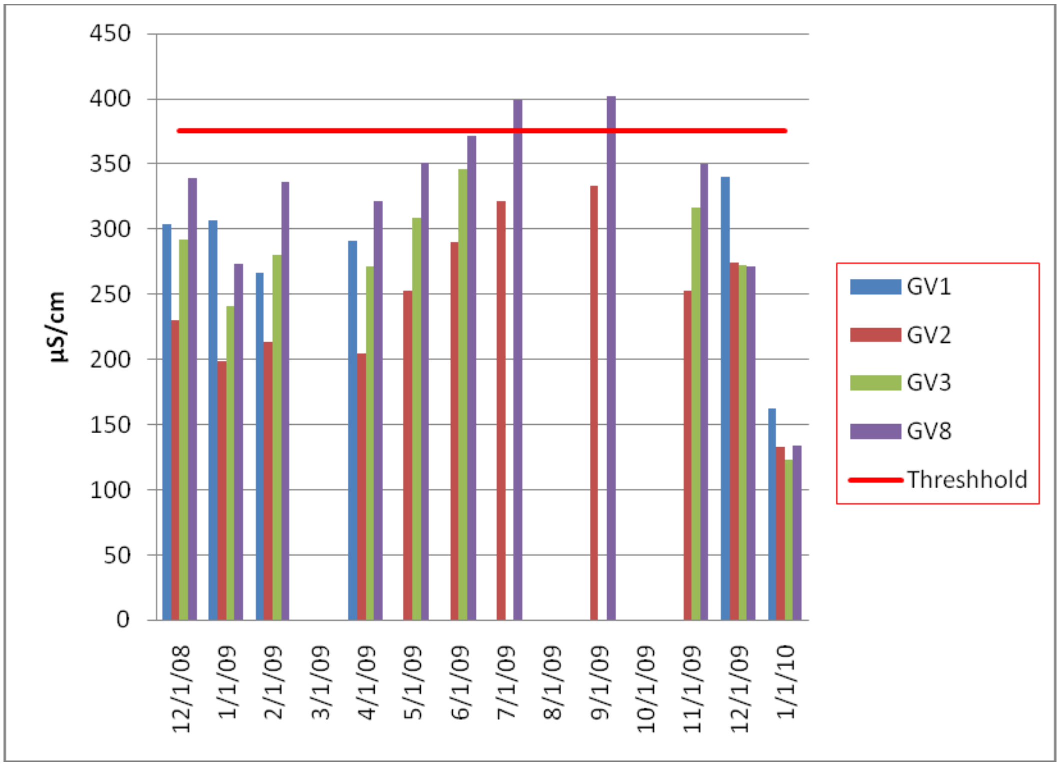


Chart 5. Conductivity

During the fourteen months that conductivity was monitored in the watershed, conductivity levels remained mostly below the upper limit value of 375 (μS/cm) set by the NCRWQCB (*Chart 5, Conductivity*). Water quality was not monitored during August 2009. The Purrington Creek location (Site 8) exceeded 375 (μS/cm) in June and July, which may indicate a pollution discharge event in the vicinity.

[1] 50% upper and lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit.

[2] 90% upper and lower limits represent the 90 percentile values for a calendar year. 90% or more of the values must be less than or equal to an upper limit and greater than or equal to a lower limit.

Data Gaps

The past fourteen months of water quality monitoring represent the beginning of GRRCD's focused water quality monitoring program in the Upper Green Valley and Purrington Creek subwatersheds. Continued and enhanced monitoring will provide a more thorough understanding of current water quality conditions and establish a baseline for comparison.

Water quality monitoring has been conducted in the watershed since 2005 by the Atascadero–Green Valley Watershed Council through the Community Clean Water Institute (*Appendix 4, AGVWC / CCWI Water Quality Monitoring Data*). These data were not readily available in the short period during which the first Phase of the Plan was drafted, however, we will make sure to utilize them as the Plan moves to Phase II (provided it is SWAMP compatible).

Historic water quality data – especially during the periods in which coho were plentiful – would be very valuable to provide targets for management activities and projects.

Conclusion

Results from the past fourteen months of monitoring suggest that overall water quality in the Upper Green Valley Creek watershed meets most standards for salmonid survival at different life stages. The Purrington Creek location (Site 8) most often met standards and retained pool connectivity throughout the summer months. However, the spike in pH in June and conductivity measurements above the threshold in June and July may indicate that a pollutant discharge occurred upstream of Site 8 during the early summer.

Summer months pose the greatest challenge for water quality, likely due to the low flow regime during that time. Low flow conditions result in less water volume available to dilute the concentration of pollutants or attenuate the high summer temperatures, both of which drastically affect the quality and availability of aquatic habitat. Temperature increases, low levels of DO, and an absence of habitat may limit survival of juvenile salmonids in the watershed. Because these factors are so closely related, efforts to increase summer flow are likely to have a beneficial effect on water temperature and DO concentrations.

Water Quality Goals:

1. Promote and protect the Beneficial Uses of the watershed
2. Reduce nonpoint source sedimentation
3. Reduce summer water temperature and provide increased summer flows through a combination of offstream storage and conservation practices

Chapter II, Section D discusses sedimentation in more detail. BMPs that support sustainable agriculture, improve road development and maintenance, and reduce the impact of rural residential development are discussed in detail in *Chapter III, Management Considerations*. Specific, measurable actions that implement BMPs to achieve water quality goals are presented in *Chapter IV, Looking Forward*.

Water Quality Recommendations:

1. Surface water quality monitoring should continue with enhanced equipment at an increased number of sites:
    a. Parameters measured to include continuous stream discharge, temperature, DO, TSS, and nutrients.
    b. Develop SWRCB-approved Monitoring and Assessment Plan and Quality Assurance Project Plan to guide monitoring activities.
    c. Install temperature loggers in select sites through the summer months.
    d. Obtain instrumentation/lab facilities/funding to measure total suspended solids (TSS) as a measure of turbidity. These measurements can be useful to calculate total quantities of material within or entering a stream system and are not possible with NTU measurements.
    e. Obtain repeat TSS measurements during periods of high turbidity to determine duration of high turbidity. This will provide more information about potential impacts to aquatic wildlife.
    f. Conduct bioassessment using benthic macroinvertebrate assemblages as an indicator of aquatic habitat quality.
    g. In stream reaches where algae are consistently present, conduct bioassessment using algal communities as an indicator of nutrient impacts to aquatic habitat quality.
2. Implementation of BMPs to decrease sediment loads.
    a. Road-related sediment reduction measures
    b. Vineyard and orchard cultivation-related sediment reduction measures
    c. Grazing management practices to limit sedimentation

    d. Restoration and enhancement of riparian buffers
3. Implementation of BMPs to decrease summer water temperatures, increase flow, and improve DO.
    a. Winter water storage measures to decrease summer diversions
    b. Vineyard, orchard, and livestock pasture-related water conservation measures
    c. Rural residential and light commercial-related water conservation measures
    d. Restoration and enhancement of riparian buffers

C. Hydrology & Instream Flow

Introduction

The Upper Green Valley Creek watershed fits within a band along the Pacific coast characterized as having a Mediterranean-type climate, distinguished by warm dry summers and mild wet winters, one of 6 such regions with this climatic type on the globe (Conacher and Conacher 1999). Recognizing these unique features, the Greek philosopher Aristotle noted that the Mediterranean climate is the only type suitable for human habitation (James 1959). In addition to this annual pattern of mild rainy winters and warm dry summers, regions with a Mediterranean climate typically share a feature more commonly associated with semi-arid regions – climatic events typically show greater inter-annual variability, such that drought and flooding are common characteristics of this climate type.

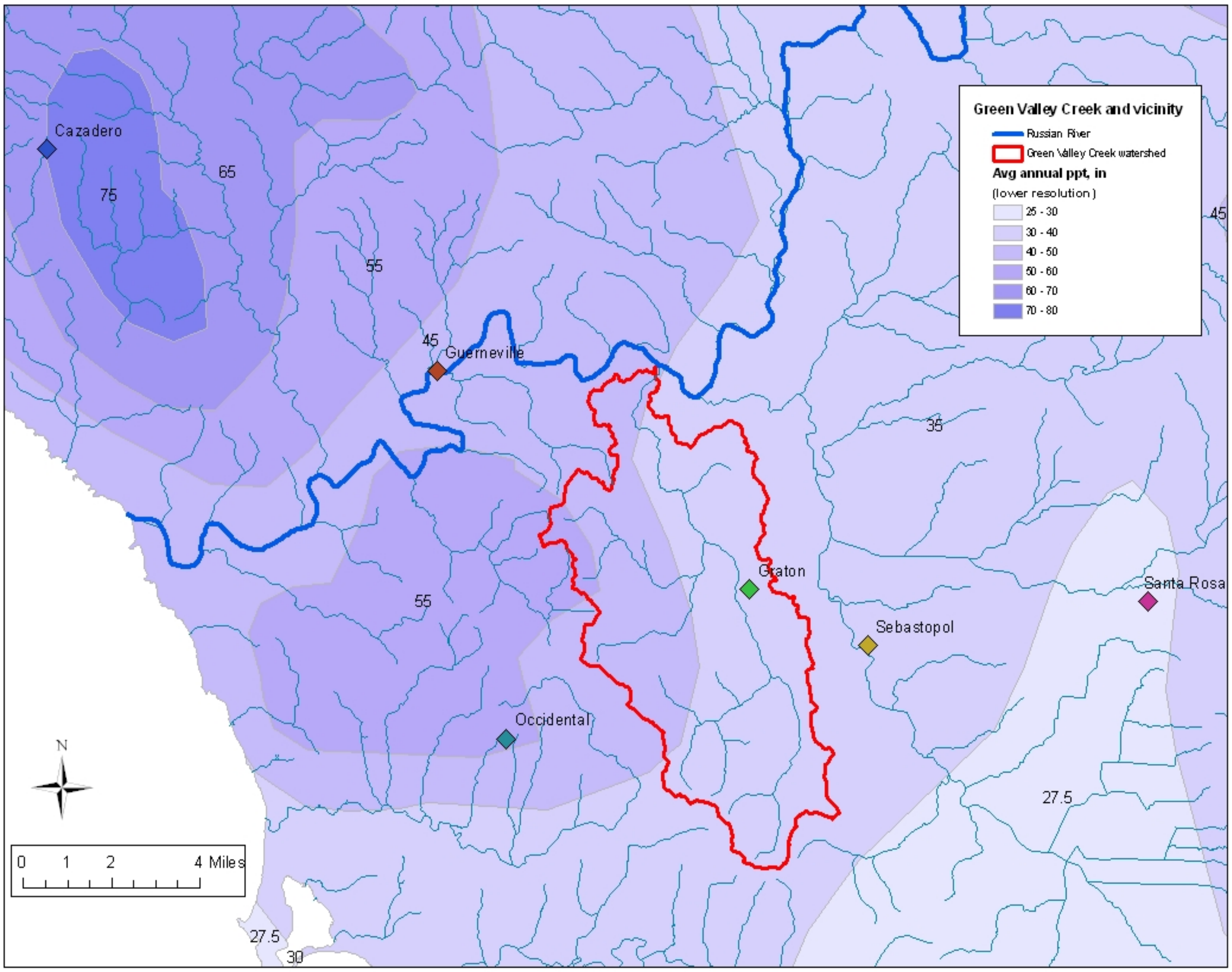
The following discussion will describe in detail the defining hydrologic characteristics of the Upper Green Valley Creek watershed and surrounding area. The central tenets of the Mediterranean climate, namely the seasonal and inter-annual patterns described above, can be described in the context of precipitation data gathered in or near the watershed. The discussion will also illustrate how these precipitation trends relate to streamflow in the region, within the same year as well as from one year to the next. It also will examine trends among long-term climate records to identify any differences that may have occurred in recent decades.

Finally, this discussion will describe how the general climatic and hydrologic characteristics of the Upper Green Valley Creek watershed may affect human activities and the potentential influence this may have on planning decisions. In addition to describing the volumes of water that reach the watershed and variations among long-term records, this discussion will examine the amount of water needed for human use within the watershed given the current extent of development and consider how changes in climatic characteristics that have occurred in recent decades may influence availability in the near future.

Rainfall

Precipitation is the foundation of hydrology. The timing, magnitude, and form (whether rain or snow) of precipitation dictate the remainder of the hydrologic cycle: how much water leaves as discharge, how much is available to vegetation, and how much becomes groundwater. This section will describe the dynamics of precipitation over time in the Upper Green Valley Creek watershed and surrounding area, with special attention to the basic features of the Mediterranean climate.

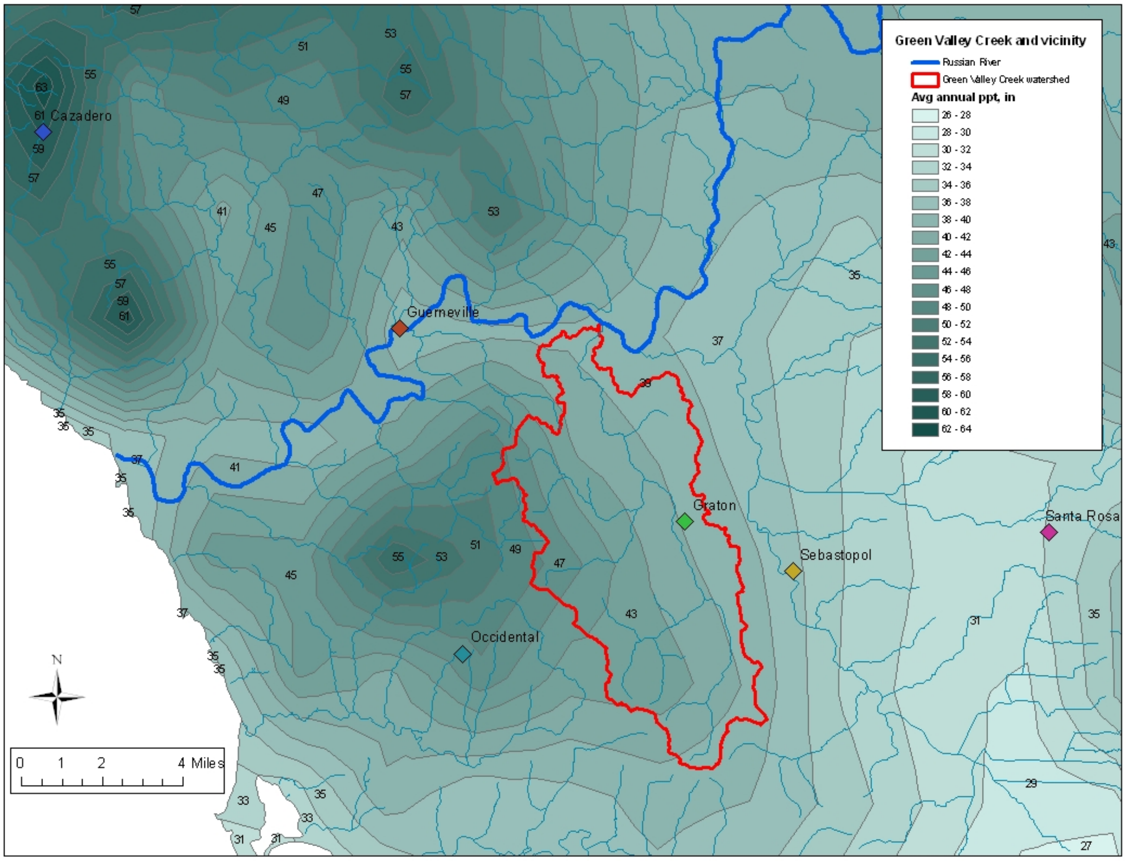
One characteristic of Mediterranean-climate regions is large spatial variability in precipitation. Precipitation is partly dictated by terrain, which produces microclimates across the greater landscape (Dallman 1998). Two spatial expressions of precipitation data of the Green Valley Creek watershed and surrounding area generated by computer models illustrate this variation across space: one was created using long-term mean annual precipitation records from USG Geological Survey, California Department of Water Resources, and the California Division of Mines (*Map7, Mean Annual Rainfall in Green Valley Creek Watershed and Surrounding Areas based on Long-term Records*); and the other is based on precipitation models generated by researchers at Oregon State University (referred to as PRISM; *Map 8, Mean Annual Rainfall in the Green Valley Creek Watershed and Surrounding Areas based on PRISM*). According to these two data sets, average annual rainfall within 10 miles of the Green Valley Creek watershed may be as high as 60-70 inches, or as low as 25-27 inches (*Maps 7, 8*). Though the two models show differing results in some portions of the surrounding region, the Green Valley Creek watershed itself is relatively consistent between models: average annual precipitation according to both models ranges from less than 40 inches to the southeast, to nearly 50 inches in the northwest portion of the watershed. Outputs from both models can be integrated over space to calculate an average annual rainfall for the Green Valley Creek watershed: the lower-resolution model (i.e., fewer bands of equal rainfall, called isohyets) predicts 39 inches, and the higher-resolution model predicts 42 inches.



Map 7. Mean annual rainfall in the Green Valley Creek watershed and surrounding area, based on long-term records compiled by California Department of Water Resources and US Geological Survey (low-resolution map).

In general, the isohyets mirror long-term records from precipitation gauges in and near the Green Valley Creek watershed. Five locations with more than 40 years of rainfall records available through NOAA's National Climatic Data Center[3] provide empirical support to the variation of mean annual rainfall across space in the area surrounding the Green Valley Creek watershed predicted by the spatial models discussed above (*Table 6*).

[3] Locations of long-term precipitation stations were placed in Figures 1 and 2 using corresponding latitude and longitude as provided through NCDC information. See http://www.ncdc.noaa.gov/oa/climate/stationlocator.html



Map 8. Mean annual rainfall in the Green Valley Creek watershed and surrounding area, based on PRISM (high-resolution map).

The principle characteristic of Mediterranean-climate regions is the seasonality of precipitation; long-term records of the 6 rainfall gauges listed above illustrate this seasonality (*Chart 6*). Most rainfall occurs during wet winters with little rain falling between May and October. These data also highlight the variation in monthly rainfall among long-term sites: precipitation at Cazadero (northwest of the Green Valley Creek watershed; see *Maps 7,8*) is approximately double the precipitation at Sebastopol and Santa Rosa on each month through the winter. Despite the large differences in average monthly rainfall among these long-term sites, the *proportion* of rainfall occurring each month relative to the entire year is similar and consistent among all sites (*Chart 7*). These data also illustrate the extent of precipitation seasonality: the proportion of rainfall occurring during the 6-month period November 1 – April 30 ranges from 88.8 % to 90.3 %.

Another characteristic common to the Mediterranean climate is variability of precipitation, which may be most easily described in terms of total annual precipitation over a long-term period. Long-term records from Sebastopol, Graton, and Occidental (mean precipitation 30 inches, 41 inches, and 54 inches, respectively) all illustrate the variability in precipitation from one year to the next (*Chart 8a-c*).

Long-term data sets also can provide insights into trends over long timescales. Models predicting effects of climate change in coastal California predict that precipitation will become more variable and more intense than current or recent conditions; long-term data sets can be used to illustrate whether these predicted effects of climate change can be detected in data from recent years, relative to the earlier portion of long-term records. Precipitation data from Graton provide an ideal resource for such an analysis because precipitation records date to 1927. To examine whether precipitation variability is greater at an annual scale more recently compared to earlier portions of the record, the average precipitation over (a) the previous 10 years and (b)

Table 6. Average annual precipitation at 6 long-term precipitation gauges in and near the Green Valley Creek watershed.

Location	**Period of record**	**Average annual precipitation, inches**
Cazadero	1944-1978; 1996-2009	74.9
Occidental	1944-2009	54.1
Guerneville	1944-1982	48.2
Graton	1926-2009	40.7
Sebastopol	1949-2009	29.9
Santa Rosa	1931-2009	30.3

the previous 5 years was calculated for each year of record. If precipitation is more variable in recent years, it could be expected that the magnitude of 10-year and 5-year averages would be different. 10-year average data beginning in 1936 (encompassing 1927-1936) through 2009 (encompassing 2000-2009) and 5-year average data beginning in 1931 (encompassing 1927-1931) through 2009 (encompassing 2005-2009) suggest that average precipitation is not more variable in recent years compared to earlier in the record (*Appendix 5 Average Annual Precipitation over the Previous 10 Years and Previous 5 Years*). Additionally, the consistency of the pattern in variation among 10-year and 5-year average values over time suggests that the frequency of high- and low-rainfall years is consistent over the more than 80-year period of record as well.

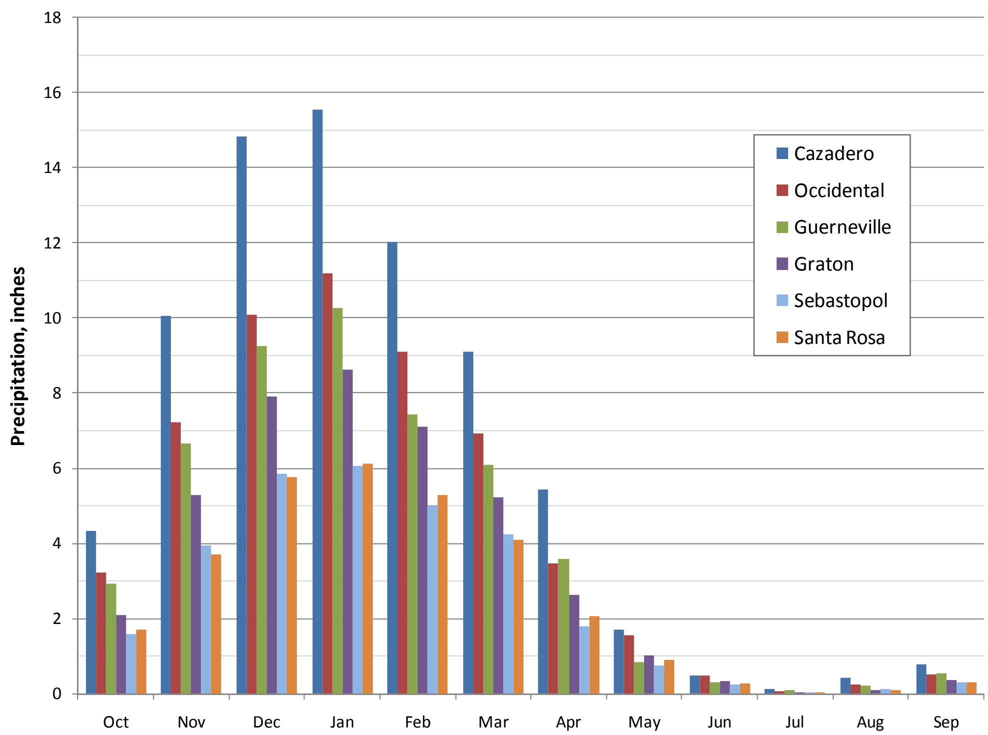


Chart 6. Average monthly rainfall, in inches, 6 long-term rainfall gauges in and near the UGV watershed.

Another trend suggested as likely to occur with climate change is increased magnitude of high-rainfall events. Long-term records can also be used to examine whether rainfall events of high magnitude occur more frequently in recent years compared to earlier in the period or record. For this analysis, daily precipitation and cumulative three-day consecutive precipitation data were ranked and sorted by magnitude. Daily precipitation values greater than 3 inches and three-day precipitation values greater than 6 inches, were plotted over time (*Chart 9 a-b*). Long-term records indicate that the magnitude and frequency of high-rainfall events appear to be no greater in recent years than in earlier years. These data suggest that the watershed is not currently experiencing predicted precipitation consequences of global climate change (see *Section III B, Climate Change*).

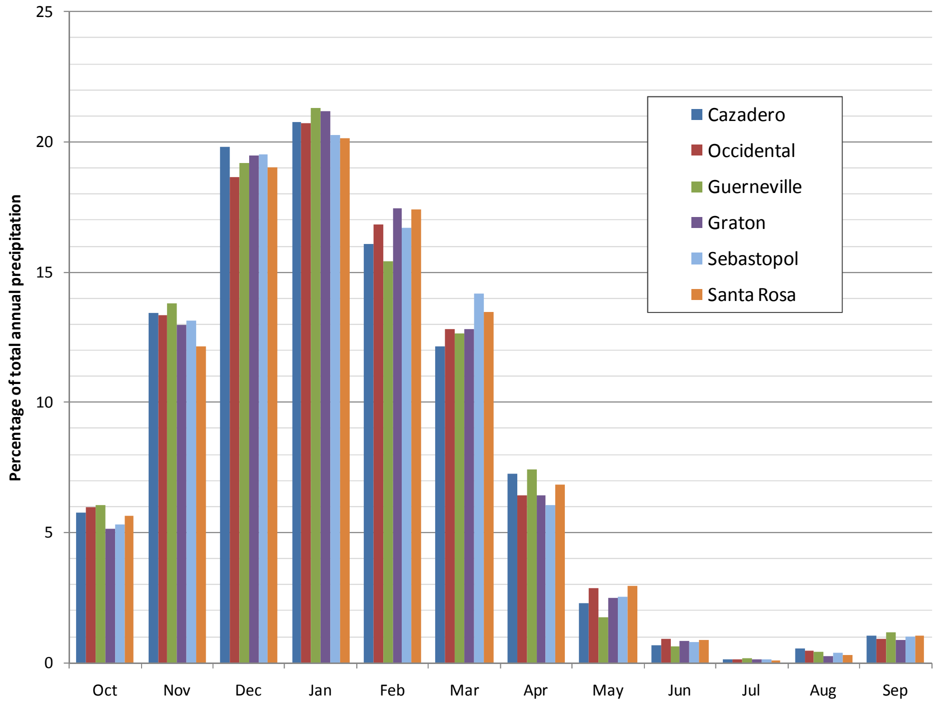


Chart 7. Percentage of total annual rainfall each month at 6 long-term rainfall gauges in and near the UGV watershed.

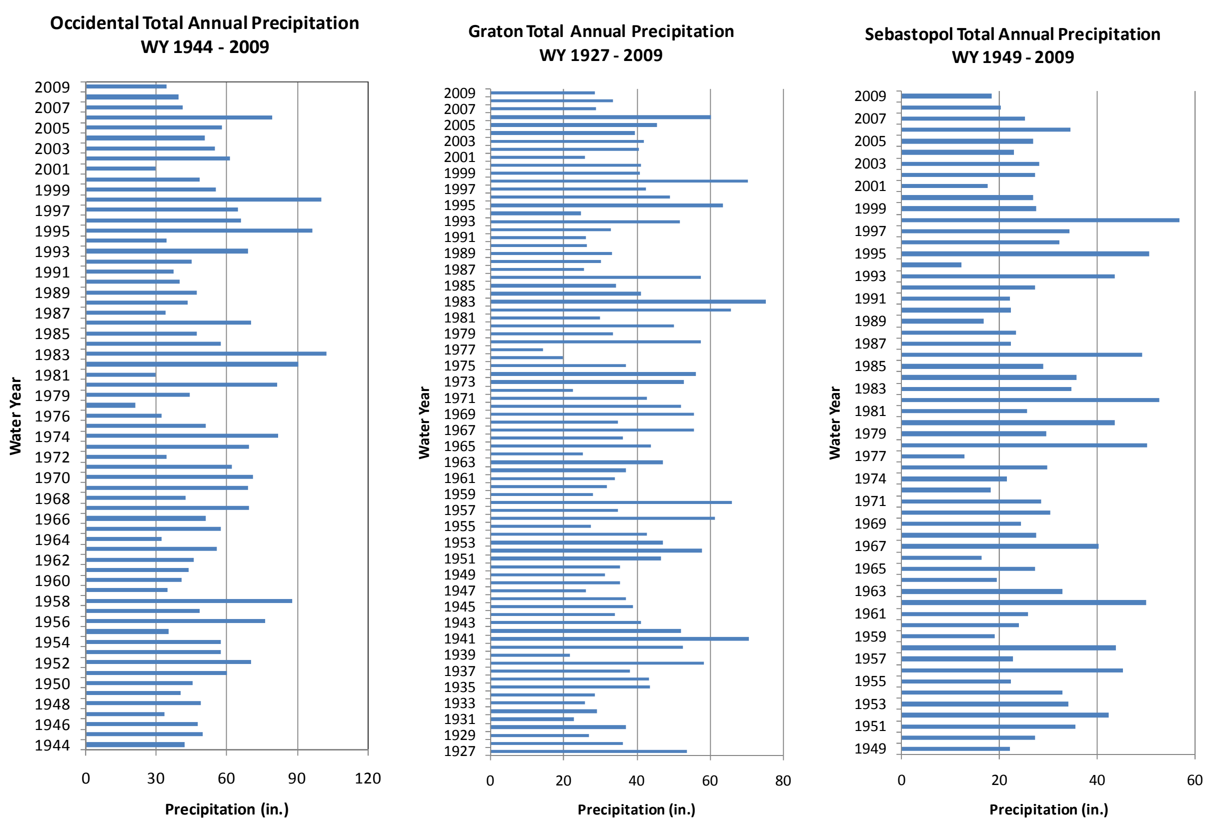
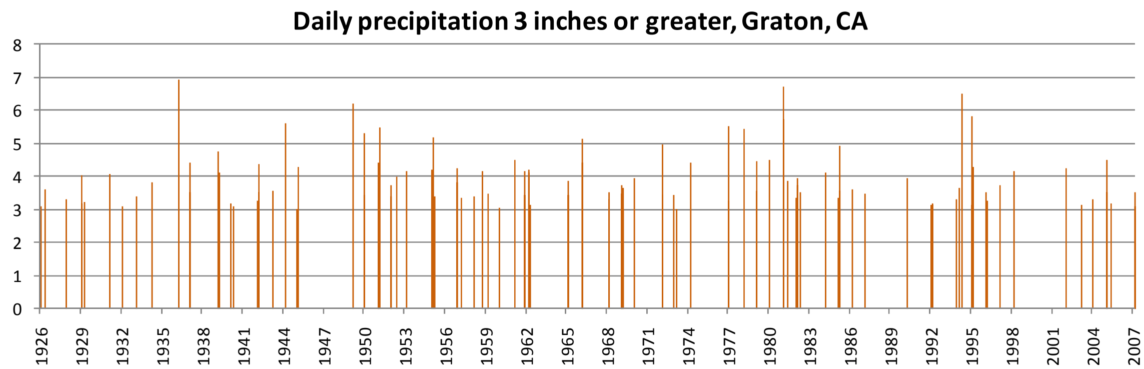


Chart 8 a-c. Distribution of annual rainfall at Occidental, Graton, and Sebastopol over long-term periods of record.

Streamflow

If precipitation is the primary input for the hydrologic cycle, streamflow is the most visible means of output. The water that appears in a stream has likely taken a combination of several pathways through shallow and deep groundwater, over lengths of time from hours to years (McDonnell 2003, McGlynn et al. 2004). Understanding the dynamics of streamflow in a watershed is essential for watershed planning because streamflow plays an important role for human development, and because aquatic organisms rely on water in streams for their survival.



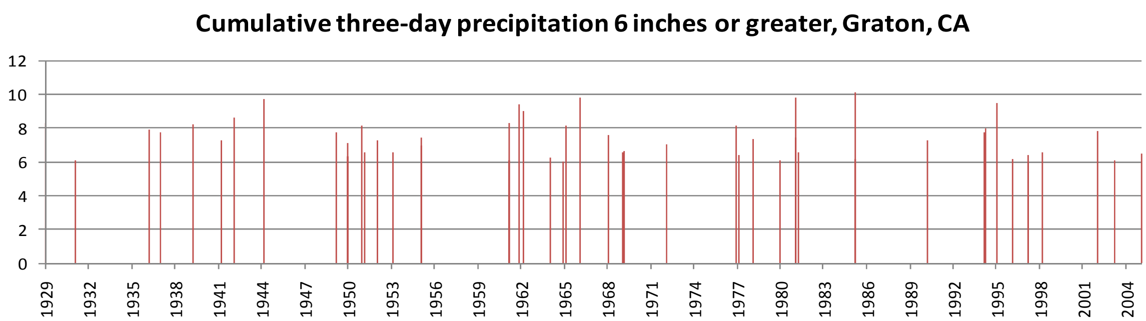


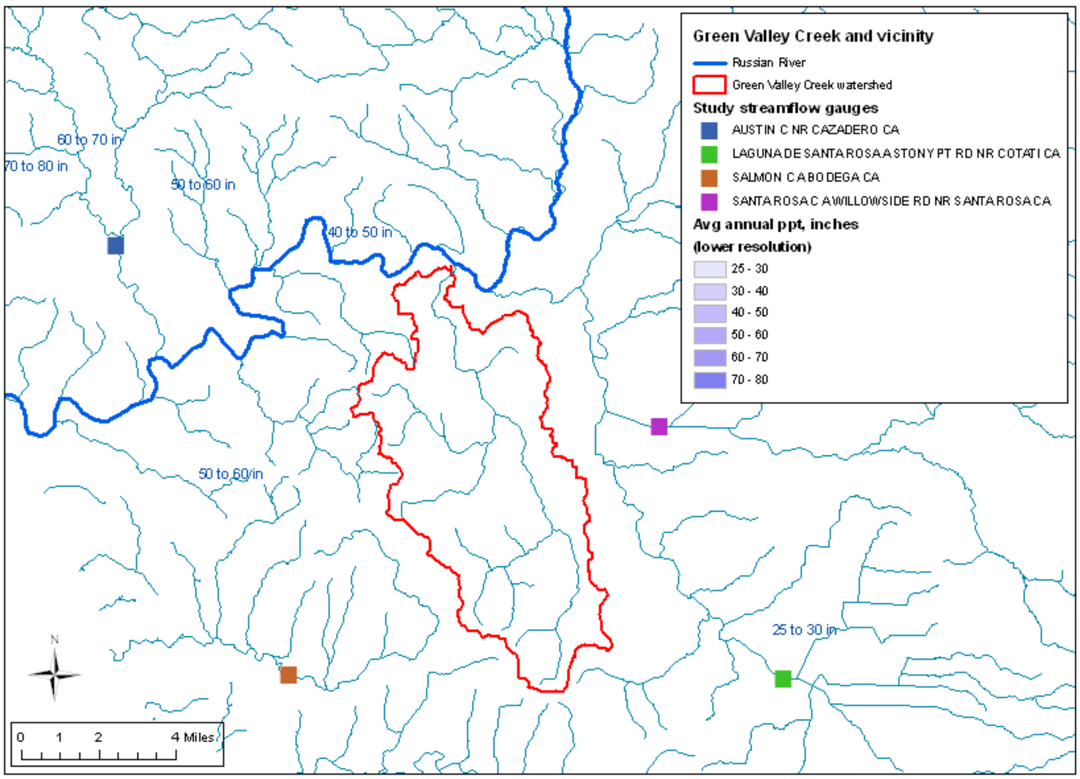
Chart 9 a-b. Distribution of daily precipitation greater than 3 inches and three-day cumulative precipitation greater than 6 inches at Graton, California.

Unlike rainfall, few long-term records of streamflow records exist in the region: no streams within the Green Valley Creek watershed were gauged by state or federal agencies. The US Geological Survey (USGS) gauged four streams of comparable size to Green Valley Creek near the Green Valley Creek watershed for a period of more than 10 years: Laguna de Santa Rosa from 1999 to 2009; Santa Rosa Creek from 1999 to 2009; Austin Creek from 1960-1966 and 2004-2009; and Salmon Creek from 1963-1975 (*Map 9*)[4]. Because of the variations in upstream

[4] USGS gauge sites and locations used for this analysis are: Laguna de Santa Rosa at Stony Point Rd, gauge number 11465680; Santa Rosa Creek at Willowside Rd, gauge number 11466320; Austin Creek near Cazadero, gauge number 11467200; and Salmon Creek at Bodega, gauge 11460920.

catchment size among these four gauges, analyses compare discharge in terms of volume per area, thus normalizing by catchment size.

Streamflow records illustrate trends similar to precipitation data. Annual discharge can be expressed as total depth over the watershed in inches to make coarse comparisons to precipitation in inches, calculated using mean daily flow data commonly available through the USGS web site. The first step listed below converts discharge to acre-ft over the entire year; acre-ft is a unit of volume commonly used in watershed-scale planning, representing the



Map 9. Streamflow gauges near UGV Creek

number of acres over which water could be covered to a depth of one foot. Equation 2 then converts this volume in acre-ft to inches over the entire watershed:

1. $$\textit{Annual Discharge, acre ft} = \left(\sum \textit{mean daily flow, year}, \frac{ft^3}{sec}\right) \times \left(\frac{1\ acre}{43560\ ft^2}\right) \times \left(\frac{86400\ sec}{1\ day}\right)$$

2. $$\textit{Annual discharge, inches} = \left(\frac{\textit{Annual discharge acre ft}}{\textit{watershed area}\ mi^2}\right) \times \left(\frac{1\ mi^2}{640\ ac}\right) \times \left(\frac{12\ in}{1\ ft}\right)$$

Discharge follows similar trends across space as precipitation: discharge is higher to the north and west, and less to the south and east (*Chart 10, Table 7*). Discharge converted to inches also illustrates the trend that substantially less water leaves the watershed as discharge than enters as precipitation - Rantz and Thompson (1967) estimate that, in this region, approximately 50-60 % of precipitation falling in a watershed exits as runoff. Also like precipitation, the percentage of runoff in each month is similar (*Chart 11*); and the proportion of discharge occurring during the 6-month period from November through April ranges from 93.0 % (Santa Rosa Creek) to 97.8% (Salmon Creek).

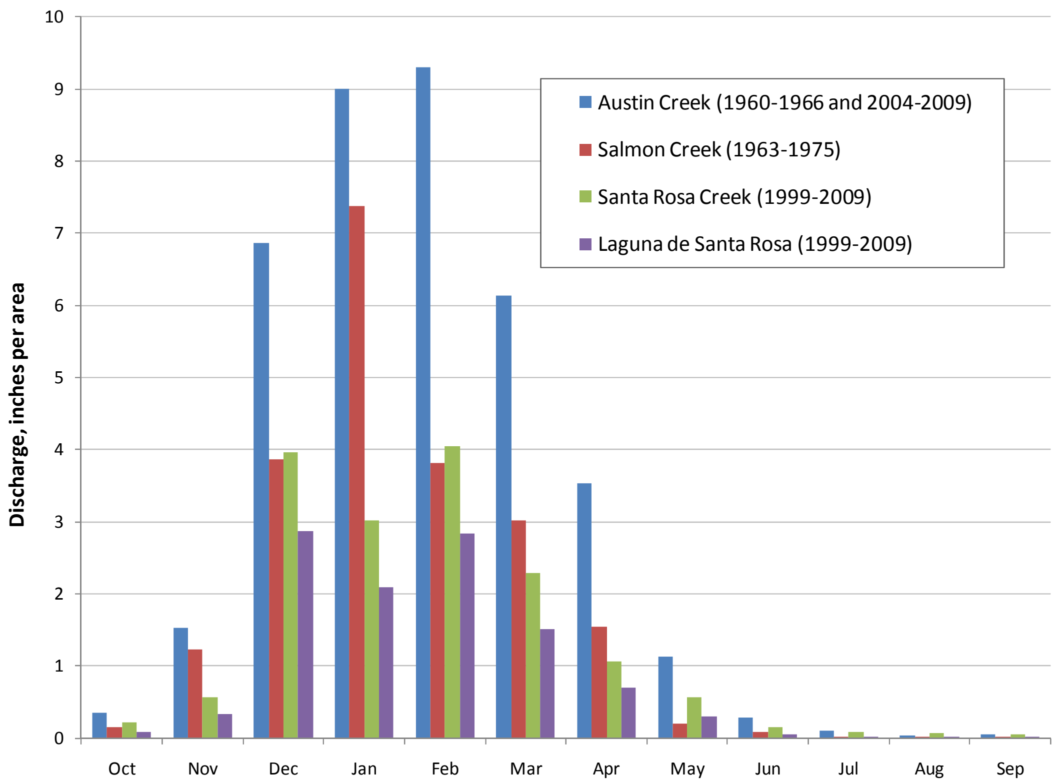


Chart 10. Average discharge from four streams near the GVC watershed, Sonoma County (as inches of runoff over the entire watershed).

The slightly higher proportion of winter discharge compared to winter precipitation is likely due to the tendency for precipitation occurring early in the water year (October-November) contributing principlely to groundwater recharge rather than streamflow. Hydrologists working in Mediterranean-climate regions attribute this as an effect of the prolonged dry summer, during which shallow groundwater is depleted through soil evaporation and plant transpiration (Gasith and Resh, 1998). A sufficient volume of water must replenish these reservoirs before streams can flow consistently through winter. Historical data reflect this trend

– while the proportion of rainfall occurring in October as compared to the entire year is generally near 5%, the proportion of streamflow in October is approximately 1 to 2% of the discharge for the year (*Map 8, Chart 11*). Plots of cumulative precipitation at Occidental and discharge at Salmon Creek over four consecutive years (1964-1967) show that between 5 and 10 inches of precipitation falls at Occidental before Salmon Creek carries elevated flows each winter (*Chart 12 a-d*).

Table 7. Average annual discharge as measured at four streamflow gauges near the Green Valley Creek watershed.

Site name	Gauge number	Watershed area, mi^2	Period of record	Discharge, ac-ft	Discharge, inches over watershed	Discharge, m3
Santa Rosa Creek at Willowside Rd near Santa Rosa	11466320	77.6	1999-2009	66,580	16.1	82,130,000
Laguna de Santa Rosa at Stony Point Rd near Cotati	11465680	40.8	1999-2009	23,490	10.8	28,970,000
Salmon Creek at Bodega	11460920	15.7	1963-1975	17,870	21.3	22,040,000
Austin Creek near Cazadero	11467200	62.8	1960-1966, 2004-2009	120,500	38.3	148,640,000

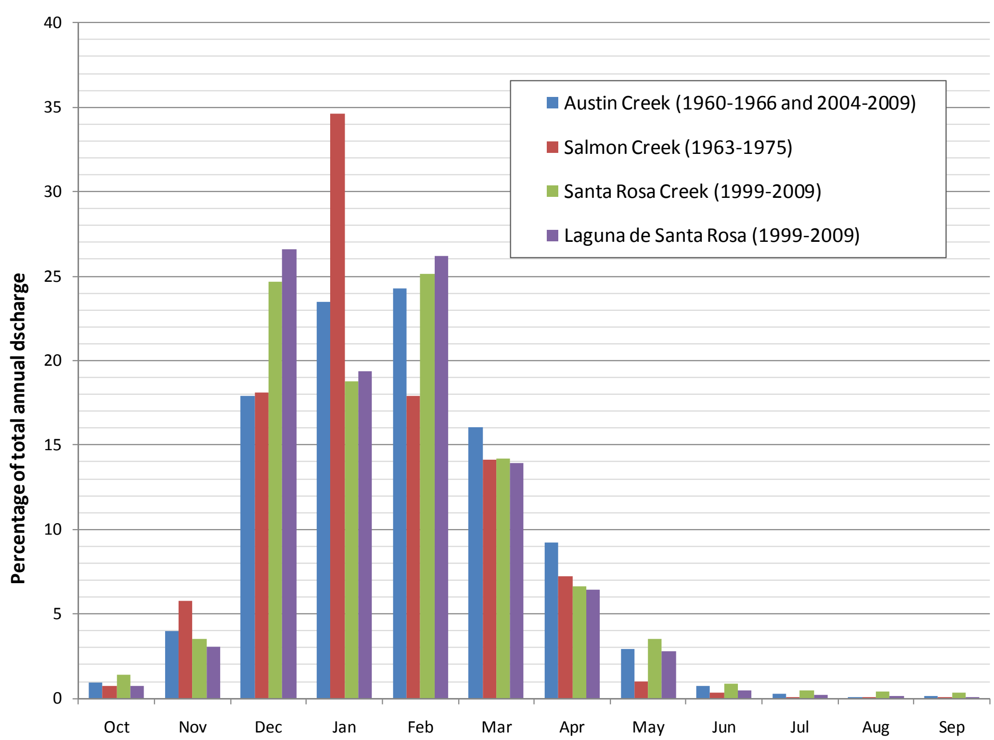


Chart 11. Average Percentage of Discharge Occurring Each Month.

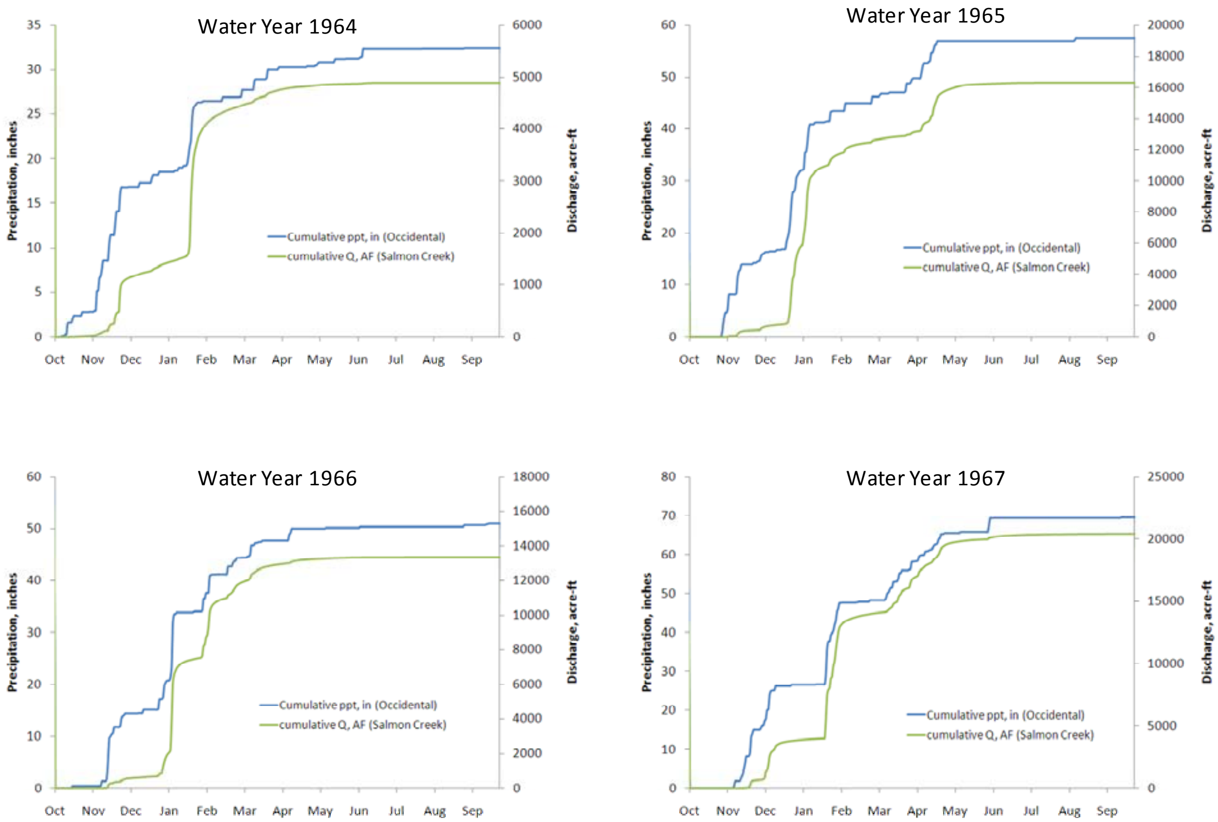


Chart 12 a-d. Cumulative precipitation (Occidental) and discharge (Salmon Creek) through four consecutive years, 1964-1967.

Extrapolating Discharge to the Upper Green Valley Creek Watershed

As stated above, there are no records describing streamflow in the Green Valley Creek watershed. However, because such data are important for watershed planning, several methods are commonly employed to predict streamflow and discharge in a stream like Green Valley Creek. The following discussion presents two methods by which annual discharge can be calculated for the Upper Green Valley Creek watershed and describes variations among these commonly used methods.

In its worksheet for Water Availability Analysis and Cumulative Flow Impairment Index, the State Water Resources Control Board (SWRCB) outlines two methods for extrapolating annual discharge to ungauged watersheds. The first method described is an adaptation of the Rational Runoff Method that is described by the California Department of Transportation (CalTrans) in its Highway Design Manual. The Rational Runoff Method was designed to predict peak storm flows and ideally is applicable for watersheds of 200 acres or smaller (Dunne and Leopold, 1978), but it is widely applied to larger basins, and is listed by SWRCB as a method for calculating annual discharge. The Rational Method calculates average annual discharge Q as

3. $$Q = C \times I \times A$$

where *C* represents a Runoff Coefficient, *I* represents the average annual precipitation (in feet), and *A* represents the watershed area in acres. In this equation, the runoff coefficient *C* represents the proportion of rainfall that is converted to discharge.

For the CalTrans method, C is a function of relief, the capacity of soil to store water, vegetal cover, and surface storage; the components of calculating the Runoff Coefficient appear in Figure 819.2A in the Highway Design Manual (CalTrans, 2001). For this comparison, the Green Valley Creek watershed was estimated to have:

a. Generally rolling relief with average slope between 5 and 10%: range 0.14 to 0.2
b. Soil saturation is slow to allow infiltration, imperfectly drained: range 0.08-0.12
c. Vegetal cover fair to good; 50% of the area wooded or grassland: range 0.06-0.08
d. Surface storage is normal, with some ponds and defined channels: range 0.06-0.08.

Based on these estimates, the runoff coefficient is between 0.34 and 0.48. If it is assumed that average annual precipitation is approximately 44.6 inches (3.72 ft) and the size of the Upper Green Valley Creek watershed is 6,560 acres (10.25 mi^2), then the average annual discharge according to the Rational Runoff Method ranges from 8,290 to 11,700 ac-ft (between 15.2 and 21.4 inches per area).

The second method described by SWRCB in its Water Availability Analysis protocols for extrapolating discharge to ungauged streams is a method of scaling streamflow from a nearby gauged stream to the ungauged stream of interest. This scaling method begins with average annual discharge from the gauged stream ($Q_{\text{gauged stream}}$), and then scales that value by a ratio of catchment area and average annual precipitation, according to the equation

4. $$Q_{\text{ungauged stream}} = Q_{\text{gauged stream}} \times \left(\frac{\text{Area ungauged wshd}}{\text{Area gauged wshd}}\right) \times \left(\frac{\text{Avg ppt ungauged wshd}}{\text{Avg ppt gauged wshd}}\right)$$

Equation 4 accounts for differences in watershed size by assuming that discharge from an ungauged stream will vary from a gauged stream by a linear ratio of watershed area (e.g., a watershed of twice the size should have twice the discharge) and for differences in precipitation by a linear ratio of average annual precipitation (e.g., a watershed receiving twice the rainfall should have twice the discharge). SWRCB recommends using this method only with historically gauged streams without large dams upstream and with more than 10 years of record.

Of the four gauged streams listed above near the Upper Green Valley Creek watershed, Salmon Creek may be the closest and most similar to Upper Green Valley Creek. In addition to Salmon Creek being adjacent to the Upper Green Valley Creek watershed to the southwest, Geographic Information System (GIS) analysis using the high-resolution precipitation data in *Map 8* indicates that the average annual precipitation is nearly the same between the two catchments: 44.2 inches in Salmon Creek, and 44.6 inches in Upper Green Valley Creek. Over its period of record (1963 – 1975), the average annual discharge from Salmon Creek was 17,870 ac-ft; when scaled by precipitation and by a ratio of catchment area (Upper Green Valley Creek watershed is 6,560 acres and Salmon Creek watershed above the USGS gauge is 10,060 acres), the average discharge from the Upper Green Valley Creek watershed would be 11,760 ac-ft (or 21.5 inches over the entire watershed area).

(Using discharge and estimated watershed area, it is possible to calculate the Rational Method Runoff Coefficient for Salmon Creek. Given the average annual discharge of 17,870 ac-ft during the 1963-1975 period of record, upstream watershed area of 10,060 acres, and average precipitation of 3.69 ft, the runoff coefficient for the Salmon Creek watershed is 0.48.)

This method of extrapolation from nearby USGS streamflow can have many other uses. Historical data depict actual streamflow that has occurred in the relatively recent past; assuming that the flow regime has not changed substantially between the period of record and the present, historical data can provide a foundation for future scenario planning. Historical data from Salmon Creek scaled to Upper Green Valley Creek can estimate the likely variation in discharge that might occur in Upper Green Valley Creek: the average

Table 8. Estimated discharge from upper Green Valley Creek watershed, based on Salmon Creek data (scaled by watershed area and differences in catchment precipitation), for each year from 1963 to 1975 (ranked by magnitude), along with exccedence probability. Annual discharge with an exceedence probability of 0.50 is likely to be

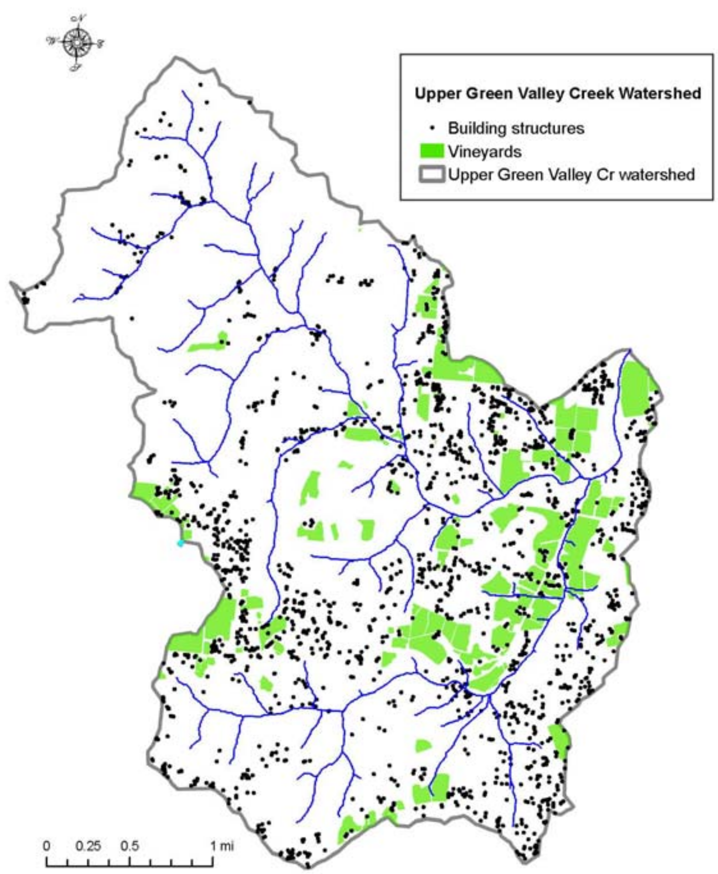
Year	Annual Discharge (ac-ft)	Exceedence probability
1974	20,060	0.07
1973	17,700	0.14
1970	16,580	0.21
1969	16,490	0.29
1967	13,440	0.36
1975	13,220	0.43
1971	11,680	0.50
1965	10,750	0.57
1963	10,510	0.64
1966	8,790	0.71
1968	7,400	0.79
1964	3,220	0.86
1972	2,930	0.93

discharge may be 11,760 ac-ft, but the range based on 13 years of record may be as high as 20,060 ac-ft and as low as 2,930 ac-ft (*Table 8*).

Though the two methods described above to estimate average annual discharge in the Upper Green Valley Creek watershed are not exactly the same, they both indicate that approximately half the water that falls as precipitation in the watershed is likely to become streamflow. More importantly for planning, records from multiple years show the range of annual discharge likely from the watershed. A very dry year may result in less than one-fourth of the total annual discharge in an average year, which would likely place severe stresses on humans and on aquatic organisms that depend on streamflow for survival.

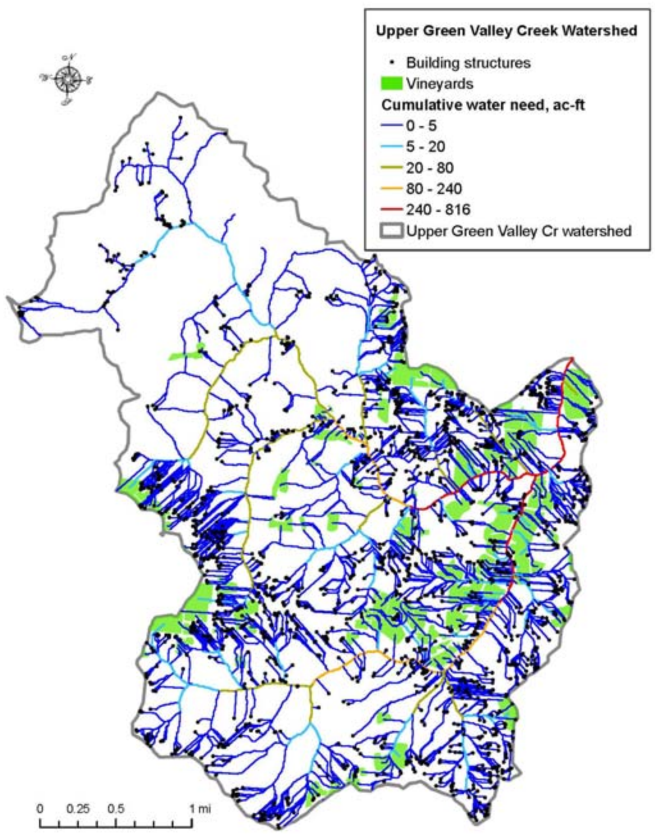
Calculating Water Needs

Human water need in the Upper Green Valley Creek watershed can be estimated using similar units of volume as discharge analyses above. The discussion that follows provides a method for creating a coarse estimate of *summer* water need based on two components: agricultural water needs and residential water needs. Water needs for each watershed are based on information defined by digital orthorectified aerial photographs in a GIS framework: using these aerial photographs, all land as vineyard and all building structures were identified (*Map 10*; orchards were not included in this analysis). Each vineyard was assigned a summer water need value of 0.67 ac-ft per acre and each building structure was assigned a summer water need value of 0.207 ac-ft. From these data, water needs can be accumulated through the watershed to



Map 10, UGVC Watershed and Drainage Network show the cumulative water need through the Upper Green Valley Creek drainage network (*Map 11*).

In this analysis, summer agricultural and residential water needs are both likely to be overestimated. A volume of 0.67 ac-ft per acre represents a high-end irrigation water need (Smith et al. 2004), and not all buildings identified in the GIS are residences (barns, for example, may not have any summer water needs). These coarse estimates do, however, provide a preliminary foundation for comparing the likely water need in the watershed to its discharge.



Map 11, Upper Green Valley Creek with Cumulative Water Needs

In this analysis, the total water need for the Upper Green Valley Creek watershed is 816 ac-ft, comprised of 411 ac-ft for agriculture and 405 ac-ft for residential need. This comprises less than 10% of the likely average discharge of the Upper Green Valley Creek watershed (and less than 4% of the average annual precipitation), but more than one quarter of the dry-year discharge.

Conclusions and Recommendations

The data and analyses presented here highlight the disparity across time between hydrology and human water needs, and the challenges of planning to meet those needs while maintaining aquatic ecosystems in Mediterranean-climate California. A small fraction of rainfall (and subsequently, streamflow) occurs during the dry half of the year, yet this dry period is when water needs for residential water uses (which may include garden irrigation and recreational uses) and for agriculture tend to be the greatest. If the absence of rainfall during the summer causes grape growers and people living in the watershed to tap streams for water supply, these diversions are likely to place substantial pressures on aquatic organisms that live in these streams.

Despite these challenges, the ample precipitation that typically falls in the Upper Green Valley Creek watershed indicates that it should be possible to maintain a healthy aquatic ecosystem while still providing the water necessary for human uses. However, this may take some careful planning to meet all of these needs. Winter water storage is likely the most significant improvement that can be made to provide for agricultural and residential water needs while providing sufficient resources for aquatic biota.

If the amount of water needed for human use in the Upper Green Valley Creek watershed is approximately 800 acre-ft and the watershed receives approximately 22,000 acre-ft of water through precipitation in an average year, it seems likely that this amount of water needed for human uses (representing less than 4% of the average annual precipitation) can be stored in ways to minimize impacts to aquatic biota. Rainwater catchment off rooftops may provide much of the water needed for residential uses, though some considerations may be necessary to ensure that many structures do not cause unpredicted cumulative effects on streamflow in adjacent streams.

In cases where rooftop catchment is not sufficient, reservoirs may provide ample water storage for larger water uses. Reservoirs could be filled in winter either from streams or groundwater, though appropriate considerations must be implemented and instream flow studies conducted to ensure that surface or groundwater diversions do not adversely affect instream flows for fish. Considering the variability in discharge from one year to the next, it may be necessary to store water for multiple years as well. Winter water storage can likely provide sufficient resources to meet human and ecological water needs, but considerations of cumulative impacts and instream flow studies are also essential to offer appropriate ecological protections.

D. Sediment Sources and Impacts

Introduction

Human activities over the last century or so have altered the natural erosion and hydrologic regimes of the Upper Green Valley Creek watershed. Through changes in land use and construction of an extensive road network the rate and volume of erosion and the surface hydrology of the watershed have been changed. In addition, some stream channels in the watershed may have been straightened, deepened, or both, to protect farmland from the effects of flooding. The combination of these factors has caused dramatic changes in the mechanisms and rates of erosion in the watershed with consequences for both stream channel form and aquatic habitat quality.

The delivery of sediment to streams is controlled by the rate and extent of various erosion processes on the landscape and by the mechanisms through which eroded sediment is transported to streams. Historically, it is likely that smaller streams in the Upper Green Valley watershed delivered sediment derived from upland sources to mainstem stream channels and their broad alluvial floodplains at a slow but steady rate. Mainstem stream channels meandered freely on their floodplains, reworking alluvial sediments and transporting them downstream. This background pattern of steady erosion and transport of sediment was punctuated by larger pulses of sediment derived from landslides and debris flows that occurred in the steeper uplands during infrequent extreme rainfall events.

In the last 100-150 years, significant changes have been made to land cover types, land uses and stream channels by human activity. Moderate to high intensity logging has taken place in the forested portions of the upper watershed at various times during the past century, increasing storm runoff and sedimentation (CDFG 2004). Formerly undeveloped native grasslands, timberlands and scrub have been converted for a variety of uses including orchards, grazing, rural residential development, and vineyards. This conversion has had the effect of exposing more bare and compacted soil areas to rainfall, further increasing runoff volumes and erosion of fine sediments. Many bare and compacted soil areas, as well as impervious surfaces such as roofs, driveways and roads, drain directly to streams, increasing peak stream discharges during storm events, and very effectively delivering eroded fines.

Accompanying changes in land use has been the development of a fairly dense rural road network. In addition to county roads, many private roads have been constructed for orchard and vineyard access, as well as for accessing rural residential homesites. These roads interact with erosion processes in a variety of ways, with the net effect of further increasing both peak stream discharge and sedimentation.

Erosion Processes in the Upper Green Valley Watershed

To date, only limited systematic assessment of erosion and sediment delivery to streams has been performed in the Upper Green Valley watershed. However, from this work, as well as other studies, field observations and anecdotal evidence, channel incision and road-related erosion appear to be the most significant anthropogenic sources of sediment in the watershed (LMA 2003).

A CDFG stream inventory conducted in 1994 observed extensive channel incision and bank erosion in Upper Green Valley Creek, as well as reaches where excess fine sediment delivery was causing embeddness of gravels (CDFG 2006a). The CDFG report posited that changes in land use and the extensive road network were contributing fine sediment and causing flashier streamflows in the upper watershed. O'Connor and Rosser (2003) examined 5 reaches of Upper Green Valley Creek, and noted stream entrenchment in all 5, although they did not observe particularly high embeddedness values or fine sediment fractions. CDFG (2006b) noted in 1994 that Purrington Creek was deeply entrenched in its lower, alluvial reach, with moderate to severe gravel embeddeness throughout. Entrenchment in both lower and upper Purrington Creek was also observed by O'Connor (2010) (*Appendix 6, Purrington Creek Geomorphic Assessment*).

There may also be a substantial input of fine sediment derived from rainsplash, sheet and rill erosion on agricultural lands and other lands where cover conversion has occurred, but no systematic survey or modeling work on this process has yet been performed. From a review of aerial photography of the watershed, it appears that although mass movements undoubtedly occur, they are not currently major anthropogenic sources of sediment, except in areas where they result from stream channel incision.

Channel incision

Stream channel incision (entrenchment) is the process whereby a stream erodes its bed, lowering its level over time. It usually occurs in response to changes in the stream channel and/or watershed that result in the stream having excess energy to spend on its bed and banks, and in locations where the stream cannot spend this energy in other ways, such as by meandering. Changes can include increase in discharge, decrease in sediment load, channel straightening or deepening, decrease in channel boundary roughness (through removal of wood, vegetation, large sediment clasts, etc.), or a combination of some or all of these. Incision can also be initiated by a lowering of the local or absolute base level of the

Incised channel. Photo courtesy of Matt O'Connor.

stream, and in these cases incision generally occurs through the upstream migration of a series of knickpoints.

There are many geomorphic and hydrologic consequences that result from channel incision. The most important of these are the hydrologic disconnection of the floodplain from the stream, and streambank instability. Hydrologic disconnection occurs as the floodplain water table lowers in response to the lowering of the streambed. During an episode of stream incision, water table lowering tends to roughly correspond to the level of the stream, and this can cause changes in floodplain vegetation and the dewatering of shallow wells in the floodplain, among other impacts. The deepening of the stream channel also causes larger, higher energy flows to be confined within the channel, instead of spreading out on the floodplain. Confinement of large flows causes accelerated bank erosion, and can contribute to further stream incision. And flow confinement can also increase the size and amount of sediment the stream is competent to transport during a given flow.

Streambank stability is also decreased in response to incision. As the stream incises, its banks become higher and steeper than before incision, and thus more susceptible to failure in the form of sloughing or toppling, undercutting and mass failure, and slumping. Groundwater sapping on the steep banks can also work to destabilize them, and gullies can form through headcutting as overland stormflow encounters the steep banks. These processes can deliver large amounts of sediment to the stream over time, and all appear to be common throughout incised reaches of both Upper Green Valley and Purrington Creeks.

There are several possible causes of channel incision in the Upper Green Valley Creek system, however the two most important are increased stream discharge due to increased storm runoff, and alterations in stream channel form, such as straightening and deepening.

Bank Collapse/Erosion. Photo courtesy of Matt O'Connor.

Increased runoff tends to occur after periods of intensive logging, as removal of forest cover and degradation of the organic layer of the soil cause less rainfall to be infiltrated and retained. The conversion of land cover from forest or native grassland to agricultural uses increases the area of bare soil and the level of soil compaction, which also causes rainfall to run off rather than infiltrate the soil. Roads – both dirt and paved – have multiple effects on surface hydrology and shallow groundwater processes; these effects also lead to increased runoff and heightened peak stream flows.

Changes in channel form can also result in channel incision. Channel straightenng has historically been used to make more floodplain land suitable for agriculture, and is oftenaccompanied by levee construction for flood control. Straightening a stream channel has the immediate effect of creating higher-energy stream flows, and if the stream cannot spend this excess energy by developing meanders, downcutting and incision will often result. Channel straightening and deepening have also been used in tandem in the past to confine high flows and reduce the risk of flooding. In this case too, flow confinement creates higher-energy flows and prevents the stream from flooding, and channel deepening becomes a self-reinforcing process.

It is unclear from the historical evidence whether stream channel straightening or deepening have been employed in the Upper Green Valley Creek watershed in the past. However, analysis of channel planform (the map view of the channel) in the lower reach of Purrington Creek reveals a much straighter channel than would be expected for a medium-sized stream in an alluvial valley.

Significant reaches of both Upper Green Valley Creek and Purrington Creek appear to have incised dramatically in the relatively recent past, and this observation is supported by historical and anecdotal evidence. In his examination of the geomorphology of Purrington Creek, O'Connor (2010) observed that the stream was moderately to deeply incised throughout its low-gradient, alluvial reach, incising into Wilson Grove Formation bedrock in some areas. Bank heights in incised reaches of lower Purrington Creek now average between 25 and 30 feet, with some locations measured at nearly 35 feet. Although rates of incision are very difficult to estimate, O'Connor documented field evidence that supports a current incision rate of up to 1 foot per decade. Anecdotal evidence suggests that incision in the past 100 years or so may have been even more rapid (Younger, personal communication, 2009).

In areas where Purrington Creek is incising into alluvial material, extensive bank collapse and slumping have occurred, resulting in the formation of lower, inset terraces and locally increasing the supply of sediment (O'Connor 2010). In essence these processes can be viewed as Purrington Creek expending energy to widen its channel and form a new floodplain at its incised elevation.

O’Connor also observed channel incision throughout the steeper upland reach of Purrington Creek, with the channel confined between high and steep streambanks. Bank heights in this reach were measured at 20-30 feet, and landslides and slumps were locally abundant. Because of the steeper stream gradient, sediment delivered to this reach is transported downstream fairly rapidly. Although historic management practices have undoubtedly played a role in the incision of the upper reach of Purrington Creek, relatively rapid tectonic uplift has also very likely influenced incision of this reach.

In an earlier study, O’Connor and Rosser (2003) examined geomorphic characteristics of selected reaches of Upper Green Valley Creek between the Purrington Creek and Harrison Creek confluences. All study sites were observed to be deeply entrenched. Although this study did not specifically examine bank stability, field observations indicate that bank collapse, slumping and gullying are widespread and common.

Channel incision has likely increased the overall sediment load of the entire mainstem of Green Valley Creek . No systematic assessment of channel incision and its impact on sediment load has yet been undertaken, but GRRCD has secured funding from the California Department of Fish and Game to conduct a geomorphic assessment of the Upper Green Valley watershed in 2010-11. In addition, GRRCD and our partners have conducted assessments of erosion sites on an individual, site-by-site basis, on the properties of cooperating landowners. These assessments support the assertion that channel incision-related erosion is common throughout the watershed, but are insufficient in estimating a total future erosion volume for these processes for the watershed.

Surface Erosion

Rainsplash, sheet and rill erosion are small-scale surface erosion processes that can occur over large areas, depending on land use and cover type. Rainsplash erosion is the physical movement of soil particles that results from raindrop impact. This process makes soil particles available for transport through sheet and rill erosion. Sheet erosion occurs as unconcentrated overland flow (sheet wash) entrains soil particles. Sheetwash coalesces into rills, which are essentially small channels measuring less than 1 ft^2 in cross-sectional area. This concentrated flow of water can be highly erosive, depending on the surface composition and permeability, and is very effective at transporting soil material delivered by sheet wash or rainsplash, and mobilized from the banks and bottom of the rill.

Both rainsplash and sheet erosion generally occur on surfaces with minimal vegetative cover and/or low permeability. In areas of limited vegetative cover, or where vegetation is removed or diminished in extent or density (through physical removal or conversion to a less dense cover), greater soil area is exposed to these processes. Sheet erosion can also occur on surfaces with limited or reduced permeability (soil that has been compacted, for example), where less water can be infiltrated into the soil column.

Vineyard drainage. Photo courtesy of Matt O'Connor.

No systematic assessment or modeling of surface erosion has been conducted for the Upper Green Valley Creek watershed, but it is likely that the process of converting native grasslands and woodlands first for grazing and orchards and later for vineyards has increased surface erosion over historical levels. In vineyards, the problem of increased surface erosion is compounded by drainage systems that typically have been designed to route surface flow rapidly to streams. This results in higher (and more erosive) peak stream discharges, as well as very efficient delivery of surface erosion-derived sediments to stream channels.

Gullying

Gullies occur where surface flow (sheetwash, rills, and other forms of surface runoff) coalesces into channels larger than 1 ft^2 in cross-sectional area. Gullies can be described as newly formed stream channels, but they are located in places where a stream has not existed in the past, such as on hillslopes. Gullies contribute sediment to streams in two ways: through the process of gully expansion, which occurs by headcutting of the gully and bank collapse, and as very efficient conduits for fine sediments eroded through other processes and delivered to the gully.

Gullying does not currently appear to be a major source of sediment in the Upper Green Valley Creek watershed. Field observations indicate, however, that gully formation is becoming more common on floodplain surfaces adjacent to incised stream channels throughout the watershed.

The Impacts of Roads

Roads tend to increase erosion over natural, background levels through a variety of interactions with rainfall, surface flow and shallow groundwater. Because roads (both paved and unsurfaced) have compacted, generally impermeable surfaces, and have historically been built with poor drainage and insloped shapes, they effectively collect and concentrate rainfall, surface flow, and shallow groundwater flow. Along with this flow, roads also collect fine sediment derived on a continuous basis from unpaved road surfaces, cutbanks, and inboard ditches (chronic surface erosion). As with gullies, flow concentrated on a road erodes its own channel, either in the road's inboard ditch or as a gully where the concentrated flow outfalls from the road onto a hillslope, or both. These gullies rapidly deliver both eroded sediment and flow to streams, increasing both sedimentation and peak stream discharge (Weaver and Hagans 1994).

Stream crossing in poor condition on upper Green Valley Creek. This crossing is a barrier to coho salmon passage. Photo courtesy of John Green.

In addition, locations where roads cross streams are subject to accelerated and sometimes extreme erosion on an episodic basis. Stream crossings can be constructed in a number of forms, the most common of which utilizes a culvert to convey streamflow across the road. Historically, culverted stream crossings have been poorly built, with culverts that are undersized for peak stream discharge, poorly placed and installed, and prone to plugging. When a culvert plugs or is overwhelmed by streamflow, the crossing can fail, causing immediate delivery of a large volume of sediment directly to the stream. In some cases, the stream can divert down the road, usually resulting in an extreme volume of sediment delivery as the stream finds its way back to its channel.

Road assessments

In the last few years, multiple assessments of road-related erosion and sediment delivery to streams have been conducted in the Upper Green Valley watershed. In 2007-08, Pacific Watershed Associates (PWA) conducted a partial assessment of erosion on private, unpaved roads throughout the greater Green Valley-Atascadero watershed. A total of 25.2 miles of roads were assessed in the Upper Green Valley Creek watershed. Overall, the assessed roads were deemed insufficiently constructed with regard to preventing or controlling erosion, with poorly constructed stream crossings and inadequate road drainage. PWA identified a total of 133 individual road-related erosion sites, each of which was assigned a treatment priority based on the likelihood of erosion, volume of sediment delivery, and other factors. Together, the assessed sites had the potential to deliver nearly 15,000 yds^3 of sediment to streams over the next decade if left untreated. In addition, road segments totaling nearly 11 miles in length were determined hydrologically connected to streams, and PWA estimated that these segments accounted for roughly 1,000 yds^3 of fine sediment delivered to streams in the assessed area per year through chronic surface erosion. PWA recommended treatments for erosion prevention and erosion control for both individual erosion sites and hydrologically connected road segments (PWA 2008).

The 25 miles of road assessed in the PWA project were located on parcels totaling 1,162 acres, about one-fifth of the total area of the Upper Green Valley watershed. If we assume that both the road density and the hydrologically connected proportion of total road length in the entire 6,420 acres of the watershed approximate that of the assessed portion, a fine sediment volume on the order of 5,500 yds^3 per year is currently being delivered to the Upper Green Valley stream system. There is reason to believe that this estimate might be conservative, since the assessment included only roads located on larger parcels with fairly low road densities. Most parcels have at least one driveway or access road, so on smaller parcels road densities tend to be higher. Although an overall sediment budget has not been calculated for the watershed, the estimate of 5,500 yds^3 per year likely represents a significant increase in fine sediment delivery over historic background levels.

Ledwith (2008) conducted an assessment of erosion along 93 miles of county roads throughout the greater Green Valley-Atascadero watershed, including all paved county roads within the Upper Green Valley Creek watershed. This assessment identified a total of 59 road-related erosion sites requiring treatment, with the potential to deliver over 15,000 yds^3 of sediment to the Upper Green Valley stream system, and recommended preventive treatments for each site. Each site was assigned a treatment priority based on the potential for near-term sediment delivery to streams, and opportunity to prevent sediment delivery by implementing the recommended treatment (Ledwith 2008).

Impacts to Aquatic Resources

Aquatic resources are very sensitive to changes in both the sediment load and hydrologic regime of a stream. Changes in peak and low-flow discharge, the volume of sediment or the rate at which it enters a stream can degrade water quality and aquatic habitat and result in severe impacts to biotic communities. These impacts are discussed in greater detail in *Chapter II, Section F.*

Impacts of accelerated erosion can be obvious to the untrained observer, as streams appear muddy during and immediately after rainstorms, excess sediment is stored in channel bed forms, and fine sediment causes gravel embeddedness. Less obvious are both the downstream effects of accelerated erosion and the impacts of changes in surface hydrology, through road construction, land conversion, and increases in impermeable surface area.

Eroded sediment is moved through the system by streamflow, and if the stream is encumbered by a larger sediment load than that which formed it, channel form can change. Specifically, increased sediment load can cause aggradation of lower-gradient reaches. Upper Green Valley Creek has seen dramatic aggradation of the reach immediately upstream of its confluence with Atascadero Creek.

As discussed above, greater compacted and impervious surface area increases runoff, which in turn causes higher peak stream discharge and reduces infiltration as more water is rapidly routed through the stream system. Infiltrated shallow groundwater is a major source of summer baseflow, and in areas where groundwater resources are stressed by water diversions for residential and agricultural uses, further reduction by decreased wet season infiltration can have a drastic effect on summer low flows. In a Mediterranean climate, this can mean that streams run dry earlier in the summer than they normally would.

The combination of increased aggradation and lower summer baseflows can result in extensive reaches where the stream is dry even earlier in the year, as flows are lower and go subsurface more quickly. This appears to be the case in Upper Green Valley Creek just upstream of its confluence with Atascadero Creek, as well as for extensive reaches downstream of the confluence (which are outside the scope of the plan). Water scarcity in these areas may prove to be strongly related to anthropogenic changes to the upstream watershed, which have increased both erosion and runoff.

Conclusion

Through field observations and studies completed to date, a picture emerges of anthropogenic changes to the geomorphic regime of the Upper Green Valley watershed, and the impacts of these changes on the streams of the watershed and their suitability as salmonid habitat. Erosion through a variety of processes has accelerated as a result of past and current management practices. Sediment derived from accelerated erosion is routed rapidly through high-gradient reaches (upper Purrington Creek) and confined reaches (lower Purrington and middle Green Valley Creeks), where streamflow has excess energy. In confined reaches, gravels may be mobilized by smaller, more frequent flows, decreasing available spawning locations and scouring redds. Eroded sediment is flushed through these reaches and deposited in unconfined, low-gradient and hence lower-energy reaches (Green Valley Creek downstream of Purrington), aggrading the channel. Green Valley Creek has seen dramatic aggradation throughout the reach that includes its confluence with Atascadero Creek, and this aggradation contributes to flooding and potential fish stranding in the Green Valley Road / Korbel Vineyard area. To compound these problems, increased runoff and decreased infiltration lower summer baseflows, and the aggraded channel goes dry, with flows going subsurface, earlier in the summer season. This poses a problem for salmonids, as dry stream reaches are neither appropriate as habitat nor conducive to fish passage. Further study is needed, but if this picture proves to be accurate, efforts to reintroduce salmon in Upper Green Valley Creek must account for and address the impacts of all of these processes if they are to be successful.

Sediment Sources and Impacts Recommendations

Our research of existing information and current geomorphic conditions highlights several issues related to erosion and sediment delivery in the Upper Green Valley Creek watershed, and points toward a course of action designed to limit anthropogenic erosion, normalize surface hydrology, and guide future management decisions.

The first two recommendations are intended to address a lack of solid data on watershed geomorphology, erosion processes operating in the watershed, and impacts of erosion. The third and fourth recommendations focus on implementation: reducing the anthropogenic sediment load in streams throughout the Upper Green Valley watershed by implementing erosion control and prevention treatment recommendations outlined in earlier assessments.

1. Assess watershed and reach-scale geomorphic processes. Conduct an in-depth hydrologic and geomorphic assessment of the Upper Green Valley watershed. This assessment should include:

a. Hydrologic modeling to identify critical factors affecting runoff patterns, groundwater and summer base flow conditions. Modeling may also prove useful in evaluating bank stability conditions related to flow confinement and water table position.
b. Identifying the extent, causes and impacts of channel incision, and recommending a strategy for arresting or reversing it, and mitigating its effects.
c. Analysis of the processes influencing aggradation of the Green Valley Road / Korbel Vineyard reach of Green Valley Creek, with a goal of identifying a project designed to minimize flooding and fish stranding in the Korbel Vineyard, encourage year-round flow through this reach, and allow for both adult and juvenile salmonid passage.

Gold Ridge RCD has secured funding from the California Department of Fish and Game for an assessment of geomorphic processes in selected reaches of Green Valley Creek and its tributaries.

2. Expand assessment of erosion and sediment delivery.
Partial assessments have been conducted for road-related erosion and upland and bank erosion, and these assessments should be continued. The focus should be expanded to include assessment of surface erosion with an emphasis on agricultural lands. All assessment of anthropogenic erosion and sediment delivery should also evaluate hydrologic impacts.

    a. Plan and conduct a second phase assessment of private, unpaved roads
    b. Assess the extent, severity and impacts of surface erosion on agricultural lands. This assessment should also address the hydrologic impacts of compacted and impervious surfaces and include recommendations for mitigation of those impacts.
    c. Expand and continue assessment of non-road-related bank and upland erosion sites. This assessment should include a systematic watershed-wide evaluation of incision-related bank stability if possible.

3. Develop a program to arrest channel incision through grade control in lower Purrington Creek.
Build on hydrologic modeling and geomorphic assessment work to identify appropriate sites, materials and designs for effective grade control to prevent further channel incision and bank failure, retain gravel, and enhance channel complexity in incised reaches of lower Purrington Creek.

4. Reduce anthropogenic erosion and sediment delivery.

Erosion assessment work completed to date includes prioritized recommendations for treating identified erosion sites and issues. Implementation of the recommended treatments should be carried out as funding becomes available.

a. Implement recommended treatments at priority road-related erosion sites, including both public and private roads. Gold Ridge RCD has secured funding from CDFG for a first phase of erosion implementation on selected high-priority sites in the Upper Green Valley watershed, and a Phase II proposal is in preparation. The Sonoma County Department of Transportation and Public Works is collaborating with FishNet 4C to prepare grant proposals addressing high-priority county road stream crossings, with regard to both fish passage and erosion.
b. Implement restoration treatments at high-priority bank and upland erosion sites (PWA 2008)
    i. Site BOMA1
    ii. Site RIER2
    iii. Site BOMA2

As geomorphic and erosion assessment work progresses, the results and recommendations of these studies should assist in targeting scarce implementation funding, both toward addressing those processes that pose a greater threat to healthy aquatic systems, and toward high priority sites and stream reaches.

E. Flood Risk

Heavy, episodic rains during winter can result in streambank overflow when stormwater runoff exceeds the capacity of the stream channel to carry it. Flooding along the lower Russian River most frequently occurs in Guerneville, Monte Rio, and Rio Nido; seventeen floods ranging between 32 feet and 49 feet (stage height) have been recorded since 1940 (Russian River Historical Society 2006).

Flooding on Green Valley Road at the Korbel Vineyard. Photo courtesy of John Green.

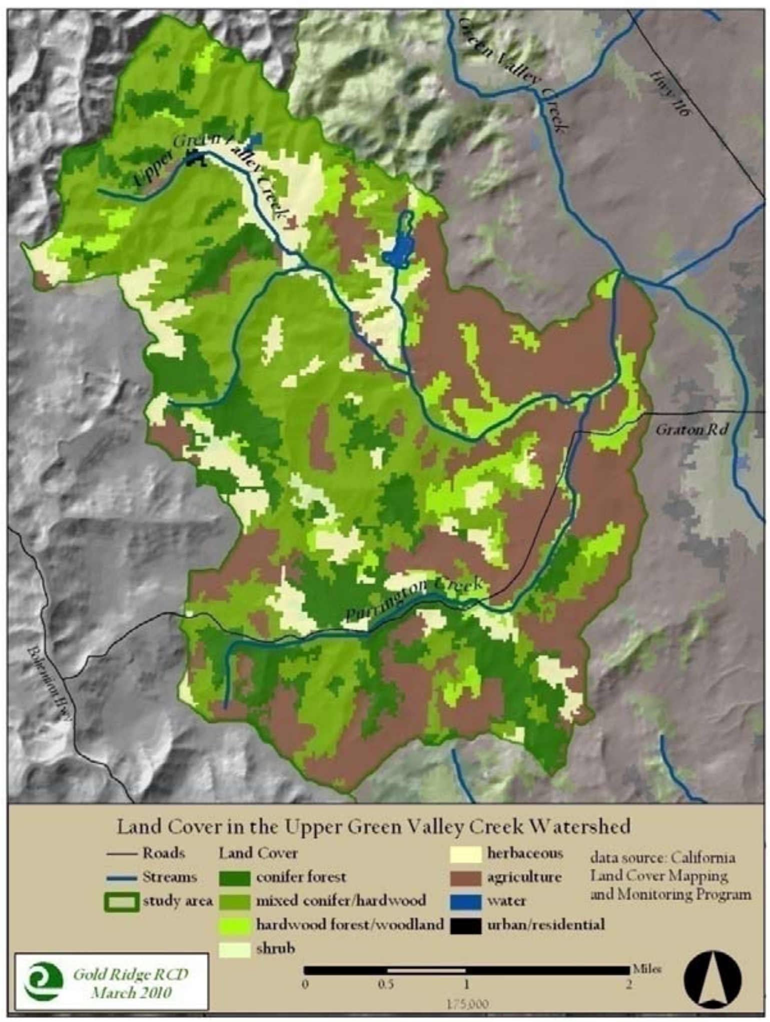
Additionally, flooding occurs frequently on Green Valley Road near the cemetery and Korbel Vineyard in the area of the confluence of Atascadero and Green Valley Creeks.

In Sonoma County, floodplain management has been utilized to limit the type and extent of new construction in FEMA identified flood hazard areas and by raising existing structures above flood levels. The Sonoma County General Plan 2020 (Sonoma County PRMD 2008) identifies flood damage as a major and persistent problem on the Russian River as well as the Petaluma River and Sonoma Creek; Sonoma County has been identified as one of the highest repetitive flood loss communities in the United States.

F. Biological Resources of the Upper Green Valley Creek Watershed

Introduction

The Upper Green Valley watershed supports a diverse assemblage of biological resources (*Map 12*). The watershed supports a number of native vegetation communities including coniferous forests, oak woodlands, and annual grassland, which in turn provide habitat for a numerous fish and wildlife species. Of particular importance within the watershed are instream and riparian habitats, which support the endangered coho salmon (*Oncorhynchus kisutch*) and threatened steelhead trout (*O. mykiss*), as well as special-status northwestern pond turtle (*Actinemys marmorata marmorata*), California-red legged



Map 12. Upper Green Valley Watershed Land Cover and Vegetation Types

and foothill yellow-legged frogs (*Rana aurora* and *R. boylii*), and California freshwater shrimp (*Syncaris pacifica*).

Habitat Changes in Upper Green Valley Creek Watershed

Vegetation communities in Upper Green Valley Creek have been altered over time due to land use practices such as logging, grazing, agriculture, and rural development. Logging was prevalent from the 1920s through the 1950s followed by extensive grazing (CDFG 2006a). Logging occurred in the upper watershed while grazing likely occurred in the lower watershed in grassland habitat. By the early 1900s, many of the natural grasslands and meadows had been converted to apple orchards; more recently, many of these orchards have since been converted to vineyards, particularly over the past 20 years (PWA 2008). Native oak woodlands and coniferous forests have also been converted to vineyard. Agricultural (vineyards and apple orchards) and rural residential development are the primary land uses within the study area (see *Map 4, Land Use in the Upper Green Valley and Purrington Subwatersheds*).

In addition to altering native vegetation communities, land use changes within the watershed have had a profound effect on instream habitat. Over the last few decades, land uses changes and various forms of development have caused accelerated erosion and sediment delivery to creeks. A detailed discussion of erosion and sediment and their effects is provided in Chapter II, Section D.

Existing Communities

Existing communities of the Upper Green Valley Creek and Purrington Creek subwatersheds include forests, woodlands, riparian and aquatic habitats, grasslands, and agricultural lands. The relatively steep western hills support coast redwood (*Sequoia sempervirens*) and Douglas-fir (*Pseudotsuga menziesii*) forest. Lower in these hills, forest composition changes and oaks (*Quercus spp)*, California bay (*Umbellularia californica*), and madrones (*Arbutus sp*.) become more dominant. Patches of endemic chaparral and Sargent cypress (*Cupressus sargentii*) are found in association with outcroppings of serpentine rock. Most of the gentler terrain of the eastern Upper Green Valley Creek watershed is used for agricultural and residential purposes. Occasional mature oaks dot these landscapes, remnants of what was probably extensive oak woodland and native grassland in historic times. Threats to the remaining upland habitat include habitat loss and fragmentation due to development, spread of invasive species, and Sudden Oak Death (SOD)[5] infestations.

As noted above, the existing vegetation communities support a number of special-status species, including both plants and animals. Special-status species occurrences are noted below under the appropriate community discussion. Further life history and listing status information is provided in the *Special-status Species* section that follows. Although the characteristic assemblages of species occur predictably within certain vegetation types, it should be recognized that relatively few species are restricted to a single habitat, and indeed some species may require more than one habitat type. Wildlife species' common names are used because they are unequivocal.

Coast redwood trees. Photo courtesy of Joan Schwan.

Coniferous Forest

Coast redwood and Douglas-fir forest occur in the upper reaches of the watershed. Redwoods are found in moister areas, while Douglas-fir dominates drier sites. Many of these lands have been logged or cleared for other purposes in the past, and now support younger forests. In mature stands, these large conifers create a dense canopy and the understory is often sparse. Common understory species include shade-tolerant plants including sword fern (*Polystichum munitum*) and false Solomon's seal (*Smilacina racemosa*). In younger, more open stands with a history of disturbance such as logging, other woody species can also be abundant. These include coast live oak (*Quercus agrifolia*), California bay, tanoak (*Lithocarpus densiflorus*), poison oak (*Toxicodendron diversilobum*), and wood rose (*Rosa gymnocarpa*). No special-status plant species have been documented in the coniferous forests of the watershed (CDFG 2010).

[5] Sudden Oak Death – a tree disease caused by the pathogen *Phytophthora ramorum*

Several invasive species occur in the watershed's redwood and Douglas-fir forests, particularly at forest edges where human activities have disturbed the ground or where landscape plants have escaped from cultivation. Periwinkle (*Vinca major*) and Himalayan blackberry (*Rubus discolor*) are examples of two aggressive species that can inhibit native plant regeneration. Redwood and Douglas-fir forest supports a high abundance of wildlife species. Representative bird species found in this habitat include chestnut-backed chickadee, band-tailed pigeon, northern spotted owl, pileated woodpecker, hairy woodpecker, Steller's jay, brown creeper, winter wren, golden crowned kinglet, hermit thrush, dark-eyed junco, and purple finch. Typical mammals include deer mouse, dusky-footed woodrat, Douglas's squirrel, and Trowbridge's shrew. Large trees and snags provide prime habitat for a number of local bat species. A number of common amphibians also inhabit the coniferous forests of the watershed. Ensatina, California giant salamander, and California slender salamander can be found in moist, protected places under logs or forest litter. Special-status animals documented in the coniferous forests of the western portion of the watershed include northern spotted owl (*Strix occidentalis caurina*) and Sonoma tree vole *(Arborimus pomo)* (CDFG 2010).

Hardwood Forest/Woodland

At lower elevations, redwood and Douglas-fir forests give way to mixed woodlands of oaks (coast live oak; black oak, *Q. kelloggii*; and Oregon oak, *Q. garryana*), California bay, tanoak, and madrone (*Arbutus menziesii*). Like the coniferous forests of the watershed, these woodlands have undergone many changes due to historic land use practices. Clearing for agricultural and residential development and firewood harvesting has fragmented and reduced the extent of oak and bay forests in the watershed. SOD has infected bays and killed tanoaks and live oaks in the watershed (UC Berkeley 2010).

The understory of the watershed's hardwood forests and woodlands include a variety of shrubs and vines, including poison oak, snowberry (*Symphoricarpos albus*), California rose (*Rosa californica*), toyon (*Heteromeles arbutifolia*), coffeeberry (*Rhamnus californica*), and honeysuckle (*Lonicera hispidula*). Annual grasses and forbs, as described in the grasslands section below, are also abundant. In places protected from disturbance, native herbaceous species including California fescue (*Festuca californica*), blue wildrye (*Elymus glaucus*), miner's lettuce (*Claytonia perfoliata*), and Douglas iris (*Iris douglasiana*) can be found. No special-status plant or animal species have been documented in the hardwood forests and woodlands of the watershed (CDFG 2010).

Invasive species that occur in the mixed woodlands of the watershed include Himalayan blackberry, Scotch broom (*Cytisus scoparius*), and French broom (*Genista monspessulana*). In some locations, English ivy (*Hedera helix*) both carpets the ground and grows up the trunks of many native trees, suppressing their growth and preventing regeneration.

Forest and woodland habitats provide nesting opportunities, food, and shelter and may serve as corridors or islands during migration for a variety of wildlife species. Common bird species include chestnut-backed chickadee, ruby and golden-crowned kinglets, Steller's and western-scrub jays, American robin, acorn woodpeckers, and common bushtit. The understory also provides foraging and nesting habitat for ground-dwelling species such as the California towhee, California quail, dark-eyed junco, and spotted towhee. Large trees and snags (i.e., dead or dying trees) provide nesting opportunities for cavity-nesting birds and serve as acorn granaries for acorn woodpeckers and provide po10tial roosting sites for various bat species in the crevices and tree hollows found throughout the watershed.

Mixed woodlands of the watershed support a number of mammalian species. The understory and tree cavities provide escape, cover, and nesting sites. Some of the most commonly observed mammals include western gray squirrel, dusky-footed woodrat, northern raccoon, and black-tailed deer. Woody debris piles and layers of duff provide habitat for amphibians such as California slender salamander and Ensatina. Additional amphibians, including arboreal salamanders, newts, and western toad, use forested and woodland habitats during the non-breeding season. Common reptiles of these communities include western fence lizard, alligator lizard, and gopher and garter snakes.

Serpentine Chaparral and Cypress Forest

Sargent cypress © Christopher L. Christie.

Chaparral and other shrub-dominated plant communities are not abundant in this area, but chaparral does occur on one region of serpentine-derived soils in the western part of the watershed. Serpentine soils have unusual levels of some minerals important to plant survival and growth; as a result, serpentine plant communities are often unusually rich in native and endemic species. A serpentine area spanning Harrison Grade Road supports a unique suite of native plant species (McCarten 1987).

Part of the area is dominated by a stand of Sargent cypress, a closed-cone conifer which depends on fire to release seeds from cones and to prepare the soil surface for germination (Esser 1994). The other dominant vegetation is serpentine-adapted chaparral, including Jepson ceanothus (*Ceanothus jepsonii*) and two special-status plant species, Baker's manzanita (*Arctostaphylos bakeri* ssp. *bakeri*) and Pennell's bird's-beak (*Cordylanthus tenuis* ssp. *capillaris*).

Both Baker's manzanita and Pennell's bird's-beak occur only in Sonoma County; Baker's manzanita is known from only eight occurrences, and Pennell's bird's-beak is known from only four. Both are considered threatened by road maintenance, non-native plants, dumping of trash, and development of private parcels (CNPS 2010). A portion of this unique serpentine habitat is owned and protected by the California Department of Fish and Game (CDFG 2010). One additional special-status plant species, Greene's narrow-leaved daisy (*Erigeron greenei*), was documented historically in serpentine or volcanic chaparral of the watershed, but has not recently been observed.

Chaparral provides habitat for a wide variety of wildlife adapted to shrub-dominated communities. Numerous rodent species inhabit chaparral, and deer and other herbivores make extensive use of it for browse and protective cover. Some small herbivores use chaparral species in fall and winter when grasses are not abundant. Brush rabbits eat twigs, evergreen leaves, and bark from chaparral plants. Shrubs are important to many other mammals (e.g., bobcat, gray fox) as shade during hot weather. Reptiles frequently observed in chaparral include western fence lizard, alligator lizard, and gopher snake. Chaparral provides for a variety of habitat needs for birds in the form of seeds, fruits, insects, and protection from predators and climate, as well as singing, roosting, and nesting sites. Typical birds found in chaparral include California quail, Anna's hummingbird, Bewick's wren, spotted towhee, western scrub-jay, common bushtit, and California thrasher.

Grassland and Agriculture

Most of the eastern portions of both the Upper Green Valley and Purrington Creek subwatersheds have been developed for agricultural and rural residential uses. Vineyards, orchards, livestock pasture, and other agricultural lands are common. Historically, this part of the watershed probably supported oak woodland interspersed with native grassland. Today, mature native trees including coast live oak, black oak, and Oregon oak occur in undisturbed locations, but little native grassland remains in this agriculturally-productive area. Where grassland remains, it is dominated by non-native annual species. Many of these species were introduced from the Mediterranean during the Mexican and American expansion into

California. Historic disturbances, including livestock grazing and clearing for agriculture, facilitated the conversion of native perennial grassland and savanna to annual grassland.

Typical non-native grass species include wild oats (*Avena* spp.), ripgut brome (*Bromus diandrus*), ryegrass (*Lolium multiflorum*), and velvetgrass (*Holcus lanatus*). Common forbs found in these grasslands include non-native filaree (*Erodium* spp.), cut-leaf geranium (*Geranium dissectum*), bur-clover (*Medicago polymorpha*), vetch (*Vicia* spp.), and clovers (*Trifolium* spp.). A few hardy native grasses and forbs remain in less-disturbed locations, including California oatgrass (*Danthonia californica*), purple needlegrass (*Nassella pulchra*), California poppy (*Eschscholzia californica*), soaproot (*Chlorogalum pomeridianum*), and California buttercup (*Ranunculus californicus*). Occasional native shrubs including coyote brush (*Baccharis pilularis*) and California rose can be found in the grasslands. No special-status plant or animal species have been documented in the grasslands of the watershed (CDFG 2010).

California poppy. Photo courtesy of Jennifer Michaud.

Invasive species of particular concern in the watershed's grasslands include Himalayan black berry and velvetgrass. Historic plantings of eucalyptus (*Eucalyptus* spp.) and acacia (*Acacia dealbata*) are common and often spread into wildlands. Pampas grass (*Cortaderia jubata*), Scotch broom, and French broom are common along roadsides.

Annual grasslands and edges of agricultural fields provide habitat and foraging opportunities for a range of common wildlife species. Grasses, low-growing shrubs, and associated invertebrates provide foraging opportunities for a variety of ground-foraging birds, such as American robin, sparrows (e.g., white-crowned, golden-crowned, song), dark-eyed junco, western bluebird, western meadowlark, and numerous other resident and migratory birds. Predatory hawks, including northern harrier, American kestrel, and white-tailed kite, frequent these areas as well. Small vertebrates and invertebrates within the habitat serve as a food source for these birds and other predatory vertebrates. Subterranean foragers, such as Botta's pocket gopher and California mole, commonly occur in grasslands of the watershed. In addition, small mice (e.g., deer and harvest), California vole, black-tailed jackrabbit, coyote, and black-tailed deer are frequently observed. Reptiles of this community include western fence lizard, alligator lizard, California king snakes, gopher snakes and common garter snakes. Bat species also forage over grasslands.

Rural Residential Areas

The Upper Green Valley Creek watershed contains significant rural residential development. While these areas have been moderately developed, vegetation remains an important component of the landscape and wildlife continues to use some areas. Occasional mature oaks and disturbance-adapted shrubs such as coyote brush occur naturally in places. Landscaping typically consists of a mixture of native and nonnative trees, shrubs, and groundcovers. Ornamental landscaping includes a wide range of introduced species that provide shade and contribute to the aesthetics of the landscape.

Several highly invasive plant species occur in developed areas. Of particular concern in this watershed are Himalayan blackberry, acacia, periwinkle and English ivy, all of which can spread into nearby undeveloped lands.

The wildlife habitat values of the rural residential parts of the watershed are generally lower than those of surrounding natural habitats. Roads, turf, and routine landscape maintenance limit protective cover and opportunities for movement and foraging. Wildlife in these developed areas are more acclimated to human activity, and include species such as western scrub-jay, mourning dove, house sparrow, American robin, northern mockingbird, American crow, Norway rat, house mouse, northern raccoon, and Virginia opossum. Mature trees do provide roosting and potential nesting substrate for many species of birds, particularly where they occur in close proximity to open space, riparian corridors, and native woodlands. Fruit trees provide supplemental food for wildlife, and landscape shrubs can provide nesting habitat for generalist bird species, including the house finch and Anna's hummingbird.

Riparian Woodlands and Wetlands

Riparian woodlands are an important component of a healthy watershed. This community includes those plants species occurring along a narrow corridor adjacent to a stream channel. Healthy and intact riparian habitat provides streambank protection, erosion control, and improved water quality. Within the Upper Green Valley Creek watershed, much of the overstory vegetation in the riparian zone consists of alders (*Alnus* spp.) and willows (*Salix* spp.). Other trees present include California bay, Douglas-fir, boxelder (*Acer negundo*), and big-leaf maple (*Acer macrophyllum*). Shrubs and herbaceous plants found in the understory include dogwood (*Cornus sericea*) and poison oak. While many trees line the creek, the riparian corridor has been encroached upon by human and agricultural development, leaving only a thin strip in most locations and none in others.

Riparian area. Photo courtesy of Diana Hines.

Patches of seasonal wetland occur in low-lying areas along the stream corridors and within shallow upland depressions and seeps. Plants typically found in these areas include common rush (*Juncus patens*), meadow barley (*Hordeum brachyantherum*), and spikerush (*Eleocharis macrostachya*). Historically, wetland habitat within the watershed supported a number of rare plant species, including federally endangered Sonoma alopecurus *(Alopecurus aequalis* var. *sonomensis)*, as well as saline clover *(Trifolium depauperatum* var. *hydrophilum)*. With agricultural and residential development, marsh habitat has declined, and none of these species has been documented in recent times.

The following includes a general discussion of the wildlife communities associated with riparian woodlands and instream habitat; further discussion of the physical properties is provided below. In general, riparian woodlands and stream channels such as those occurring within the watershed provide nesting opportunities, food, and shelter and may serve as corridors or islands during migration for a variety of wildlife species. Birds represent the most abundant and prominent wildlife species. Common bird species found in the riparian habitat of the Upper Green Valley Creek watershed include red-tailed hawk, American kestrel, acorn woodpecker, Nuttal's woodpecker, common bushtit, winter wren, American robin, yellow-rumped warbler, spotted towhee, California towhee, western scrub-jay, fox sparrow, song sparrow, white-crowned sparrow, golden-crowned sparrow, California quail, hooded merganser, and turkey vulture (Madrone Audubon Society 1999).

Riparian woodland and instream habitats support a number of mammalian species. The understory and tree cavities provide escape, cover, and nesting sites. The presence of a large number of vertebrate species may serve as a significant food source for larger predatory mammals (e.g., bobcat and gray fox). Some of the most commonly observed mammals include western gray squirrel, dusky-footed woodrat, northern raccoon, and black-tailed deer. In addition, common bat species may forage over this habitat.

Woody debris piles and layers of duff provide habitat for amphibians such as California slender salamander and Ensatina. Additional amphibians, including arboreal salamanders, newts, and western toad, may utilize uplands during the nonbreeding season. Common reptiles of these communities include western fence lizard, alligator lizard, and snakes (e.g., gopher and garter snakes).

The creeks are an important community for a variety of aquatic organisms. Aquatic salamanders (e.g., rough-skinned and California newts, California giant salamander) utilize channels seasonally. Macroinvertebrates (e.g., waterstrider [Gerris sp.], water boatman [Corisella sp.]) serve as the food base for terrestrial and other aquatic species. Fish are abundant, and the creeks support several species of state and federally protected anadromous salmonids (i.e., coho salmon and steelhead). Special-status northwestern pond turtles, foothill yellow-legged frogs, and California freshwater shrimp are also known to occur within the watershed.

Special-status Species

In California, special-status plants and animals include those species that are afforded legal protection under the federal and California Endangered Species Acts (ESA and CESA, respectively) and other regulations. Consideration of these species must be included during project evaluation in order to comply with the California Environmental Quality Act[6] (CEQA), in consultation with State and federal resources agencies, and in the development of specific management guidelines for resource protection.

Special-status plants and animals of California include, but may not be limited to:

- Species listed or proposed for listing as threatened or endangered under the federal ESA.

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[6] Projects undertaken, funded, or requiring a permit by public agency must comply with the California Environmental Quality Act (CEQA). The primary purpose of CEQA is to inform decision makers and the public about the potential environmental impacts of the proposed activities.

- Species listed or proposed for listing as threatened or endangered under the California ESA.
- Species that are recognized as candidates for future listing by agencies with resource management responsibilities such as U.S. Fish and Wildlife Service, NMFS, and California Department of Fish and Game (CDFG).
- Species defined by CDFG as California Special Concern species.
- Species classified as Fully Protected by CDFG.
- Plant species, subspecies, and varieties defined as rare or threatened by the California Native Plant Protection Act (California Fish and Game Code Section 1900 et seq.).
- Plant species listed by the California Native Plant Society as List 1 and 2 and some List 3 plants under CEQA (CEQA Guidelines, Section 15380).
- Species that otherwise meet the definition of rare, threatened, or endangered pursuant to Section 15380 of the CEQA Guidelines.

Background Research

A background literature and database search was conducted to provide a comprehensive list of all special-status species with documented occurrences in the watershed. The review focused on California Natural Diversity Data Base (CNDDB) maintained by the California Department of Fish and Game (CDFG) for reported occurrences of sensitive plants, animals, and communities; however, additional relevant studies and reference materials were also consulted. The background literature review identified the potential presence of 5 special-status plants within these subwatersheds (*Table 9. Special-status Plants of the Upper Green Valley Creek Watershed*). A number of special-status animals were also identified based on reported occurrences within the watershed and/or high probability of occurrence based on the presence of suitable habitat and known occurrences within the region. Special-status animals of the watershed are described in the text below including listing status and general habitat/life history descriptions (Zeiner et al. 1990).

Special-status Plants

Table 9. Special-status Plants of the Upper Green Valley Creek Watershed

Common Name *Scientific Name*	**Listing Status FEDERAL/ STATE/ CNPS**	**Life Form, Blooming Period, and General Habitat**
Sonoma alopecurus *Alopecurus aequalis var. sonomensis*	FE/--/List 1B.1 (Seriously endangered in California)	Perennial herb. Blooms May-July. Freshwater marshes and swamps, riparian scrub. 5-365 m.
Baker's manzanita *Arctostaphylos bakeri ssp. bakeri*	--/SR/List 1B.1 (Seriously endangered in California)	Perennial evergreen shrub. Blooms February-April. Chaparral, often serpentinite. 75-300 m.
Pennell's bird's-beak *Cordylanthus tenuis ssp. capillaris*	FE/SR/List 1B.2 (Fairly endangered in California)	Annual herb, hemiparasitic. Blooms June-September. Closed-cone coniferous forest, chaparral (serpentinite). 45-305 m.
Greene's narrow-leaved daisy *Erigeron greenei*	--/--/List 1B.2 (Fairly endangered in California)	Perennial herb. Blooms May-September. Chaparral, often serpentinite or volcanic. 80-1005 m.
saline clover *Trifolium depauperatum* var. *hydrophilum*	--/--/List 1B.2 (Fairly endangered in California)	Annual herb. Blooms April-June. Marshes and swamps, valley and foothill grassland (mesic, alkaline), vernal pools. 0-300 m.

STATUS CODES:

FEDERAL:
FE = Listed as endangered (in danger of extinction) by the federal government
FT = Listed as threatened (likely to become endangered within the foreseeable future) by the federal government

STATE OF CALIFORNIA:
SE = Listed as endangered by the State of California
ST = Listed as threatened by the State of California
SR = Listed as rare by the State of California

Northern spotted owl. The northern spotted owl (*Strix occidentalis caurina*) is federally listed as threatened and State listed as a California Species of Special Concern. It is an uncommon permanent resident of dense forest habitats in northern California and oak and oak-conifer habitats in southern California. This nocturnal species requires dense, multi-layered canopy cover for roosting sites. Spotted owls feed upon a variety of small mammals, birds, and large arthropods. Nest sites include tree or snag cavities or broken tops of large trees. The breeding period lasts from early March through June with two offspring typically produced each season. A pair of owls may utilize the same breeding site for 5 to 10 years; however, they may not breed every year. Individual territories are typically several hundred acres. The spotted owl has experienced a population decline due to the loss and degradation of existing mature and old growth forests. They are a fairly common permanent resident in Sonoma County where they occupy "old-growth coniferous forests of redwood, Douglas-fir or pines blended with smaller evergreen hardwoods" (Burridge 1995).

Northern spotted owl. Photo courtesy of Gerald and Buff Corsi, California Academy of Sciences.

Occurrence within the watershed. According to the CNDDB, there is documented occurrence of a spotted owl territory within the Purrington Creek subwatershed (CDFG 2010; see *Map 8, Special-status Species Locations*). There are also reported occurrences within the surrounding watersheds in dense forested habitats. Spotted owls may occupy the denser, multi-story habitats of the watershed beyond what is currently reported.

Sonoma tree vole. The Sonoma tree vole (*Arborimus pomo*) is a California Species of Special Concern. It occurs in coniferous forest in humid areas where it is reported to be rare or uncommon. They are largely nocturnal and active year-round. Their home range generally consists of one to several fir trees. Within California, they primarily feed on the needles of Douglas-fir. Needle resin ducts are removed before eating and often used to line the nest cup.

Nests are typically constructed from 6 to 150 feet above ground preferably in tall trees and located on outer branches or on whorl of limbs against the trunk. Breeding occurs year-round, with peak activity from February to September. The primary predators of voles are spotted owls, saw-whet owls, and possibly raccoons.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of Sonoma tree vole within forested habitats at the boundary of the Purrington Creek and Dutch Bill Creek watersheds. They are also known to occur within the lower Green Valley Watershed in the vicinity of the Canyon Rock Quarry in Forestville (J. Michaud personal observation) and within the surrounding watersheds (i.e., Dutch Bill and Salmon Creeks). Sonoma tree vole may occur throughout the older Douglas-fir forests of the watershed.

Northwestern pond turtle. The northwestern pond turtle *(Actinemys marmorata marmorata)* is listed as a California Species of Special Concern by CDFG and one of two distinct subspecies of the western pond turtle (*A. marmorata*). The western pond turtle occurs from Washington south to Baja, Mexico. The northwestern subspecies occurs from the San Francisco Bay north, and the southwestern pond turtle (*A. m. pallida*) occurs from the San Francisco Bay south. There is a zone of intergradation between the two subspecies throughout San Francisco Bay and the San Joaquin Valley. It is the only native turtle in the North Bay region.

Male northwestern pond turtle. Photos courtesy of Jennifer Michaud.

Pond turtles are most commonly found in or near permanent or semi-permanent water sources in a variety of suitable habitats throughout their range. Western pond turtles can be observed basking in the sun on the banks of ponds or on logs floating on the surface of the water. They appear to be sensitive to sound and will dive underwater when approached too closely. In water, they prefer wood structures that provide underwater refugia from predators. During winter, they often burrow under logs and other suitable structures for extended periods.

The size of pond turtle varies from 3.5 to 7 inches length. The upper shell is olive, dark brown, or blackish in color, occasionally without pattern but usually with a network of spots, lines, or dashes of brown or black. The underside is yellowish tan. Pond turtles nest from May to August with peek activity occurring from June to July (Bash 1999). The nests are usually located in full sunlight in dry, well-drained soils, with grass, herbaceous vegetation, shrubs, and trees nearby (Hays et al. 1999). The young hatch the following spring. Western pond turtle populations have decreased due to a combination of overharvesting for food (from the late 1800s to the 1930s), habitat loss, and predation by non-native species (Bash 1999). Juvenile pond turtles are susceptible to predation by non-native species such as bullfrogs and largemouth bass (Bash 1999). Habitat loss due to urbanization, the drainage of wetlands for agriculture or development, and the alteration of watercourses has also contributed to the decline of this species. Fire suppression, water diversion projects and grazing may have altered riparian vegetation, creating habitat less suitable for turtles.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of northwestern pond turtles in the upper portion of Atascadero Creek (CDFG 2010; see *Map 8 Special-status Species Locations*). They are also known to occur in the surrounding watersheds and are relatively abundant along the mainstem Russian River. While there are limited reported observations within the general area, pond turtles are likely abundant in off-channel reservoirs, ponds, and along stream channels throughout the watershed.

Foothill yellow-legged frog. The foothill-yellow legged frog (*Rana boylii*) is a California Species of Special Concern with CDFG. They occur from southern Oregon south to the Salinas River in Monterey County, California, and in isolated patches in the Cascade and Sierra Nevada foothills. These frogs are moderately sized with adults ranging from 1 ½ to 3 inches in length (Jennings and Hayes 1994). Coloration is highly variable ranging from dark to light gray, brown, green, or yellow with a somewhat mottled appearance (Jennings and Hayes 1994). The lower belly and undersurfaces of the legs are yellow or orange/yellow. They are found in or near

Foothill yellow-legged frog. Photo courtesy of Jennifer Michaud.

partly shaded rocky streams from near sea level to 6,300 feet in a variety of habitats. Breeding generally occurs from mid-March to early June after high winter flows have subsided. Egg masses are attached to the downstream side of rock and gravel in shallow, slow, or moderate-sized streams. Tadpoles require three to four months to attain metamorphosis. Adults feed on aquatic and terrestrial invertebrates, and tadpoles graze along rocky stream bottoms on algae and diatoms. During all seasons, this species is generally found in or within close proximity to streams. Garter snakes are the principle predators of tadpoles, juvenile, and adults. Eggs are eaten by non-native centrachid fish such as bass and sunfish.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of foothill yellow-legged frogs along Upper Green Valley Creek, above the confluence with Atascadero Creek (CDFG 2010; see *Map 8, Special-status Species Locations*). While there are limited reported observations outside of this area, foothill yellow-legged frogs are likely abundant along stream channels throughout the watershed where suitable habitat exists.

California red-legged frog. The California red-legged frog (*Rana draytonii*) is federally listed as threatened and a California Species of Special Concern with CDFG. They were federally listed as threatened in 1996 due to a significant decline or extirpation throughout most of their range primarily due to habitat loss and introduced predators [i.e., nonnative American bullfrog (*Rana catesbeiana*) and predatory fish (i.e., sunfish (*Lepomis sp*.)]. Historically, they occurred throughout the foothills of the Central Valley and coastal drainages from Marin County to Baja Mexico (Cook 1997). Most remaining populations are restricted to coastal watersheds from the San Francisco Bay area south to Ventura County (Jennings and Hayes 1994).

California red-legged frog. Photos courtesy of Jennifer Michaud.

The red-legged frog is the largest frog native to California, reaching up to 5 inches in length. They have brown or reddish brown to dark brown on the dorsal side of their body and red on the underside of their hind limbs and on the lower abdomen and underside of their hind legs, often overlying yellow ground color. One key characteristic used to identify this species is a skin fold running from the back of the eye to the posterior end called the dorsolateral fold. Red-legged frogs inhabit streams that typically consist of small pools with emergent and overhanging vegetation such as willow (*Salix* spp.) and marshes with emergent vegetation [i.e., cattail (*Thypa* spp.) and bulrush (*Scirpus* spp.)]. They also frequent livestock pond, reservoirs, and other bodies of water with emergent vegetation and free of predatory fish and bullfrogs. Breeding occurs from November through April depending on the location. Egg masses are attached to emergent vegetation near the water's surface. Tadpoles require 3.5 to 7 months to attain metamorphosis. Adults take invertebrates and small vertebrates. Larvae are thought to be algal grazers.

Occurrence within the watershed. California red-legged frogs are known from a small area just outside the watershed boundary, within an approximate one-mile radius (CDFG 2010) and there is anecdotal information of an unconfirmed sighting within the watershed. While there have been few documented occurrences within the watershed or surrounding areas, private ponds and off-channel reservoirs likely support this species and they could be more widely distributed than is currently documented.

California freshwater shrimp. The California freshwater shrimp (*Syncaris pacifica*) is federally and State listed as endangered. The shrimp is endemic to Marin, Sonoma and Napa counties north of San Francisco Bay, California and currently occupies 23 coastal streams in this area including Green Valley Creek (USFWS 2007). These shrimp are typically found in low elevation (less than 380 feet) low gradient streams (generally less than 1%) (USFWS 1998). The habitat usually consists of perennial freshwater or intermittent streams with perennial pools with undercut banks, exposed roots, and overhanging vegetation or woody debris.

California freshwater shrimp. Photo courtesy of Bill Cox.

California freshwater shrimp are small crustaceans and adults are typically about two inches in length from eye orbit to the tip of the tail. Coloration is variable – females have been found with a dark brown to purple color while males are typically translucent to transparent. The shrimp have the unique ability to darken their bodies to create the illusion that they are submerged, decaying vegetation. They accomplish this with small surface and internal color-producing cells clustered in a pattern to help disrupt their body outline (USFWS 1998). Mating occurs around September and by November most females are bearing eggs. The eggs stay attached to the female throughout the winter incubation period. Young are released in May or early June and grow rapidly. California freshwater shrimp live for about three years. Population declines have occurred due to many factors including deterioration or loss of habitat resulting from water diversion, impoundments, agricultural activities and developments, flood control activities, timber harvesting, migration barriers, and water pollution.

Occurrence within the watershed. According to the CNDDB, there are reported occurrences of California freshwater shrimp along Upper Creek Valley Creek, above the confluence with Atascadero Creek (CDFG 2010; see *Map 8, Special-status Species Locations*). While there are limited reported observations outside of this area, shrimp are likely abundant along stream channels throughout the watershed where suitable habitat exists.

Salmonids. Historic and ongoing land-use practices, combined with changes in ocean conditions, have had a dramatic effect on salmonid populations within the Upper Green Valley Creek watershed. Steelhead (*Oncorhynchus mykiss)* and coho salmon (*Oncorhynchus kisutch*) were once abundant in Green Valley Creek and its tributaries. Now only a small population of steelhead continues to return each year. Native runs of coho salmon are believed to be extirpated and the watershed is now part of a reintroduction program. Populations of steelhead and coho salmon have declined from historic levels due to past land-use practices, including logging, channel modifications, stream diversions, land development, sedimentation, and increasing water use; however, efforts are being made to reverse this trend. The watershed, in particular Purrington Creek, is identified as one of the core areas for advancing coho salmon recovery in the Russian River watershed (NMFS 2010).

Steelhead and coho salmon are anadromous fish; they spawn in freshwater and mature in the ocean. Steelhead that never enter the ocean and remain in freshwater streams are called rainbow trout. Green Valley Creek steelhead are part of the central California coast Distinct Population Segment (DPS), which is federally listed as threatened by NMFS. Coho salmon, central California coast DPS, are both federally and State-listed as endangered. See Appendix 7 for detailed life history information.

Adult steelhead migrate upstream from the ocean during the rainy season, anytime from December through April. They enter the stream only when sufficient flow has opened the downstream coastal lagoon. Steelhead spawn (mate and lay eggs) typically at the downstream edge of pools where cover habitat exists nearby for predator protection. Eggs are laid in a

Adult coho salmon. Photo courtesy of Simpson Timber Company

depression dug into cobble or gravel substrate called a redd. Unlike salmon, steelhead can migrate out to the ocean after spawning and return in subsequent years to spawn again. Eggs hatch in 3 to 14 weeks, depending on stream temperatures. The newly hatched fish (alevins) stay in the gravel for a few additional weeks until their yolk sac is absorbed. When they emerge, they seek slow-water areas, often at the stream margins. As they grow bigger, the juvenile fish move into faster water to feed on drifting insects.

Juvenile steelhead remain in freshwater streams from 1 to 3 years, depending on their rate of growth. Rearing juveniles have many habitat requirements. Most important, they need sufficient, cool streamflow to transport drifting insects for feeding and cover habitat, such as undercut banks, woody material, boulders, and deep pools, to hide from predators and areas for refuge during high flows. When juveniles are large enough, they migrate out to the ocean as smolts typically from March through June. During out-migration, steelhead and salmon need adequate streamflow to swim past barriers and cover for predator protection.

Coho salmon have a similar, but more rigid, lifecycle than steelhead. Upstream migration typically occurs as soon as winter rains have commenced and stream flows increase with peak spawning activity around December. Coho spend their first year in freshwater streams, migrate downstream the following spring and spend two years in the ocean to mature. Coho salmon return to their natal streams when they are three years old to spawn; therefore, coho salmon develop three consecutive "year classes" in each stream. Like steelhead, coho salmon are vulnerable to extreme environmental conditions, such as droughts, floods, and the timing of winter storms, which affect when the sandbar opens for upstream migration and influence survival juveniles and viability of redds[7].

[7] Definition of redd: Spawning area or nest of trout or salmon.

History of Salmonid Fish Surveys and Stocking

Salmonid Fish Surveys

The earliest fish survey of Green Valley Creek was conducted by the Division of Water Resources in 1966 (CDFG 2006a). During this survey, steelhead and coho salmon were found throughout the creek. CDFG conducted surveys in 1969 and again in 1991 and observed steelhead, but no coho salmon. Coho were not recorded again until 1993, when several were observed during a City of Santa Rosa survey (Merritt Smith Consulting 2003). CDFG surveys in 1995 found a few juvenile coho salmon. Subsequent monitoring efforts by UC Cooperative Extension (UCCE) found coho salmon in Green Valley Creek each year from 2001 through 2004; although by 2004, less than 10 individuals were found (Conrad et al. 2005). The last wild coho salmon were documented in Green Valley Creek in 2004.

In the spring of 2005, UCCE staff installed an outmigrant trap, which captures fish as they migrate downstream, in the watershed (Conrad et al. 2005). A total of nine wild coho salmon smolts were captured in the trap. Six hatchery fish were also captured in the trap, as indicated by the lack of an adipose fin which is removed in the hatchery to distinguish them from wild fish; however, no hatchery fish had been planted in Green Valley Creek.

In the spring and summer of 2005, snorkel surveys were conducted by UCCE to locate potential wild broodstock and to document a suspected decline of wild coho populations from Upper Green Valley Creek. A total of 35 pools were snorkeled in the reach that runs from the confluence of Purrington Creek upstream to the confluence of the Bones Road Bridge. There were no coho salmon found in this reach. In the summer of 20006, another snorkeling survey was conducted in Upper Green Valley Creek. No coho juveniles were found.

Broodstock Program

Coho salmon populations were greatly reduced in other tributaries of the Russian River throughout the 2000s; these significant population declines were the impetus for the Russian River Coho Salmon Captive Broodstock Program (RRCSCBP). The program began in 2001 to help return coho salmon to the Russian River Watershed. Green Valley Creek was chosen as a stocking location because it was considered to have fairly suitable habitat, cooperative landowners, and high potential for successful monitoring.

During the summer of 2001, CDFG personnel captured coho salmon for the broodstock program in the Upper Green Valley Creek mainstem between the confluences with Purrington and Harrison Creeks. A survey conducted by SCWA two weeks later found 422 juvenile coho salmon in the same reach of creek. In the summer of 2002, 12 juvenile coho salmon were documented. In 2004, seven juvenile coho salmon were captured using hand seines. The oldest and first collected year class was spawned in December 2003. The young from these fish were planted in other Russian River tributaries, but not Green Valley Creek.

In the fall of 2006, the first broodstock coho salmon were planted in Green Valley Creek (*Table 10 Broodstock Coho Stocking in the Upper Green Valley Creek Watershed*). This included 4,278 juveniles with coded wire tags implanted in their snouts. In the spring of 2007, outmigrant traps were installed and 504 hatchery coho smolts were captured, giving an apparent overwinter survival of 33%. This was considered a moderate survival rate and within the range observed for wild coho salmon in streams in west Marin County. In the fall of 2008, juvenile coho salmon (10,023 juveniles) were released again. Only 163 were captured in the outmigrant traps the following spring, indicating a very low survival rate. In the spring of 2009, 2,850 coho smolts were released with only 386 smolts captured in the outmigrant trap a few weeks later – the second year in a row with an apparently poor survival rate. It is not known if these fish failed to outmigrate and stayed in the upper watershed, or if they died due to some other variable such as predation, poor water quality, excessive sediment in the creek (which might be clogging their gills), or stranding due to insufficient water. Local biologists and other stakeholders are currently trying to better understand and resolve this issue.

Table 10. Broodstock Coho Stocking in the Upper Green Valley Creek Watershed

Year	**2006**		**2007**		**2008**		**2009**		**2010**
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Number of coho	-	4,278	-	7,883	-	10,023	2,850	5,200	3,099

Instream Habitat

Healthy stream channels are critical for supporting salmonids and other aquatic species. Like most aquatic species, steelhead and salmon require a number of instream habitat elements to support them through their various freshwater life stages. These include access to clean spawning cobble and gravel without fine sediments, year-round supply of cool oxygenated water, diverse habitat with deep, quiet pools and shallow riffles, stable creek banks, dense canopy cover, lots of woody material and other forms of cover, and an adequate food supply. The quality of instream habitat has been shown to have a direct impact on juvenile survival, rates of adult returns, and successful spawning.

Suitable water quality conditions are also critical for the development, growth, and survival of all salmonid life stages. Steelhead and salmon need cool water temperatures, high dissolved oxygen, and low quantities of fine sediment for successful juvenile rearing and adult migration and spawning. They also require sufficient stream flows – both during winter and summer rearing. During winter rearing, they require high flow refuge habitat to reduce their vulnerability during storm events and sufficient stream flows in summer to provide optimal rearing potenial, which can be compromised when pools become isolated or dry up.

Salmonid production within the Upper Green Valley Creek watershed appears to be limited due to the physical structure of the instream habitat, below optimal water quality conditions, and insufficient stream flows. To date, a thorough study of limiting factors – habitat conditions that pose limitations to a species' survival – has not been conducted for the Upper Green Valley watershed. However, habitat analysis and monitoring conducted by a number of entities suggest several factors are contributing to the poor production of salmonids, specifically coho salmon, within the watershed.

Various deficiencies in channel complexity such as low pool depths and shelter value and a lack of off-channel habitat may play a major role in limiting the success of steelhead and coho salmon within the watershed. A lack of adequate surface flows in the summer to support juvenile rearing is evident in many reaches, and is likely one of the top factors. Reduced flow also likely contributes to low levels of dissolved oxygen which has been shown to limit juvenile rearing, and may reduce smolt survival as well. Finally, high water temperatures during the summer rearing period may also limit the survival of juvenile salmonids. Each factor influences the survival and reproduction of steelhead and coho salmon during various life stages; therefore, it is likely that multiple factors limit salmon production to varying degrees in the Upper Green Valley Creek watershed.

Watershed Assessments

In 1994, the Green Valley/Atascadero Creek watershed was evaluated by the California Department of Fish and Game as part of their standardized habitat inventories for California streams (CDFG 1998). Inventories were conducted from the confluence with the Russian River to the upper limits of Green Valley Creek, Purrington Creek, and other creeks within the watershed (e.g., Atascadero, Jonive). The goal of the inventories was to assess the quantity and condition of aquatic habitat, with an emphasis on salmonid habitat, and document the presence and distribution of aquatic species (CDFG 2006a and 2006b). The habitat analysis included measurements of specified stream reaches and an evaluation of nine stream components: flow, channel type, temperatures, habitat type, substrate composition, gravel embeddedness, shelter rating, and canopy and bank composition.

The results of the Green Valley Creek and Purrington Creek habitat analyses found a low number of deep pools, low instream shelter values in pools, and gravels/cobbles embedded with fine sediment (CDFG 2006a and 2006b). Canopy cover was noted to be good – above the 80% coverage recommended for salmonid streams. During both inventories, steelhead and coho salmon were noted; however, further biological inventory results are not described here. Results of the habitat analysis component are summarized in Appendix 8 and described in detail below.

Recently, more detailed assessments were completed on Green Valley Creek between the confluences of Harrison and Purrington Creeks (O'Connor and Rosser 2003) and mainstem Purrington Creek (O'Connor 2010). The Green Valley Creek assessment included a habitat inventory based on CDFG guidelines, detailed substrate sampling and channel surveys, flow estimates, and woody material survey at 5 sites in Upper Green Valley Creek in 2002. Habitat inventory findings were consistent with the conditions documented by CDFG in 1994, including a low number of deep pools. The most common type of pool present was scour pools associated with large woody debris. Detailed substrate sampling found high quality spawning habitat within the reach surveyed based on the appropriate particle size and distribution and low percentages of fine sediment.

In 2010, a study comparing the results from the 1994 CDFG inventory was conducted on Purrington Creek to evaluate whether or not significant changes over the past 16 years had occurred to affect fish habitat quality and abundance (O'Connor 2010). The study found that pool forming processes and conditions have not changed significantly between the two surveys. Overall, pools were found to be relatively abundant but lacking depth and cover complexity. Woody debris abundance was also low; however, when present it is typically associated with greater pool depth, abundance, and cover. Rearing habitat was rated as fair based on current geomorphic conditions. Due to high flows during the study, spawning habitat could not be fully evaluated. However, it was noted that based on pool and riffle configurations, spawning habitat likely occurs in relatively small patches.

Primary Pools and Pool Shelter

Deep pools are a critical component of healthy salmonid habitat as they provide cover and rearing space for juvenile fish and high flow refuge habitat. They also provide cool water refuge during the summer months when water and air temperatures can be high and stream flows diminish. CDFG evaluates pool depth and frequency by determining the number of primary pools according to stream order. In first and second order streams, a primary pool has a maximum depth of at least two feet, occupies at least half the width of the low-flow channel, and is as long as the width of the low-flow channel; primary pools in third and fourth order[8] streams are three feet deep or more. In coastal salmonid streams, more than 50% of the total available habitat should be comprised of adequately deep and complex pools (CDFG 1999).

Overall, both Green Valley Creek, a third order stream, and Purrington Creek, a first and second order stream, have a low percentage of deep pools. Based on the 1994 Green Valley Creek CDFG inventory, only 30% of the pools were found to have a maximum depth of three feet or more, comprising 34% of the habitat by length(CDFG 2006a). Similar results were found in O'Connor and Rosser (2003) with only two pools out of 12 identified being greater in depth than three feet. Results are similar for Purrington Creek, with only 38% of its pools found to have a maximum depth of two feet or more. Thus 28% of the habitat, by length, is comprised of primary pools (CDFG 2006b), this being consistent with the more recent study by O'Connor (2010). Contributing factors in the low number of deep pools are the high level of streambank erosion, which results in excessive sedimentation, and lack of large woody debris to form deeper pools (O'Connor and Rosser 2003). In an eight-year study, Merritt Smith Consulting (2003) noted that sediment was filling pools, making them shallower.

Sufficient shelter is another important component of instream habitat, and is a useful indicator of pool complexity. Shelter in the form of large and small woody debris, undercut banks, root wads, aquatic vegetation and boulders provides fish with areas to hide from predators. These habitat features also provide territorial niches and can help reduce density-related competition. Deeper water habitats provide velocity refuge from high flow events. A pool shelter rating of 80% is desirable. Mean shelter values in pools in Green Valley and Purrington Creeks were found to be 20 and 18, respectively (CDFG 2006a and 2006b). These low shelter values are largely due to the lack of log and root wad cover structures.

Spawning Habitat and Cobble Embeddedness

Salmonids need clean, adequately aerated gravels for successful spawning. Typically, steelhead and coho salmon construct their redd, a salmon nest dug in the streambed where eggs are deposited, at the head of riffles near pool-tail outs. This is where sufficient oxygen circulation for developing eggs, interstitial flow to remove metabolic waste, and water temperature regulation are maximized (CDFG 2004). When gravels contain excess sediment, the eggs and alevin become enveloped by sediment and suffocate. The depth of cobble embeddedness, the degree to which materials are buried in fine materials, at pool-tail outs is a key element in

[8] A first order stream is an unbranched or unforked stream. Two first order streams joining together form a second order stream, two second order streams joining together form a third order stream, and so on.

determining the success of spawning salmon. Embeddedness ratings of 25% or less are considered desirable.

During the CDFG inventories, cobble embeddedness ratings of less than 25% were noted in two reaches in Green Valley Creek above the confluence with Purrington Creek; however, they also noted low percentages of gravels within the riffle habitats, which is considered fair for spawning salmonids (CDFG 2006a). O'Connor and Rosser (2003) noted ideal spawning conditions in GreenValley Creek based on low embeddedness (or fine sediment deposition) and appropriate particle size distribution. Cobble embeddedness in Purrington Creek was above the desired rating throughout much of the survey area. However, CDFG noted a high percentage of low gradient riffles with gravels in Purrington Creek, which is generally considered good for spawning (CDFG 2006b). In 2010, spawning habitat within Purrington Creek was noted to be present in relatively small patches with less than ideal substrate conditions (O'Connor 2010).

Riparian Cover and Buffers

Healthy, mature riparian vegetation is critical for maintaining ecosystem function. Intact riparian corridors keep water cool and clean, protect streambanks from excessive erosion, slow flows by increasing stormwater retention and infiltration, and provide roots and wood that are vital to create the complex instream habitat that salmonids and other aquatic species need. Riparian vegetation is also important for the production of salmonid food sources – terrestrial insects and leaf litter on which aquatic insects feed. Canopy cover of 80% is considered desirable for salmonid bearing streams. During the CDFG inventories, canopy cover on both Green Valley and Purrington Creeks was above the desired 80% (CDFG 2006a and 2006b). Canopy cover conditions in Green Valley Creek were noted to be the same in 2002 (O'Connor and Rosser 2003).

In addition to adequate cover, buffers[9] are critical for maintaining riparian functions (i.e., filtering sediment and pollutants, providing shade, bank stabilization, and instream wood production). Buffers of at least 100 feet or more are recommended to support natural regeneration and woody debris (Ledwith 1996, Chris10sen 2000, Beschta et al. 1987). The CDFG inventory noted a thin riparian buffer in Purrington Creek, with similar values likely occurring in Green Valley as well.

[9] Riparian buffer - "a complex assemblage of plants and other organisms in an environment adjacent to water. Without definitive boundaries, it may include stream banks, floodplain, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic habitat. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season." (Lowrance, Leonard, and Sherida 1985)

Macroinvertebrates

Macroinvertebrates are animals lacking backbones (invertebrates) that are large enough to be seen with the naked eye (i.e., insects and worms). In 2006, a study was conducted by UCCE to evaluate the relationship between macroinvertebrate biomass in Green Valley Creek and the availability of food for salmonids, particularly coho salmon stocked as part of the Russian River Captive Broodstock Program (Obedzinski et al. 2008), as macroinvertebrates are their primary food source. The study found a high density of macroinvertebrates. During the same year (spring 2006), smolts captured in outmigrant traps were found to be larger than other streams. In 2007, the same study was repeated and it was again found that smolts in Green Valley Creek were notably larger than in other streams (i.e., Sheephouse and Ward Creeks) (Obedzinski et al. 2008). The high density of macroinvertebrates in Green Valley Creek likely contributed to the large smolt size, as there is a strong relationship between growth rates and food availability. The high density of macroinvertebrates within the watershed is important because smolts have a higher chance of survival if they are larger when entering the ocean, which likely leads to higher adult return rates (Holtby et al. 1990).

Floodplain Connectivity

Seasonal connectivity of the stream to floodplains and off-channel habitat is another form of channel complexity that is important to juvenile rearing, overwintering, and outmigration. Land development has tended to simplify the channel form, isolating it from adjacent floodplains, which in turn results in channel incision. According to watershed landowners and long-time residents, Upper Green Valley Creek has become very incised over the last few decades – in some locations, the creek bottom has dropped over twenty feet. This has created a channel that is completely disconnected from its floodplain. The loss of channel complexity along with reduced pool and shelter components, has likely reduced the carrying capacity[10] of coho salmon in Upper Green Valley and Purrington Creek subwatersheds. Channel incision is discussed in more detail in *Chapter II, Section D, page 49.*

[10] The carrying capacity of a biological species in an environment is the species population size that can be sustained by the environment indefinitely given adequate food, shelter ,water and other habitat needs available in the environment.

Water Quality and Quantity

Temperature. Salmonids need adequately cool water temperatures to thrive, with coho salmon being more restrictive in their tolerances than steelhead or other species (Sullivan 2000). Water temperatures for optimal survival and growth of juvenile coho salmon range from 10 to 15°C (McMahon 1983). Growth ceases at temperatures above 20.3°C and swimming speeds are reduced above 20°C (McMahon 1983). Based on a limited data set collected at four monitoring site by Gold Ridge RCD within the Upper Green Valley Creek watershed, water temperatures appear to be within acceptable ranges during the winter spawning and incubation stages. However, in the summer months, water temperatures are above the optimal level for juvenile rearing (see *Chapter II, Section B*). Additional water quality monitoring by UCCE indicates a similar summer time trend (Obedzinski et al. 2008). Based on this small data set, water temperatures during the summer months appear to be below optimal levels for coho salmon; however, further data collection is needed (and results from volunteer monitoring efforts by the Community Clean Water Institute need to be analyzed) to make more robust conclusions about temperature conditions within the watershed.

Dissolved Oxygen. Salmon and steelhead need an adequate level of dissolved oxygen (DO) at all life stages to support respiration. DO is affected by water temperature, stream flow, and amount of instream organic matter. Water Quality Objectives from the North Coast Regional Water Quality Control Plan set minimum DO levels at 7.0 mg/l for the Russian River HU (NCRWQCB 2007). The suitable range for migrating adult coho is greater than 4.0 mg/l, while the optimum range for rearing juveniles as well as eggs and fry is 6.0 mg/l (see *Chapter II*, *Section B*). Low DO can occur in streams when flows are low and nutrient levels are high. Low DO levels can affect juvenile rearing salmonids by causing rapidly declining growth at concentrations below 5 mg/l and mortality at levels below 2.3 mg/l (Deas and Orlob 1999). Based on data collected by Gold Ridge RCD within the Upper Green Valley Creek watershed, DO levels appear to be sufficient during the winter and early summer, but fall below acceptable levels when flows become low during late summer and early fall. However, as noted above, further data collection is needed and data collected in volunteer monitoring efforts by the Community Clean Water Institute should be analyzed to make more robust conclusions about instream water quality conditions.

Turbidity. Turbidity is a measure of the transmissivity of light through water. This attribute is defined as levels of suspended sediment (resulting from both natural and anthropogenic origin) which may cause acute, sub-lethal, or chronic effects on salmonids or their habitat. Coho are particularly sensitive to excessive turbidity (Bjornn and Reiser 1991). Elevated levels of turbidity can disrupt normal feeding behavior and efficiency, reduce growth rates, increase stress, and reduce instream dissolved oxygen, respiratory functions and tolerance to diseases, and can also cause mortality (Bjornn et al. 1977, Crouse et al. 1981, Sigler et al. 1984, Velagic 1995,). Displacement of coho can occur in waters with turbidities greater than 70 Nephelometric Turbidity Units (NTU) (Bash et al. 2001). The length of time that fish experience increased turbidity is important. Newcombe and Jensen (1996) found that 148 milligrams per Liter per Day (mg /L/Day) is lethal to spawning salmonids. Adults will stray from turbid tributaries into those with clear water, if they are available (Sigler et al. 1984).

Based on data collected by Gold Ridge RCD within the Upper Green Valley Creek watershed, measurements of turbidity during storm events at various sites within the watershed indicate extended periods of "significantly impaired" conditions for salmonids in both the mainstem and tributaries. During the last year of water quality monitoring, turbidity readings have oftenbeen above the 25 NTU threshold for physiological effects; however, duration of these levels was not measured (see *Chapter II*, *Section B*).

Summer Flow. Summer flows are critical for the survival of rearing juvenile fish and maintenance of high quality habitat. Flows provide rearing space, allow for movement between habitats, maintain water quality and temperature, and facilitate delivery of food for juvenile salmonids. Within the Upper Green Valley Creek watershed, pools typically become disconnected during the summer and fall. In the late summer of 2001, a survey conducted by the Sonoma County Water Agency noted that many pools in the creek were either isolated or received very little inflow (Cook and Manning 2002). More recently, staff at GRRCD has observed dry sections of the creek throughout the watershed during the summer months while conducting water quality monitoring (see *Chapter II*, *Section B*). In 2009, the mouth of Harrison Creek went dry in the beginning of the summer. By fall, parts of Green Valley creek just above the confluence with Atascadero Creek were also dry. A single monitoring site on Purrington Creek was the only location to retain water throughout the summer. However, by October of 2009, flow had returned to all monitoring sites.

Summer flows have likely been reduced due to increased water consumption in the watershed from groundwater and direct stream withdrawals. Over an 8-year study, it was noted that summer juvenile salmonid rearing habitat in Green Valley Creek was likely limited by diminished flow due to water diversions (Merritt Smith Consulting 2003). As described above, this trend has continued, leaving many sections of the stream dry during the summer and limiting the amount of suitable habitat available for rearing juveniles.

Instream Barriers

Instream barriers are obstacles that prevent or inhibit the natural movement of fish and other aquatic species from fully utilizing their habitat. These barriers typically include man-made features such as culverts, dams, weirs, and floodgates, but they can also include natural features such as log jams. Barriers can restrict the upstream movement of spawning adults and multi-directional movements of juvenile fish as they seek cool water, food, and cover throughout their rearing period and downstream migration to the ocean.

Within the Russian River watershed, an assessment of all man-made instream barriers was conducted by Ross Taylor and Associates in 2001 through 2003 (Taylor et al. 2003). A number of barriers were noted within the Atascadero/Green Valley Creek watershed including several within the Upper Green Valley Creek watershed. Two barriers were identified on the mainstem of Purrington Creek. These included a culvert at the upper Graton Road crossing (upstream of the intersection with Green Hill Road) that restricts passage for all life stages of salmonids (i.e., adults, residents, and juveniles) under all flow conditions. The second barrier, just upstream of a private driveway, provides 0% passage of juveniles; however, it does provide passage for adult salmonids and resident trout under most flow conditions. A third barrier was noted on Green Valley Creek at the upper Green Valley Road crossing, near the confluence with Harrison Creek. This barrier provides some passage for adults but restricts passage of juvenile salmonids and resident trout under all flow conditions. The upper Graton Road culvert has been identified as a high restoration priority by the County of Sonoma and is slated for retrofitting in 2010 or 2011.

Conclusion

The Upper Green Valley Creek watershed supports a wide variety and abundance of fish and wildlife species due in part to the diverse upland vegetation communities and riparian and instream habitats. Despite the recent decline in coho salmon in the watershed, it still supports key habitat elements and a number of special-status species including steelhead, California freshwater shrimp, northwestern pond turtle, northern spotted owl, and foothill yellow-legged frog. With immediate management actions including habitat restoration and changes in land use practices, conservation and enhancement of existing fish, wildlife, and plant communities is possible.

Biological Resources Recommendations

1. Protect and enhance the riparian corridor. Planting native vegetation will improve forested riparian buffer function by increasing buffer width, vegetation density, species complexity, and functional diversity in areas that have minimal cover and/or lack a multi-age, diverse canopy.
    a. Install riparian fencing along stream reaches accessed by livestock. Although currently there is limited livestock in the study area, if land uses should change to grazing based agriculture, then landowners should be encouraged to adopt conservation plans which follow rotational grazing paterns.
    b. Identify stream reaches with inadequate riparian cover and promote regeneration.
    c. Increase the width of the riparian corridor by increasing native plant diversity and providing shade to protect coldwater habitat and promote long term large wood recruitment.
    d. Utilize biotechnical techniques for stream bank stabilization projects.
    e. Educate landowners on the benefits and components of a healthy riparian corridor.
    f. Manage invasive species (see below).

2. Improve instream habitat.
    a. Install large wood structures in order to allow for habitat feature development and increased channel complexity and cover
    b. Educate landowners on the importance of leaving woody debris accumulations and downed trees.
    c. Remove or modify instream barriers.

3. Manage sediment delivery.
    a. Identify instream and upland sources of sediment.
    b. Treat potential sources including from streambank and upland gully erosion, and vineyard and road runoff.

4. Increase summer base flows.
    a. Reduce water withdrawals during summer rearing season and develop alternative sources of water.
    b. Improve riparian cover over the stream channel to reduce evaporation.
    c. Monitor streamflows.

   d. Educate landowners on water rights, water conservation, and conservation strategies designed to effectively use water

5. Monitor and improve water quality.
   a. See Water Quality recommendations section.

6. Protect and enhance upland habitats.
   a. Identify priority areas for protection including habitats that support special-status species (i.e., northern spotted owl, Sonoma tree vole) and habitat connectivity.
   b. Map Sudden Oak Death infestations within the watershed and educate landowners on forest management and spread prevention practices.
   c. Develop a fuel-load management plan with resource agencies to protect residents and natural ecosystem function.
   d. Work with Sonoma County Agricultural Preservation and Open Space District to promote easements and habitat enhancement projects on trusted lands.

7. Monitor and enhance habitat for salmonids.
   a. Support on-going monitoring efforts of salmonids populations within the watershed.
   b. Support coho salmon captive broodstock reintroductions.
   c. Implement instream and riparian habitat enhancement recommendations (see above).

8. Monitor and enhance habitat for wildlife.
   a. Collect baseline information on foothill yellow-legged frog, California freshwater shrimp, and northwestern pond turtle abundance and distribution within the watershed.
   b. Identify habitat protection and enhancement actions for special-status wildlife species.

9. Work with the agricultural community to promote on-farm habitat enhancement projects.
   a. Develop Pollinator Farm Plans.
   b. Develop Habitat Enhancement Program, including workshops and educational materials.

III. Management Considerations

Management Actions for Watershed Improvement

Land use cover and associated activities have been described in *Chapter II, Section A, Regional Setting* and impacts to water supply, fisheries, and aquatic habitat were explained in detail in *Chapter II, Section C, Hydrology and Instream Flow*, *Chapter II, Section D, Sediment Sources and Impacts*, and *Chapter II, Section F, Biological Setting*. This chapter will present management context, issues and actions associated with the two largest land uses in the Upper Green Valley Creek watershed – agriculture and rural residential.

Agricultural Sustainability

A little over 40% of the of the area of the Purrington Creek watershed and 22% of the Upper Green Valley Creek watershed is in agricultural land use (see *Map 4, Land Use and Land Cover in the Upper Green Valley and Purrington Creek Subwatersheds*) (CDFFPand USDA Forest Service 2002). Vineyards and orchards are the primary agricultural pursuits in this sub-watershed; these activities occur primarily at lower elevations, with vineyards and some livestock grazing along creeks (LMA 2003). Throughout the county, smaller farms on parcels from two to 10 acres are increasingly important economically. Grape production is one of a few crops that provide enough revenue to support small-scale farming operations (Sonoma County PRMD 2008).

Sonoma County ranks 6th in the state and 34th in the nation in agricultural productivity; the county recognizes that agriculture is an important economic, social, and historic resource and has taken measures to protect it (Sonoma County PRMD 2008a). The Sonoma County General Plan 2020 (Sonoma County PRMD 2008b) contains an Agricultural Resources Element (Element) that provides "policies, programs and measures that promote and protect the current and future needs of the agricultural industry." These provide guidelines for land use and other decisions in agricultural areas to protect existing agricultural practices. The Element also provides policies to assist in marketing and promotion of agricultural products and provide fair conditions for farm laborers. Policies AR-1e and AR-1g (*Table 11, Sonoma County General Plan 2020 Agricultural Resource Element: Policies that Promote Sustainability*) encourage and support sustainable agriculture, economic sustainability, and equitable treatment of farm workers.

The concept of sustainability is based upon the principle that management activities should meet the needs of the present without compromising future generations' ability to meet their needs. Agricultural sustainability incorporates three main goals: preservation of environmental systems and processes, economic profitability, and social and economic equity. Stewardship of both natural and human resources is important. Stewardship of natural resources includes preservation and rehabilitation of ecological processes such as groundwater recharge, pollutant sequestration, pollination services, and nutrient sequestration. Stewardship of human resources includes social issues such as health and housing conditions for laborers, the needs of rural communities, and long-term consumer health and safety. Many agricultural enterprises throughout the county practice stewardship of natural and human resources; such activities include unpaved roads maintenance and repair, riparian revegetation, and provision of agricultural employee housing.

Table 11. Sonoma County General Plan 2020 Agricultural Resources Element: Policies that Promote Sustainability

Policy AR-1e: Encourage and support farms and ranches, both large and small, that are seeking to implement programs that increase the sustainability of resources, conserve energy, and protect water and soil in order to bolster the local food economy, increase the viability of diverse family farms and improve the opportunities for farm workers.

Policy AR-1g: Support the activities of the Sonoma County Agricultural Commissioner's Office and the Farm Advisors Office in promoting sustainable and organic agricultural production and encourage the exploration of possibilities for production of other diverse agricultural products.

Conservation easements are a form of sustainability involving natural and human resources – they preserve ecological processes while supporting the area's agricultural heritage. Private conservation easements are identified in the Sonoma County General Plan 2020 as a mechanism for natural resource and agricultural lands preservation and enhancement in several General Plan policies (Sonoma County PRMD 2008b). Conservation easements can be acquired through Williamson Act contracts or through purchase. Williamson Act contracts involve the landowner agreeing to maintain land in agricultural or open space condition in exchange for reductions in tax obligations. About 300,000 acres of agricultural land are under Williamson Act contracts with almost 300,000 acres in fee title easements (Sonoma County PRMD 2008a). Much of the Upper Green Valley Creek watershed and some parcels along Purrington Creek have land under Williamson Act Land Contracts[11].

[11] The California Land Conservation Act of 1965--commonly referred to as the Williamson Act--enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. In return, landowners receive property tax assessments which are much lower than normal because they are based upon farming and open space uses as opposed to full market value. Local governments receive an annual subvention of forgone property tax revenues from the state via the Open Space Subvention Act of 1971.

Efforts to increase economic sustainability include local farmers' markets and development of specialty and niche products, such as organic crops and processed products. Organic farming increased in Sonoma County from 2007 to 2008; commodities produced included fruits, vegetables, winegrapes, meats, grain, and eggs (Sonoma County Office of the Agricultural Commissioner 2008). Sustainability practices such as organic growing can provide financial gain. A sustainable agriculture certification was recently developed by two industry trade groups. The Certified California Sustainable Winegrowing Program is based upon an existing Sustainable Winegrowing Program developed in 2001 (Broome and Warner 2008). Certification requires winegrape growers to implement farming practices contained within the *Code of Sustainable Winegrowing Practices: Self-assessment Workbook (2nd ed.)*. The workbook allows farmers to rank operations based on ecological, economic, and social-equity practices through an integrated set of 16 chapters and 227 criteria with metrics to evaluate performance. Two Sonoma County wineries were among the first seventeen certified sustainable in January 2010 (California SWA 2010). Other socially conscious certifications include USDA and California organic certification and Fish Friendly Farming® Certification. Fish Friendly Farming® is a certification program for agricultural properties managed to restore fish and wildlife habitat and improve water quality.

Not only do sustainable agricultural practices reap long-term local benefit, they also contribute toward implementation of statewide goals and programs. Implementation of sediment-control, water conservation, and other BMPs contributes toward attainment of Total Maximum Daily Load (TMDLs) allocations for sedimentation, temperature, and nutrients. Sustainable agricultural practices also contribute toward achievement of goals in the North Coast Regional Water Quality Control Board Watershed Management Initiative Chapter, the California Water Plan, the California Department of Fish and Game Coho Recovery Plan, the North Coast Integrated Regional Water Management Plan, and the Sonoma County Climate Action Plan.

Agricultural Best Management Practices

All Agricultural BMPs support one or more aspect of agricultural sustainability. BMPs for vineyard and ranching operations such as those in the Upper Green Valley and Purrington Creek subwatersheds include irrigation water management, spring frost protection, development and implementation of nutrient management plans, cover cropping, prescribed grazing, riparian fencing, and riparian re-vegetation. Resources for BMP planning and implementation are abundant at the federal, state, and local levels. The table below describes several sources for BMPs that have widespread acceptance and local applicability (*Table 12, Resources for Agricultural Management Measures*). Many of these management activities are supported through funding assistance from agencies such as the Natural Resources Conservation Service (NCRS), California Department of Fish and Game (CDFG), State Water Resources Control Board (SWRCB), Department of Water Resources (DWR) and the Sonoma County Energy Independence Program.

Table 12. Resources for Agricultural Management Measures

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. Section III contains information on Conservation Management Systems, which establish standards for sustained use. Detailed information about conservation practices is available in Section IV.	All aspects of agricultural operations – extensive list of irrigation water management measures.	http://efotg.nrcs.usda.gov/treemenuFS.aspx
US EPA National Management Measures to Control Nonpoint Source Pollution from Agriculture	This technical guidance document contains information on the best available, economically achievable means of reducing agricultural sources of pollution to surface and ground water.	All aspects of agricultural operations – nutrient, pesticide, grazing, and irrigation water management, erosion and sediment control, and animal feeding operations.	http://www.epa.gov/owow/nps/agmm/index.html
US Forest Service Pacific Southwest Region Water Quality Management for National Forest System Lands in California	This technical guidance document provides BMPs for timber management, road and building construction, mining, recreation, vegetation, fuels management, watershed management, and range management. Writtenfrom an agency perspective.	BMPs that address all aspects of USFS activities in California.	http://www.fs.fed.us/r5/publications/water_resources/waterquality/

Resource	Description	Focus	URL
California State Water Resources Control Board Nonpoint Source (NPS) Pollution Control Program	Multi-tool website that contains a Management Practices Miner Tool, a Management Measures Encyclopedia, and NPS Guidance in Specific Interest Areas. The Miner Tool is a compendium of documented NPS pollution management practices collected from scientific texts, journals, web sites, grant projects, and presentations. The Encyclopedia is a free online reference guide designed to facilitate understanding of NPS pollution control and provide quick access to resources available on the internet.	All aspects of agricultural operations including erosion and sediment control, animal waste, nutrient management, pest and weed management, grazing management, irrigation water management, groundwater protection, and education and outreach. Also contains management practices for Riparian Areas.	http://www.swrcb.ca.gov/water_issues/programs/nps/tools.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/6_wtld_vts.shtml
Sonoma County University of California Cooperative Extenion Farm & Ranch Stewardship Web Page	This web page contains several UC Agriculture and Natural Resources publications to reduce Nonpoint source pollution from agricultural operations.	Water quality management – NPS reduction, vegetative buffer strips, pesticide choice, greenhouse and nursery management.	http://cesonoma.ucdavis.edu/Watershed_Management923/Farm_&_Ranch_Stewardship.htm
Sonoma County Agricultural Division New Best Management Practices for Agricultural Erosion and Sediment Control Handbook Est. January 2010	BMPs presented in this document are specific to Sonoma County agricultural practices, soil types and weather conditions.	Control of water quality impacts from accelerated erosion from agricultural sources.	http://www.sonoma-county.org/agcomm/vesco.htm

Rural Residential

Rural residential is the primary land use in the Upper Green Valley Creek watershed; the Upper Green Valley Creek watershed is 36% rural residential while the Purrington Creek watershed is 54% rural residential (LMA 2003). Rural residential development is associated with watershed impacts including sedimentation, nutrient and pesticide runoff, spread of invasive species, and water supply issues, but management practices specific to the category “rural residential land use” have not been developed for Sonoma County. In Upper Green Valley Creek, rural residential development is likely contributing to reductions in summer water supply and increased sedimentation (see *Chapter II, Sections A and F*).

Many of the issues resulting from rural residential development are experienced in a more concentrated manner by urban areas – runoff, flood control, groundskeeping/chemical control, and onsite wastewater treatment systems. Therefore, much of the information about management measures to ameliorate conditions resulting from urbanization is applicable to rural residential land use, including water conservation measures.

An aspect of rural residential development not commonly found in urban areas is the construction, use, and maintenance of unpaved access roads. Roads are widely recognized as a significant source of sedimentation (see *Chapter II, Section D*). Management practices to reduce sedimentation from roads are available from many sources. The table below lists several sources for BMPs that have widespread acceptance and relevance to local rural residential issues (see *Table 13, Resources for Rural Residential Management Measures*).

Table 13. Resources for Rural Residential Management Measures

Resource	Description	Focus	URL
USDA Natural Resources Conservation Service electronic Field Office Technical Guide (eFOTG)	This comprehensive system contains information specifically developed for Sonoma County. The information is mostly intended for large landowners.	Natural resources conservation. Road and trail closure, habitat restoration.	http://efotg.nrcs.usda.gov/treemenuFS.aspx
USEPA National Management Measures to Control Nonpoint Source Pollution from Urban Areas	This document provides guidance regarding management measures to reduce nonpoint source pollution from urban activities.	This document provides implementation actions at the municipal scale.	http://www.epa.gov/owow/nps/urbanmm/index.html#06
USEPA Protecting Water Quality from Urban Runoff	This web page gives an overview of how individual dwellings impact a watershed and provides actions individuals can take to reduce NPS pollution.	Reducing NPS pollution through individual, municipal, and planning implementation activities.	http://www.epa.gov/owow/nps/urban_facts.html#runoff

Resource	Description	Focus	URL
California State Water Resources Control Board Nonpoint Source (NPS) Pollution Control Program	Multi-tool website that contains a Management Practices Miner Tool, a Management Measures Encyclopedia, and NPS Guidance in Specific Interest Areas. The Miner Tool is a compendium of documented NPS pollution management practices collected from scientific texts, journals, web sites, grant projects, and presentations. The Encyclopedia is a free online reference guide designed to facilitate understanding of NPS pollution control and provide quick access to resources available on the internet.	*Urban areas* – most information is agency level, however individual homeowners will find useful information for landscaping and water management. *Forestry* –homeowners may find useful information regarding road construction, reconstruction, and management. *Education and Outreach* – describes specific practices on the individual household scale.	http://www.swrcb.ca.gov/water_issues/programs/nps/tools.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/2_forest.shtml http://www.swrcb.ca.gov/water_issues/programs/nps/encyclopedia/3_3_edu.shtml
FishNet 4C Roads Manual	This document provides guidelines for county road maintenance to protect aquatic habitat and fisheries.	County road maintenance, some information applicable to homeowners.	http://www.fishnet4c.org/projects_roads_manual.html
Energy Independence A Sonoma County Program	This website rovides suggestions for residential and commercial improvements to conserve water and energy.	Financial incentives for individual homeowners to implement water and energy saving measures.	http://www.sonomacountyenergy.org/
Marin County Stormwater Pollution Prevention Program Resources About Pesticides and Alternatives Web Page	This web page contains several publications that provide homeowner – level information about less-toxic pesticides, gardening, and water quality.	Reducing toxins in the environment, providing least-toxic pest management to homeowners and schools.	http://www.mcstoppp.org/pesticides.htm
House and Garden Audit: Protecting Your Family's Health and Improving the Environment, A Guidebook to Reducing Your Impacts on the Environment	"The House and Garden Audit is for all people interested in learning how to protect their health while improving the environment."	Reducing toxins in the environment through individual homeowner effort.	http://www.laurelmarcusassociates.com/housegarden.html
Less-Toxic Pest Management: Pesticides and Water Pollution.	This is an informative brochure about homeowner contributions to water quality impairments.	Provides tips for homeowner reduction of pesticide use.	http://ourwaterourworld.org/Portals/0/documents/pdf/PesticidesWQ.pdf

Climate Change

Climate change is becoming an increasingly important concern for governments, businesses, NGOs, and individuals. The state of California and the county of Sonoma are recognized leaders in climate change research and adaptation strategies. Although many impacts of climate change are unknown, models have been developed based on past weather patterns that extrapolate current conditions into projections for the future. Most model simulations provide similar projections for conditions in Northern California; the region is expected to become warmer with only a slight, if any, decrease in precipitation with storms and other weather events likely to become more extreme.

Weather Predictions

The most current predictive simulations indicate that California will retain a Mediterranean weather pattern with cool wet winters and hot dry summers. Climate model simulations project warming by about 0.5- 2.0 °C during the first thirty years of this century; warming during the last thirty years is expected to increase by 1.5- 5.8 °C (Cayan et al. 2006). With this warming, models predict that heat waves will increase in frequency, magnitude, and duration from the historical period. Where they now occur mainly in July and August, they are likely to occur any time from June through September. Conversely, freezing spells are projected to become less frequent, even in locations such as the Russian River watershed, where they are currently nearly a yearly event (Mastrandrea et al. 2009).

Variable annual precipitation and continued vulnerability to drought are predicted throughout the next century. Six model-driven climate simulations indicate only slight if any precipitation decreases for Northern California, but even if precipitation levels remain at current levels, increased temperatures are likely to lead to evaporative water loss and contribute toward drier conditions overall. In addition to increased variability in weather events from storms to heat waves, weather events are expected to become more intense – for example, heat waves will last for increasingly long blocks of time and rainfall events, though less frequent, are likely to be more intense. These changing patterns will have impacts from increased runoff and flooding during storms to increased wildfires, to increased heat-related deaths.

Potential Vegetation and Crop Changes

Climate change will affect natural ecosystems and the distribution of native plant species. Of the more than 5,500 native plant species endemic to California, about two-thirds are projected to experience range reductions of over 80% by the end of the century (Loarie et al. 2008). The rate at which climate change is expected to affect different ecosystems – that is, the rate that the biological components of these systems can migrate to remain within a preferred temperature zone – varies with topography. Mountainous habitats are expected to adjust to climate change with a gradual migration, since a small move up or down slope can result in a large temperature change. Change will be slowest in mountainous biomes such as tropical, subtropical, and temperate coniferous forests and montane grasslands. Montane landscapes are likely to shelter both plant and animal species into the next century. Additionally, complex topography is likely to provide a spatial buffer for climate change. Because much of the Upper Green Valley subwatershed is mountainous, effects of climate change on remaining natural habitat are likely to occur slightly more slowly than within the Atascadero-Lower Green Valley floodplain.

Increased temperatures and precipitation changes associated with climate change may have important effects on agricultural crops. Changes in water availability, temperature averages and maxima and minima, pest and weed ranges, and growing season length are all likely to impact crop productivity and thus, distribution. Some crop yields are expected to increase while other yields may decrease (CAT 2009). Changes in weather patterns associated with climate change may also alter the phenology of crop plants – the timing of flowering, fruit set, and senescence. These changes may disrupt pollination processes if crop phenology becomes unsynchronized with pollinator life cycles. Pathogens and parasite populations are expected to proliferate in the warmer winters and higher overall temperatures.

On a physiologic basis, elevated increased CO_2 availability gives plants a growth spurt, but this growth is not sustained. Increased CO_2 availability causes stomata – small pores on the leaf surface – to close, which can save water by reducing transpiration at the leaf scale. On the field scale, however, more water will be used by larger plants growing in a warmer climate. Indirect effects of increased CO2 include lengthening of the growing (and transpiration) seasons, stimulation of weed growth, and an increase in insect pest populations. Many crops, including wine grapes, have minimum chill requirements – the number of hours below a certain temperature that will result in plant dormancy and fruit set the subsequent season. With warmer winters, the minimum number of hours at chilling temperature may not be reached. Long-term climate records across California show a negative trend in winter chill accumulation; models show that by 2100, the occurrence of adequate winter chill may be lost for many fruit species unless cultivars requiring less winter chill are developed (Baldocchi and Wong 2006). California losses are estimated up to 40 % for wine, table grapes, and similar commodities with significant regional variation in losses (Karl et al. 2009).

Salmonid Habitat

Salmonid habitat will also be impacted by climate change. Summer instream flows are projected to decline with the greatest drop during June and July (Shaw et al. 2009). Winter flows are expected to increase by 20- 60% due to increases in extreme precipitation events, which could result in increased scouring of redds. Warmer water temperatures may cause egg hatching earlier in the year, leading to smaller young that are vulnerable to predators. Additionally, earlier hatching dates may cause the fry to become unsynchronized with insect prey life cycles. Warmer waters also increase metabolic function, increasing the need for foraging, and diseases and parasites tend to thrive with higher temperature (Karl et al. 2009).

Ocean conditions will also experience changes. Coastal ocean waters will warm more quickly than deep ocean waters; coastal estuaries and other ecosystems will experience effects of increased temperature including reduced dissolved oxygen levels, shifts in the geographic range of species, and unforeseeable changes to the food web. Nutrient cycling is affected by large weather patterns such as El Niño, Santa Ana winds, ocean temperatures, and ocean currents. Warmer water temperatures combined with changes to nutrient availability could lead to geographic range shifts and changes to fish population numbers. Sea level rise is likely to affect estuarine habitat, which could potentially impact vulnerable life stages of outmigrating coho and steelhead. Ocean acidification, which increases with increasing atmospheric CO_2 concentrations, limits growth and survival of organisms that serve as a basis for marine food chains, potentially affecting the ocean phase of the salmonid life cycle. Acidification can also impact fertilization, development, and metabolic function of marine species and change the toxicity of chemicals and other substances and the biological availability of nutrients and other compounds (CNRA 2009).

Other Potential Impacts

Additional impacts of the changing climate include increased electricity demand, reduced water quality, increased air pollution and airborne allergens, climate-sensitive infectious diseases, illness and death due to extreme weather events such as heat waves, storms, floods, or wildfires. Groups including children, the elderly, and poor are most vulnerable to the range of climate-related health effects. Native American populations are among the most vulnerable because they are often closely linked to a specific piece of land due to the established reservation system. While many of these impacts will occur on a larger scale than this watershed plan, some, such as impacts to agriculture and salmonid habitat, are likely to be relevant to resource management in the Upper Green Valley watershed.

IV. Looking Forward

Implementation Actions

Targeted actions for the Upper Green Valley Watershed Management Plan were developed to contribute toward coho recovery and agricultural sustainability in the Upper Green Valley watershed. Recommendations specific to archaeology, sediment, water quality, hydrology, and biology are contained within *Section XX, Watershed Description*. The recommendations are as specific as possible given the abbreviated planning time-frame and are summarized in the table below.

Table 14. Upper Green Valley Watershed Management Plan Actions

Technical Assessment	
Recommendation	**Actions**
Streamflow and Water Needs	
SWN1: Develop an Upper Green Valley Watershed water conservation program and task force	SWN1a: Build upon existing water conservation education efforts SWN1b: Assist agricultural producers in acquiring support through NRCS and RCD programs to develop water conservation measures. SWN1c: Conduct watershed-wide workshops and encourage water conservation practices
SWN2: Develop alternative water storage systems to reduce the dependency on diversions	SWN2a: Rainwater catchment systems SWN2b: Review timing of diversions SWN2c: Develop off-channel ponds and distribution systems for agricultural producers
SWN3: Groundwater Study	SWN3a: Funding for recharge and groundwater study

SWN4: Graton CSD Tertiary Water Re-use for Ag	SWN4a: Feasibility analysis
SWN5: Monitor effectiveness of water supply enhancement projects	SWN5a: Continue the streamflow monitoring program SWN5b: Install staff plates on private property monitored by landowners
Water Quality	
WQ1: Surface water quality monitoring should continue with enhanced equipment at an increased number of sites	WQ1a: Parameters measured to include continuous stream discharge, temperature, DO, TSS, and nutrients
WQ2: Develop goals and monitoring/analysis framework	WQ2a: Develop an SWRCB approved Monitoring and Assessment Plan and Quality Assurance Project Plan to guide monitoring activities WQ2b: Incorporate other data sources (ie CCWI and UCCE) WQ2c: Obtain repeat TSS measurements during periods of high turbidity to determine duration of high turbidity WQ2d: Conduct bioassessment using benthic macroinvertebrate assemblages as an indicator of aquatic habitat quality WQ2e: Conduct bioassessment using algal communities as an indicator of nutrient impacts to aquatic habitat quality in stream reaches where algae are consistently present.
WQ3: Implementation of Management Measures to Decrease Sediment Loads	WQ3a: Work with landowners to implement sediment reduction measures WQ3b: Implement priority road related sediment reduction measures

WQ4: Implementation of BMPs to decrease summer water temperatures, increase flow, and improve DO	WQ4a: Maintain and enhance summer season flows WQ4b: Increase riparian cover
WQ5: Assess and manage pollutant delivery	WQ5a: Conduct testing for high liklihood pollutants (ie pesticide, sewage, fertilizer, oil/gas, pharmaceuticals) to establish presence or absence WQ5b: Educate community on pollutants of concern and how to prevent water contamination WQ5c: Support AGVCWC in creek clean ups (KeepSonomaClean.org) WQ5d: Work with landowners and appropriate agencies to ensure proper disposal of toxics
WQ6: Manage stormwater	WQ6a: Disconnect impervious surfaces WQ6b: Keep stormwater onsite
Sediment and Erosion	
Sed1: Assess watershed and reach-scale geomorphic processes	Sed 1a: Identify extent, causes, and impacts of channel incision Sed1b: Identify extent, causes, and impacts of aggradation in the Korbel Reach of Upper Green Valley Creek (include reach downstream of Atascadero confluence)
Sed2: Expand Assessment of Erosion and Sediment Delivery	Sed2a: Plan and conduct a second phase assessment of private, unpaved roads Sed2b: Assess the extent, severity and impacts of surface erosion on ag lands Sed2c: Expand and continue assessment of non-road-related bank and upland erosion sites
Sed3: Implement private roads erosion reduction program	Sed3a: Implement prioritized road related erosion sites

Sed4: Reduce or prevent streambank and gully erosion	Sed 4a: Stabilize streambanks using bioengineering techniques Sed 4b: Implement restoration treatments at selected bank and upland erosion sites
Sed5: Implement agricultural BMPs	Sed5a: If there is active grazing, then resources should be made available to the operator to install riparian pasture fencing, develop off-channel water sources, and revegetate the riparian corridor. Sed5b: Improve soil and irrigation practices to prevent erosion, build soil fertility, and increase water-holding capacity through use of conservation tillage, crop rotations, fallowing, cover crops, and increasing fertilizer use efficiency.
Biological Resources	
Bio1: Protect and enhance riparian and instream habitat	Bio1a: Enhance instream habitat complexity; more shelter, large woody structures (LWS); Outreach and education effort on benefit of LWS Bio1b: Develop a plan to identify and remove or modify fish passage barriers Bio 1c: Support an outreach effort to protect riparian corridors from development Bio1d: Implement riparian habitat restoration projects
Bio2: Uplands habitat	Bio2a: Increase and improve off channel habitat Bio2b:Mapping vegetation
Bio3: Work with the agricultural community to promote on-farm habitat enhancement projects	Bio3a: Develop Pollinator Farm Plans

	Bio 3b: Develop On-Farm Habitat Enhancement Program, including workshops and educational materials
Bio 4: Biological Resources Monitoring	Bio 4a: Distribution, abundance and limiting factors of non fish species Bio4b: Monitor % vegetative cover along stream corridors Bio4c: Conduct bird surveys as part of project effectiveness evaluations
Bio5: Work with Sonoma County Agricultural Preservation and Open Space District to promote easements and habitat enhancement projects on land trusted properties	Bio5a:Assist producers in participating in programs that provide additional capital to support agricultural land values, such as conservation easements through the Williamson Act. Bio5b:Coordinate with NRCS staff to assist producers in developing Farm Bill program contracts
Bio 6: Develop an invasive species eradication program	Bio6a: Work with MSWMA and BAEDN to map the extent of invasive plant populations Bio6bDevelop an invasive species management strategy Bio6c:Support the agricultural community in adopting grazing management plans that promote grassland biodiveristy
Archaeological Resources	
Arch1: Take steps to ensure the preservation of all archaeological resources in the watershed.	Arch1a: Known resources assessment by a professional archaeologist Arch1b: Specific project area sites should be assessed by a professional archaeologist to avoid disturbance of previously unidentified cultural resources

	Arch1c: If archaeological resources are encountered during construction, work should be temporarily halted near the discovered materials and workers should avoid altering the materials and their context until a qualified professional archaeologist has been consulted. Any identified cultural resources should be recorded on DPR 523 historic resource recordation forms

Implementation Actions

The following section provides a framework to bring the Plan recommendations into existence. It identifies who would implement actions by when and addresses the value of partnerships to engage watershed residents and support Gold Ridge RCD in meeting watershed goals. This chapter presents an overall strategy for keeping watershed residents and other stakeholders current with new information and management practices.

Project selection criteria and process

Gold Ridge RCD is taking the lead for implementing many of the Plan actions. The RCD has been working for nearly 70 years to help coordinate funding resources with landowner needs and will use this plan to solicit and distribute additional funding for the Upper Green Valley Watershed. The following process describes how the RCD will assess and select projects. It recognizes that different funding sources have varying requirements and that additional selection criteria may be needed to fit specific funding programs as well as fulfill resource protection and enhancement goals. Table 15 provides a summary of implementation projects for the Phase I UGVWMP.

Proposed project selection criteria could include:

1. Improvement to water quality
2. Enhancement of summer streamflow
3. Protection, restoration, or enhancement of one or more natural processes [Examples include restoration of riparian vegetation that will provide shade, LWD, and bank stability over many years; modification of stream crossings to allow sediment transport and movement of aquatic species; and removal of non-native invasive plants.]
4. Improvement of habitat connectivity

5. Support of habitat for a diversity of plant/animal species or protection of vital habitat features for special status watershed wildlife species
6. Addressing causes as well as or instead of symptoms
7. Strong landowner commitment
8. "Pioneer" project that will promote additional projects
9. Technically sound and effective design solution is feasible
10. Cost is reasonable for benefits

Table 15. Phase I: Implementation Summary

Project Name	Project Description	Plan Recommendation that Project Implements	Time Frame	Cost
Thomas Creek Ranch Off-Channel Coho Habitat Design	A case study will be developed at Thomas Creek Ranch to assess the viability and design options for introducing off channel rearing habitat in the lower reach of Green Valley Creek. Design guidelines and project locations will also be provided for improving rearing habitat in upper Green Valley Creek. The property's location within the watershed and the geomorphic attributes of the site suggest that this reach may have once supported complex off-channel rearing habitat. Detailed surveying, hydraulic modeling, and up to three design schematics will be developed for the feasibility analysis. Design opportunities and constraints will be assessed, and a preferred alternative chosen. The preferred alternative will be designed to 70%, a preliminary cost estimate developed, and CEQA documentation completed.	**Biological Resources Recommendation 2:** Improve Instream Habitat **Biological Resources Recommendation 7:** Monitor and Enhance Habitat for Salmonids **Action Bio2:** Increase and improve off channel habitat	1 – 3 years	$50,000- $75,000
Korbel Vineyard Geomorphic Assessment and Project Design[12]	Gold Ridge RCD will undertake a geomorphic assessment of the aggrading reach and upstream processes to identify and evaluate factors influencing aggradation. Working with partner organizations, GRRCD will synthesize available digital, historic, aerial photo and other data, conduct field surveys of both the aggrading and	**Sediment Sources and Impacts Recommendation 1:** Assess watershed and reach-scale geomorphic processes **Sediment Sources and Impacts**	1 – 3 years	$50,000 -$75,000

[12] This project has been identified by the NOAA Restoration Center, the CA Department of Fish and Game, the UCCE Coho Broodstock Programs, and landowners as being of the highest priority for implementation. This is due to flooding concerns, potential fish stranding, sedimentation, and potential hazards to public safety.

Table 15. Phase I: Implementation Summary

Project Name	Project Description	Plan Recommendation that Project Implements	Time Frame	Cost
	upstream reaches, model stream hydrology and hydraulics, and evaluate sediment sources and flows to assess potential influences both within the reach and in the upstream channel and watershed area. The goals of the study will be to determine both the proximate and ultimate causes of aggradation within the reach, assess both historic and recent rates of aggradation, and recommend a range of treatment options to minimize the possibility of fish stranding, alleviate flooding, and reduce potential hazards to public safety along Green Valley Road Detailed surveying, hydraulic modeling, and up to three design schematics will be developed for the feasibility analysis. Design opportunities and constraints will be assessed, and a preferred alternative chosen. The preferred alternative will be designed to 70%, a preliminary cost estimate developed, and CEQA documentation completed.	**Recommendation 3:** Develop a program to arrest channel incision through grade control. **Biological Resources Recommendation 7:** Monitor and Enhance Habitat for Salmonids **Action Bio1:** Protect and enhance riparian and instream habitat		
Green Valley Creek Channel Stabilization and Coho Habitat Enhancement	The proposed project will improve rearing and spawning habitat for coho salmon and steelhead trout in Green Valley Creek This will be accomplished through bank stabilization projects and the installation of instream habitat improvement structures to increase habitat complexity.	**Biological Resources Recommendation 2:** Improve Instream Habitat **Biological Resources Recommendation 3:** Manage Sediment Delivery **Action Bio1:** Protect and enhance riparian and instream habitat	1-3 years	$45,000

Table 15. Phase I: Implementation Summary

Project Name	Project Description	Plan Recommendation that Project Implements	Time Frame	Cost
Green Valley Roads Implementation	Implement high and moderate road erosion sites, as previously assessed through CDFG grant P0530403 (GVC Roads Assessment). The project will implement treatments for priority road erosion sites as documented in the PWA Report, *PWA Report 08073301, March 2008.* According to the PWA report, estimated sediment savings from proposed work on the treatment sites and hydrologically connected road, ditch and cutbank surfaces is approximately 4,845 cubic yards.	**Sediment Sources and Impacts Recommendation 4:** Reduce anthropogenic erosion and sediment delivery. **Action WQ3:** Implementation of Management Measures to Decrease Sediment Loads **Action Sed3:** Implement private roads erosion reduction program	1 – 5 years	$300,000 - $400,000
Water Supply, Demand and Conservation Education Program	Educate rural residential, agricultural, and business owners on water conservation strategies designed to fit their particular land use, while at the same time maximizing the tools currently available to determine site specific water needs and support community water supply sustainability.	**Biological Resources Recommendation 1:** Improve Summer Baseflows **Action SWN1:** Develop an Upper Green Valley Watershed water conservation program and task force **Action Bio3:** Work with the agricultural community to promote on-farm habitat enhancement projects	1 - 2	$25,000

Funding

Although some projects are already underway in the Upper Green Valley Creek with other non-profit organizations, additional funding is needed to fully implement the Plan. GRRCD will actively seek funding on behalf of interested landowners. Non-profit project partners are also eligible to receive funding from many state and federal agencies, as well as from foundations. In addition to help from GRRCD and other project partners, eligible private landowners have direct access to federal cost share programs through NRCS and USFWS, state cost-share assistance from CDF, and low-interest loans through the Sonoma County Energy Independence Program (SCEIP). Table 16 identifies funding sources for Plan implementation.

Table 16. Local, State, Federal, and Foundation Funding Sources.[13]

Funding Entity	Program
Local Sources	
Sonoma County	Energy Independence Program (SCEIP). Provides low-interest loans to private and commercial property owners for water and energy conservation measures. Loans are repaid through voluntary property tax assessments.
Sonoma County Open Space and Agricultural Preservation District	Protects land through purchasing development rights and acquiring easements. Project selection is based on consistency with the current Acquisition Plan and available funding.

[13] This table was created by Liza Prunuske, (Prunuske Chatham, Inc,) for the Salmon Creek Integrated Coastal Watershed Management Plan, 2010

State Agencies	
State Water Resources Control Board with North Coast Regional Water Quality Control Board (Regional Board)	319(h) Nonpoint Source. Funding is through the Environmental Protection Agency (EPA) and is intended for improving water quality through projects that address TMDL implementation or problems to streams, bays, rivers, and lakes that have been listed as impaired. Small Community Wastewater Grant Program. The program provides assistance for planning, design, and construction of publicly-owned wastewater treatment and collection. Clean Water Revolving Loan Fund. Provides low-interest loans for stormwater and wastewater treatment, and implementation of projects to reduce nonpoint source pollution. Integrated Regional Water Management Grant Program. The intention is to integrate sustainable and reliable water supply, better water quality, stormwater management, environmental stewardship, and a strong economy.
California Department of Fish and Game (CDFG)	Fisheries Restoration Grant Program. This is a long-standing competitive grant program funded by both state and federal sources. Funding can be used for planning, barrier removal, habitat restoration, monitoring, public involvement, maintenance, and education for projects consistent with current CDFG priorities.
State Coastal Conservancy	Funding is primarily through voter-approved bond funds. Provides funding for projects to purchase, protect, restore, and enhance coastal resources.
Department of Water Resources (DWR)	Groundwater program. Includes a range of grants for groundwater monitoring and management. Integrated Regional Water Management Grant Program. DWR administers IRWM grants through Proposition 84. DWR also manages many other grant and loan programs.

California Department of Forestry (CDF)	Fire Prevention Program. Firesafe landscaping for homeowners and communities.
	California Forest Improvement Program (CFIP). Provides cost-share assistance to private landowners, RCDs, and non-profit groups for planning, planting, fish and wildlife habitat improvement, and land conservation practices.
California Department of Public Health	Safe Drinking Water State Revolving Fund. Provides funding to correct public water system deficiencies. Selection is based upon a prioritized funding approach that addresses public health risks, compliance with requirements of the Safe Drinking Water Act, and need on a per household affordability basis.
Federal Agencies	
Environmental Protection Agency (EPA)	The Environmental Protection Agency website features an extensive catalog, sorted by keyword (e.g., invasive species, monitoring, land acquisition, watershed management), of federal funding sources for watershed protection (http://cfpub.epa.gov/fedfund/keyword_list.cfm).
US Fish and Wildlife Service	Cooperative Conservation Initiative. Provides cost-share assistance to private landowners to restore natural resources and establish or expand wildlife habitat.
National Marine Fisheries Service (NMFS)	Open Rivers Initiative provides funding and technical expertise for community-driven, small dam and river barrier removals. NMFS provide funding for multi-year regional habitat restoration partnerships including watershed-scale projects that yield significant ecological and socioeconomic benefits.

	National Association of Counties and NMFS are partners in the Coastal Counties Restoration Initiative (CCRI). CCRI encourages innovative, county led or supported projects that restore important marine and coastal habitats and living resources. These projects also develop the capacity of county governments, citizens groups and other organizations to conduct community-based restoration that will enhance local watershed-based resource management and promote stewardship.
Natural Resource Conservation Service (NRCS)	NRCS manages a suite of programs to provide technical and cost-share assistance to implement conservation practices, primarily for owners of land in agricultural production.
	The Healthy Forest Reserve Program is a voluntary program established for the purpose of restoring and enhancing forest ecosystems. It can provide cost-share for conservation practices, a conservation easement in exchange for market value, and Safe Harbor from future regulatory restrictions under the Endangered Species Act.
Other Sources:	
National Fish and Wildlife Foundation (NFWF)	NFWF has a number of programs that could apply including:
	Native Plant Conservation Initiative supports projects that protect, enhance, and/or restore native plant communities.
	Marine and Coastal Conservation Initiative includes a priority to build "the capacity of local communities and watershed associations to participate in local stewardship projects that contribute to and build public support for broader restoration goals".

Private foundations	Many private foundations support conservation and restoration efforts. Some foundations limit their funding to non-profit organizations, but others also fund special districts such as public schools and RCDs.

Next Steps

GRRCD is committed to watershed planning in the Upper Green Valley watershed and has secured funding from CDFG for continuation of this planning effort. This funding will provide for greater stakeholder outreach, more sediment source assessments, and implementation of prioritized sediment reduction projects. Additionally, GRRCD is participating in the Russian River Coho Water Resources Partnership, which identified Green Valley Creek as one of 5 first priority streams important for salmonid recovery in the Russian River basin. The hydrology analysis that was started in this iteration of the Upper Green Valley watershed planning process will continue in the Coho Water Resources Partnership. Water quality monitoring will continue with grab sampling on a monthly basis until funding is secured to implement continuous water quality monitoring of temperature, DO, turbidity, and flow. Until continuous monitoring is initiated, GRRCD will coordinate monthly collection dates with the Atascadero Green Valley Creek Watershed Group / Community Clean Water Institute water quality monitoring effort.

This Upper Green Valley Watershed Management Plan is intended to serve as a guiding document for future planning efforts in the Upper Green Valley watershed. The Upper Green Valley Watershed planning approach involved an open, inclusive process, identification and recruitment of technical experts, voluntary landowner participation, and a commitment to cooperative problem-solving. The main themes in this watershed management plan are the protection of key coho habitat and creation of agricultural sustainability through education and implementation of site-specific projects and BMPs. As a "living document," this plan is expected to change, but the process utilized in plan development and the themes that guided plan development are expected to remain relevant for future iterations.

V. Plan Limitations

This plan represents the most current data available regarding the Upper Green Valley watershed; it has been developed using existing literature and data from field investigations conducted during the past year. In spite of every effort to develop a comprehensive, accurate plan, however, there are funding, time, and data constraints. With greater funding, more field assessments would have been possible, allowing for more detailed roads and geomorphologic assessments and an archaeologic assessment. These assessments would provide a greater understanding of riparian processes and impacts from past and present human activities.

This plan was developed during a seven-month period. A greater amount of time, in addition to allowing for more data collection, would have enabled the GRRCD to perform more outreach, resulting in greater landowner participation in roads and stream surveys and more opportunity for stakeholder input. Additional field data would provide a more thorough understanding of the watershed and greater certainty when prioritizing projects for implementation.

While recognizing these constraints, it is important to recognize that this plan is intended as a "living document." This plan is the first iteration of a plan intended to enable all willing landowners to improve land use practices, ameliorate legacy impacts, restore riparian function, and improve salmonid habitat and other wildlife habitat.

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VII. Appendices

Appendix 1. Public Comment and GRRCD Response

1. The plan lacks a sense of urgency in the face of imminent coho salmon extinction

   It is the intent of GRRCD to empower and facilitate landowner action using the best available scientific and technological information. GRRCD is committed to providing recent, relevant information as neutrally as possible in order to inform stakeholder land use decisions. GRRCD is a non-regulatory body that has forged important and long lasting relationships with watershed landowners through a neutral (non-regulatory, non-advocacy) and collaborative approach. Thus, a neutral, (rather than urgent) tone was utilized when discussing coho habitat reduction, in order to avoid perception of advocacy.

   To ensure that coho salmon extinction – as recognized by state and federal agencies – was addressed, the following text was added to the Overview and Purpose Section of the Plan:

   > **Over the years, several studies evaluating habitat impairments and potential limiting factors to salmonid survival have indicated a general decline in habitat quality in Upper Green Valley and Purrington creeks (CDFG 1995, 2006, Laurel Marcus and Associates 2002, Merritt Smith 2003). This decline in local habitat quality occurs at a time when coho salmon populations in the region are in danger of extinction (Weitkamp et al. 1995), with the Russian River system experiencing a "catastrophic reduction in coho salmon distribution (CDFG 2002)." Timely action to improve habitat conditions is necessary to increase salmonid populations: Purrington Creek watershed is one of several "core areas" for implementation of priority recovery actions identified in National Marine Fisheries Service's (NMFS) recently released *Recovery Plan for the Evolutionarily Significant Unit of Central California Coast Coho Salmon* (2010).**

   It should be noted that embarking upon this planning effort during a time of economic and political uncertainty is GRRCD's response to the critical need for action to address dwindling coho salmon populations in the Russian River system. Far from ignoring imminent coho salmon extinction, this plan is GRRCD's response to the threat – it gathers and disseminates information and offers opportunity for voluntary participation in salmonid habitat restoration efforts.

2. Listed implementation projects do not give the entire picture. Projects slated for future implementation projects should be prioritized as follows:

a. Enhancement of streamflow

b. Improvement to water quality
c. Protection, restoration or enhancement of one or more natural processes

Agreed. Please see attached implementation spreadsheet.

3. Projects that address low stream flow should be implemented now, rather than waiting for additional planning efforts to conclude.

GRRCD and their partners in the Russian River Coho Water Resources Partnership (OAEC, TU, CEMAR, Sotoyome RCD and UCCE) are working on the development of streamflow augmentation and water storage projects. At least one, if not more, projects that address frost protection and low streamflow in the GVC Watershed will be implemented in 2011.

4. Actions should be taken to prevent pesticides from entering streams

Please see Comment 7, which addresses pesticide monitoring concerns for general background information regarding pesticides.

GRRCD has as its primary mission landowner assistance; it implements conservation projects in partnership with willing landowners and provides technical and funding information for conservation project implementation. When working with landowners to prevent pesticide runoff, implementation projects could involve two approaches: 1) reduction in toxic pesticide use and 2) improvement of stormwater runoff systems. In this situation, the role of GRRCD is to provide technical guidance for implementation of BMPs to reduce pesticide use and filter stormwater, and to provide a conduit through which available funding can be distributed for individual landowner efforts.

There are a number of guidance documents available that detail best management practices (BMPs) for the application of pesticides as well as information about less toxic alternatives to commonly applied pesticides. Selected resources are:

- **Resources About Pesticides and Alternatives, Marin County Storm Water Pollution Prevention Program; http://www.mcstoppp.org/pesticides.htm**
- **House and Garden Audit: Protecting Your Family's Health and Improving the Environment, A Guidebook to Reducing Your Impacts on the Environment, Laurel Marcus and Associates; http://www.laurelmarcusassociates.com/housegarden.html**
- **Less-Toxic Pest Management, Pesticides and Water Pollution; http://ourwaterourworld.org/Portals/0/documents/pdf/PesticidesWQ.pdf**

These resources have been included in *Table 13. Resources for Rural Residential Management Measures*. *Table 12. Resources for Agricultural Management Measures* contains several resources addressing BMPs for pesticide runoff reduction; additions will be considered for future iterations of this UGVWMP.

5. The preservation of sustainable agriculture is not an appropriate goal for this plan (ie it is a solution, but not a goal). Coho recovery should be the only recognized goal of this plan.

   Funding for this plan includes sources other than those just targeted for the recovery of coho salmon. Residents of Sonoma County have repeatedly shown strong support for preserving local family farming traditions, voting to fund agricultural land preservation and attending over a dozen popular farmers' markets throughout the county. Multiple objectives laid out in the county's General Plan relate directly to agricultural preservation and sustainability, with the stated goal "to ensure the stability and productivity of the County's agricultural lands and industries" (PRMD, 2008a). These include assistance with marketing and promotion of agricultural products, protection of farmland from urban encroachment, and the development of agricultural support services. A second section addresses the goal "to preserve the unique rural and natural character" of the county and "protect and enhance the County's natural habitats and diverse plant and animal communities," riparian corridors, soils, and forestry resources. Large parcels provide valuable wildlife habitat and open space, while contributing to the watershed's rural character. Agricultural landowners need to be supported to sustain viable operations in order to maintain these large parcels. While updated zoning laws prohibit subdivision in some areas, the affected landowners are struggling to maintain financially viable operations to preserve these working landscapes.

6. Engage identified sustainable agricultural business partners in the planning effort

   Agreed. In Phase II, the planning team will work with vineyard operators to reduce water use and we will measure success by working toward the following implementation actions:

   - **Provide workshops and technical support for vineyard dry-farming**
   - **Assist vineyard operators in acquiring support through NRCS and GRRCD programs implement water conservation practices**
   - **Work with vineyard operators to understand and remain a step ahead of impending groundwater and instream flow regulations.**
   - **Educate the local community on vineyard practices.**

   GRRCD recognizes that grapes are not the only source of agriculture in the Green Valley Creek Watershed. Partners will also engage other agricultural groups, such as Community Alliance for Family Farmers, in ongoing planning fforts.

7. IPM, herbicide, and pesticide water monitoring should be added to the list of WQ recommendations.

   Since the UGVWMP constitutes the first phase of the water management planning effort, it is intended as a broad inventory of existing efforts and recommendations for future planning goals. The second phase of the planning process will include the development of targeted actions and strategies to inventory and improve watershed conditions over a broader geographic region. Expanded water and aquatic habitat quality monitoring will be one of the tools employed to verify that watershed conditions continue to support resident's quality of life, agriculture and ecosystem needs, including those of fish and other aquatic organisms at all life stages.

   Pesticide monitoring

   Through the public comment process of the UGVWMP, Phase I, concerns about pesticide and herbicide pollution were raised. It was requested that pesticide and herbicide monitoring be added to future water quality monitoring efforts.

   Pesticide is a broad term that includes a variety of substances intended for the prevention, destruction, repulsion, or mitigation of a targeted pest. Pesticides include herbicides, fungicides, insecticides and rodenticides. Most pesticides contain an active ingredient or agent and additional ingredients to assist with the application, dispersion, stabilization, adhesion and penetration of the agent. Pesticides are used in many settings and are routinely applied in both urban and rural areas by both homeowners and agricultural producers.

   By their very nature, most pesticides have the potential to create some risk of harm to humans, animals, and/or the environment because they are designed to kill or otherwise adversely affect living organisms. The environmental risk of any pesticide depends on a number of factors including the toxicity of the substance, the method, timing and volume of application and the conditions during application (such as precipitation and wind).

   In the US, pesticide use and application is regulated by the EPA. As a result of many studies, the EPA developed toxicity ratings, which are required for every registered pesticide. Some pesticides are considered extremely hazardous and their use is restricted to certified users. It can be difficult and extremely expensive to test for all of these pesticides at multiple locations, so tests that focus on the existing aquatic habitat's ability to support sensitive organisms, such as toxicity testing, can be employed as a first step to identifying whether there is a potential impact.

Future monitoring recommendations will include strategies to investigate whether common household and agricultural pesticides are present at levels that can harm sensitive organisms and impact the biological integrity of Green Valley Creek and its tributaries. The monitoring plan will be guided and overseen by the Technical Advisory Committee.

8. Flow monitoring, including the dissemination of real-time gauge data, should be a priority for any future monitoring efforts.

   Two flow gauges have been installed in the GVC watershed - One in Purrington Creek and on in Upper GVC. Information from these gauges can be found at the Coho Water Resources Partnership website at www.cohopartnership.org

9. Rural residential management measures should contain actions that improve community participation in creek restoration.

   There are many ways for individual rural landowners to implement actions beneficial to salmonid habitat, such as increasing landscape irrigation efficiency and reducing pesticide use. Management measures – or Best Management Practices (BMPs) – have been developed for these activities in order to optimize results per unit of effort. These management practices are often timeworn and usually vetted prior to inclusion in agency lists of BMP recommendations. GRRCD has added a reference to table 12 that contains management actions for creek bank maintenance (Home and Garden Audit); however, riparian restoration is generally considered a BMP for nonpoint source pollution prevention rather than a process requiring BMPs. Investigation of BMPs for riparian restoration will be incorporated into the next planning phase of the UGVWMP.

   GRRCD efforts to improve community participation all aspects of watershed planning – including creek restoration – are ongoing and will continue into the next planning phase. The next planning phase is scheduled to begin during summer 2010 and span three years, allowing for extended public outreach.

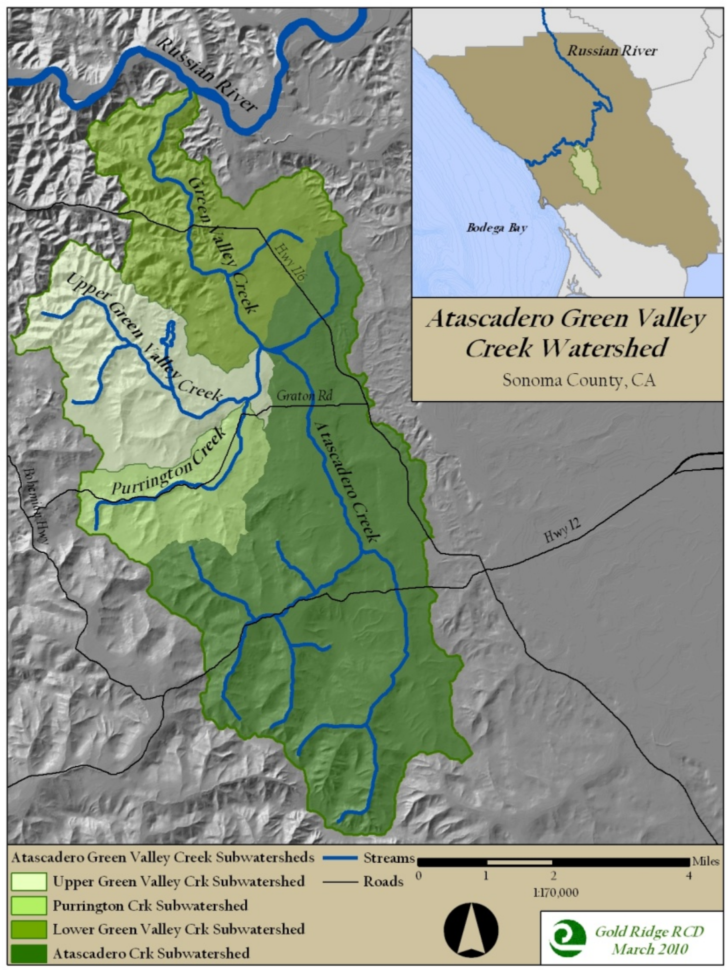
10. Project partners should seek to enlist all landowners along a stream or stream corridor in restoration projects. Piecemeal restoration is not sufficient.

    Agreed.

11. Enforcement of laws and regulations should be a measure of success of the management plan.

    GRRCD works with landowners on a voluntary basis. One of the drivers behind a watershed management plan, such as the one developed, is that it can be used as a tool for landowners so that they have the best information to make decisions for their property. While GRRCD understands that in some cases regulation is necessary, we support a voluntary approach supported by funding and education is the model that works best.

12. The term "Upper Green Valley Watershed" is confusing.



The term "Upper Green Valley" is used to differentiate the portion of the Green Valley Creek watershed upstream from the confluence with Atascadero Creek. The Upper Green Valley Creek watershed includes the Purrington Creek and Upper Green Valley Creek subwatersheds; these streams have been identified by the California Department of Fish and Game and National Marine Fisheries Service as priority habitat for coho salmon restoration. GRRCD pursued funding for planning and habitat improvement implementation projects (which resulted in this UGVWMP) for this upper watershed knowing that the entire watershed is among five identified as a priority by the Russian River Coho Water Resources Partnership. Thus, this focus on the upper watershed will be greatly enhanced because the lower watershed

will likewise undergo planning and project implementation for salmonid habitat improvement.

The term "Upper Green Valley" watershed to denote the area of interest for this plan was decided upon during a UGVWMP team meeting; it is subject to change. If the term proves confusing to many stakeholders, alternative names will be evaluated during the next phase of this planning process.

13. Public acquisition of private lands should be added as a goal to the Water Quality, Flow, and Flood Risk Sections.

    Public acquisition of private lands is often an effective management method to accomplish goals for nutrient sequestration, runoff filtration, and habitat improvement. It is, however, one of many methods to accomplish these goals and often, simple acquisition will not accomplish the desired outcome – the land must be managed subsequent to acquisition: riparian revegetation, non-native invasive plant removal, or other management activities. These activities must occur for habitat enhancement and improvement to occur regardless of ownership. Thus, although public acquisition of private lands can be an effective tool to accomplish goals, it is not, in and of itself, a goal of GRRCD or the UGVWMP.

Appendix 2. Legal Description of Atascadero-Green Valley Creek Watershed

The legal description of Green Valley Creek at its confluence with the Russian River is T8N R10W S2. It is located at 38°30′17″ N latitude and 122°54′30″ W longitude (CDFG 2006B). The AGV watershed contains CalWater Planning Watersheds 1114110103 (Green Valley Creek), 1114110202 (Purrington Creek), and 1114110201 (Atascadero Creek) (NMFS-SWR 2009).

Appendix 3: Water Quality Objectives by Parameter

Parameter (reporting units)	Water Quality Objectives	Source of Objective
Dissolved Oxygen (mg/L)	Minimum 7	NCRWQCB Water Quality Control Plan
pH	Minimum 6.5 Maximum 8.5	NCRWQCB Water Quality Control Plan
Water Temperature (°C)	Not more than 24.11	Thompson and Larsen (2004)
Conductivity (uS)	320 90% Upper Limit[1] 250 50% Upper Limit[2]	NCRWQCB Water Quality Control Plan
Turbidity (NTU)	Maximum 25	Sigler et al. (1984)

[1] 50% upper and lower limits represent the 50 percentil values of the monthly means for a calendar year. 50% of more of the monthly means must be less than or equal to an upper limit and greater than or equal to a lower limit.

[2] 90% upper and lower limits represent the 90 percentile values for a calendar year. 90% or more of the values must be less than or equal to an upper limit and greater than or equal to a lower limit.

Appendix 4. AGVWC / CCWI Water Quality Data

Site	Date	Air Temperature Degrees C	Sample Time	Water Temperature Degrees C	Dissolved Oxygen (mg/L)	pH	Turbidity (NTUs)
GVC070	08/31/2005	25	12:10:00	15	6.3	7.7	0.66
GVC070	09/28/2005	18.5	10:50:00	13.5	6.8	7.6	0.71
GVC070	10/26/2005	13	11:58:00	12.5	7.3	7.5	1.28
GVC070	11/30/2005	8	11:00:00	8	9.3	7.2	3.76
GVC070	12/21/2005	13.5	11:10:00	11.5		7	47.7
GVC070	01/25/2006		11:50:00				
GVC070	03/29/2006	10.5	11:25:00	10	10.3	7	147
GVC070	04/26/2006	16	10:35:00	12	12.1	7	5.39
GVC070	05/31/2006	19	10:35:00	15	8.6	7.9	4.57
GVC070	06/28/2006	18.5	10:25:00	17.5	9.6	8.1	1.18
GVC070	07/26/2006	23	10:45:00	20	7.7	7.9	0.93
GVC070	08/31/2006	19	10:10:00	15	6.8	7.7	1.08
GVC070	09/28/2006	11	10:40:00	12	12.3	7.9	0.78
GVC070	10/26/2006	10	10:45:00	8	8.7	7.9	0.87
GVC070	11/30/2006	8	10:25:00	5	11.3	7.4	1.79
GVC070	12/28/2006	7	10:15:00	7	10.6	7.7	18.2
GVC070	01/25/2007	4	10:07:00	4	11.4	7.8	1.03
GVC070	03/01/2007	10.5	10:10:00	8	11.05	7.6	14.6
GVC070	03/29/2007	12	10:38:00	9	10.3	7.6	1.17
GVC070	04/26/2007	16	10:25:00	11	9.8	7.3	2.6
GVC070	05/24/2007	18	10:30:00	15	8.7	7.6	1.5
GVC070	06/28/2007	21	10:50:00	17	8.5	7.5	1.65
GVC070	07/26/2007	16	10:18:00	17	7.4	7.9	0.95
GVC070	08/30/2007	21	10:37:00	17	2.2	7.6	0.33
GVC070	09/20/2007	15.5	11:30:00	13	6.5	7.7	1.08
GVC070	10/25/2007	14.5	10:28:00	10.5	7.8	8.1	1.03
GVC070	11/29/2007		10:40:00	5	9.8	8	1.21
GVC070	12/20/2007	9	10:40:00	9.5	10.5	8	95.9
GVC070	01/24/2008	5.5	10:20:00	7.5	10.6	7.3	4.35
GVC070	03/27/2008	9	10:24:00	9.5	10.1	7	1.41
GVC070	05/22/2008		10:32:00	15		7	1.73
GVC070	06/19/2008	24	10:25:00	17	7.6	7.7	0.89
GVC070	07/17/2008	18	10:30:00	17	6.2	7.7	1.63
GVC070	08/21/2008	24	10:25:00				
GVC070	09/25/2008	28	13:00:00	13.5	5.4	6.5	6.08
GVC070	10/30/2008	10	10:27:00	10	8.2	7.8	0.67
GVC070	11/20/2008	14	10:25:00	11	7.88	7.8	0.85
GVC070	12/18/2008	0	10:38:00	3	11.21	8.1	0.63
GVC070	01/15/2009	6	09:45:00	5.5	11	7.7	1.45
GVC070	02/26/2009	13	10:20:00	11	10.7	6.9	18.6
GVC070	03/26/2009	9999	10:20:00	9999	10.2	6.8	1.54
GVC070	04/16/2009	10	10:20:00	9	10.19	8.1	1.53
GVC070	05/28/2009	16	10:25:00	14	10.65	8.3	1.34

Appendix 4. AGVWC / CCWI Water Quality Data

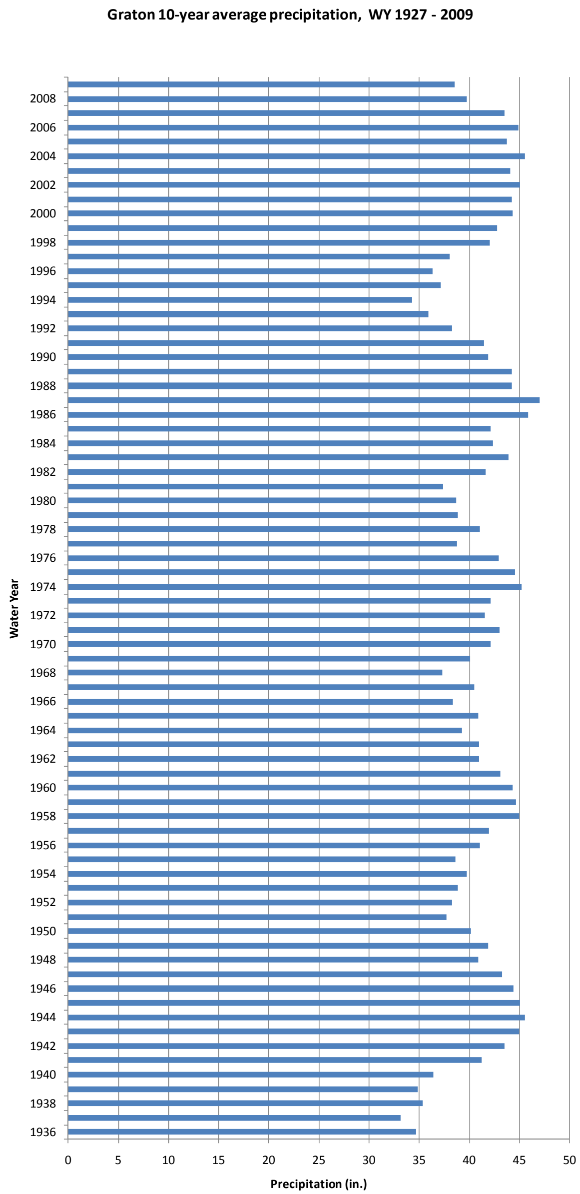
Site	Date	Air Temperature Degrees C	Sample Time	Water Temperature Degrees C	Dissolved Oxygen (mg/L)	pH	Turbidity (NTUs)
GVC070	06/25/2009	15	10:15:00	14.5	9999	8	1.02
GVC070	07/23/2009	16	10:25:00	16	7	8.1	1.97
GVC070	08/27/2009	16.5	10:25:00	16	3.35	7.6	0.58
GVC070	10/22/2009	16.5	10:20:00	13	7.2	7.8	3.61
GVC070	11/19/2009	9.5	11:13:00	7	9.62	7.9	1.28
GVC070	12/17/2009	11	10:25:00	9	11.2	7.5	11.5
GVC070	01/28/2010	10	10:20:00	10	12.1	7.5	16.4
GVC070	02/25/2010	14	10:07:00	10	12.3	7.5	20.4
GVC070	03/25/2010	12	10:27:00	11	12.2	7.2	4.19
GVC070	04/22/2010	11.5	10:20:00	10.5	10.81	8	3.34
GVC090	08/31/2005	21.5	11:15:00	14	6.9	7.9	0.82
GVC090	09/28/2005	15.5	10:30:00	12	6.6	8	0.8
GVC090	10/26/2005	13	11:25:00	12.5	6.6	7.5	1.78
GVC090	11/30/2005	8	11:25:00	8	9.8	7.2	2.08
GVC090	12/21/2005	12.5	11:30:00	12		6.9	21
GVC090	01/25/2006	8.5	11:20:00	9	13.1	7.6	6.56
GVC090	03/29/2006	9.5	10:55:00	10	11	7.6	63.8
GVC090	04/26/2006	20	11:05:00	12.5	10.5	7	5.6
GVC090	05/31/2006	17	11:07:00	13.5	8.9	7.9	1.34
GVC090	06/28/2006	18	11:10:00	16	8	7.9	0.97
GVC090	07/26/2006	23.5	11:10:00	19	6.1	7.7	0.82
GVC090	08/31/2006	16	10:32:00	14	6.8	7.5	0.72
GVC090	09/28/2006	12	11:05:00	12.5	10.1	7.8	0.43
GVC090	10/26/2006	12	11:13:00	10		7.8	0.29
GVC090	11/30/2006	6	11:38:00	5.5	10	7.6	1.21
GVC090	12/28/2006	5	10:45:00	7	10.9	7.7	11
GVC090	01/25/2007	4	10:33:00	5	12	7.8	2.05
GVC090	03/01/2007	8.5	10:45:00	8.5	10.49	7.4	11.1
GVC090	03/01/2007	8.5	10:58:00	8.5	10.69	7.4	10.6
GVC090	03/29/2007	12	11:05:00	9	10.9	7.7	1.21
GVC090	04/26/2007	15	11:00:00	11	9.8	7.4	1.58
GVC090	05/24/2007	17	10:58:00	14	9	7.6	0.78
GVC090	06/28/2007	18	11:10:00	15	7.3	7.2	1.52
GVC090	07/26/2007	17.5	10:45:00	16.5	6.4	7.9	0.48
GVC090	08/30/2007	20.5	11:05:00	17	5	7.7	0.66
GVC090	09/20/2007	14	11:50:00	13.1	5.3	7.9	0.66
GVC090	10/25/2007	12	11:02:00	10	7.3	8.1	0.86
GVC090	11/29/2007		11:10:00	5	9.4	8	0.39
GVC090	12/20/2007	8	11:12:00	9	10.6	7.9	38.3
GVC090	01/24/2008	5.5	10:55:00	7.5	10.8	7.3	4
GVC090	02/21/2008	15	11:30:00	10.2	10.5	7.9	8.6
GVC090	03/27/2008	10	11:04:00	9.5	11.8	7.7	1.23
GVC090	05/22/2008		10:50:00	14		7.4	2.39

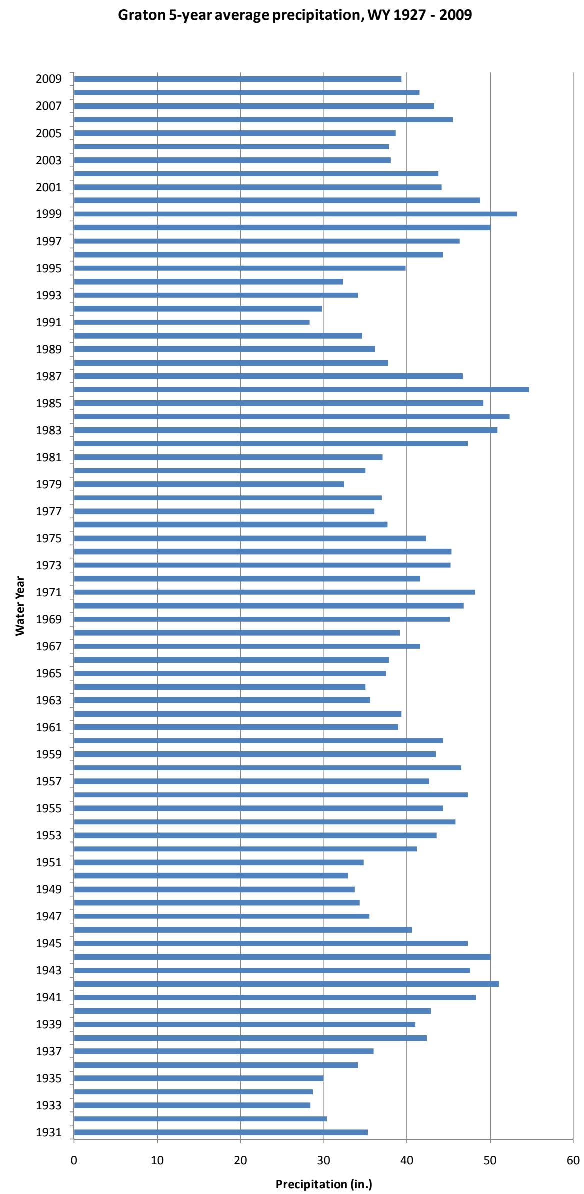
Appendix 4. AGVWC / CCWI Water Quality Data

Site	Date	Air Temperature Degrees C	Sample Time	Water Temperature Degrees C	Dissolved Oxygen (mg/L)	pH	Turbidity (NTUs)
GVC090	06/19/2008	27	10:55:00	16	7.4	7.4	0.97
GVC090	07/17/2008	17.5	11:01:00	15	7.6	7.4	2.27
GVC090	08/21/2008	20	10:35:00	16	2.9	7.1	0.76
GVC090	09/25/2008	28.5	13:30:00	13	4.8	7	3.96
GVC090	10/30/2008	10	11:05:00	10	5.3	7.7	1.15
GVC090	11/20/2008	12.5	10:50:00	11	6.96	7.9	0.77
GVC090	12/18/2008	2	11:05:00	3	10.92	8.1	0.61
GVC090	01/15/2009	8	11:05:00	6.5	11.5	7.3	0.6
GVC090	02/26/2009	12.5	10:45:00	11	10.9	6.7	9.75
GVC090	03/26/2009	9999	10:48:00	9999	11	6.4	1.34
GVC090	04/16/2009	9	10:45:00	9	10.73	8.2	0.83
GVC090	05/28/2009	16	10:55:00	13.5	10.02	8.4	0.91
GVC090	06/25/2009	15	10:45:00	14.5	9999	8	0.65
GVC090	07/23/2009	17	10:55:00	16	6.9	7.9	1
GVC090	08/27/2009	15	10:55:00	13	6.66	7.9	0.77
GVC090	10/22/2009	14	10:46:00	12	7.4	7.9	1.12
GVC090	11/19/2009	9	11:40:00	7.5	9.33	7.9	2.25
GVC090	12/17/2009	12	10:55:00	10	11.6	7.5	4.8
GVC090	01/28/2010	8	10:42:00	10	12.4	7.3	14.6
GVC090	02/25/2010	13.5	10:32:00	11	12.6	7.3	13.1
GVC090	03/25/2010	12	10:51:00	11	13	7.2	3
GVC090	04/22/2010	10	10:40:00	11	10.84	8.2	2.99
GVC110	11/30/2006	7	11:05:00	6.5	8.3	7.3	4.93
GVC110	12/28/2006	7	11:20:00	8.5	10.2	7.5	6.82
GVC110	01/25/2007	6	11:10:00	7	10.3	7.3	2.01
GVC110	03/01/2007	9.5	11:35:00	10	10.51	7.2	9.51
GVC110	03/29/2007	13	11:31:00	10	9.9	7.6	2.12
GVC110	04/26/2007	23	11:38:00	11	8.9	7.2	2.51
GVC110	05/24/2007	23	11:35:00	13	7.6	7.6	2.22
GVC110	06/28/2007	24	11:45:00	15	6.6	7.2	3.32
GVC110	07/26/2007	22	11:15:00	15	4.9	7.6	6.7
GVC110	08/30/2007						
GVC110	10/25/2007	21	11:35:00	10.5	6.6	7.8	3.97
GVC110	11/29/2007		11:43:00	6	8.4	7.8	2.45
GVC110	12/20/2007	8	11:50:00	11	11.1	7.7	13.2
GVC110	09/25/2008	28	12:40:00	14	5.8	7.4	4.75
GVC120	01/24/2008	5.5	11:35:00	11	9.4	7.4	3.27
GVC120	02/21/2008	9	11:50:00	12	9.3	7.3	14.7
GVC120	03/27/2008	11	11:35:00	10.5	9.2	6.7	2.44
GVC120	05/22/2008		11:20:00	14		7.4	3.23
GVC120	06/19/2008	28	11:37:00	16	6.1	7.1	2.17
GVC120	07/17/2008	20.5	11:33:00	16	6	6.9	4.65
GVC120	08/21/2008	23	11:10:00	17.5	4.5	6.5	

Appendix 4. AGVWC / CCWI Water Quality Data

Site	Date	Air Temperature Degrees C	Sample Time	Water Temperature Degrees C	Dissolved Oxygen (mg/L)	pH	Turbidity (NTUs)
GVC120	10/30/2008	11.5	11:47:00	12	5.1	7.3	4.81
GVC120	11/20/2008	13	11:20:00	13	5.66	7.2	3.54
GVC120	12/18/2008	5	11:30:00	8	7.23	7.4	2.14
GVC120	01/15/2009	10	11:27:00	9.5	8.4	6.7	1.69
GVC120	02/26/2009	12	11:15:00	11	9.9	7.1	4.85
GVC120	03/26/2009	9999	10:48:00	9999	9.2	6.3	1.11
GVC120	04/16/2009	11.5	11:16:00	10	8.2	7.8	1.27
GVC120	05/28/2009	17	11:25:00	13	8	8	1.07
GVC120	06/25/2009	16	11:10:00	14	9999	7.9	1.72
GVC120	07/23/2009	21	11:50:00	15.5	6.2	7.6	2.93
GVC120	08/27/2009	19	11:28:00	15	4.75	7.8	5.36
GVC120	10/22/2009	16	10:15:00	15	5.8	6.9	3.59
GVC120	12/17/2009	11	11:22:00	12	8.1	6.5	4.21
GVC120	01/28/2010	9	11:10:00	11	11.1	6.7	7.55
GVC120	02/25/2010	14	11:08:00	11.5	11.4	6.5	7.76
GVC120	03/25/2010	13	11:13:00	12	11	6.5	2.76
GVC120	04/22/2010	11.5	11:09:00	12.5	9.52	8	3.59
GVC130	01/24/2008	4.5	11:47:00	10.5	9.3	7.5	2.6
GVC130	02/21/2008	8	12:05:00	12	8.9	6.8	4.21
GVC130	03/27/2008	10	11:50:00	10.5	9.1	6.5	2.72
GVC130	05/22/2008		11:33:00	13		7.4	3.56
GVC130	06/19/2008	29	11:53:00	14	6.6	7.1	3.5
GVC130	07/17/2008	20.5	11:50:00	14	5.7	6.9	9.39
GVC130	08/21/2008	22.5	11:29:00	17.5	5.5	6.4	
GVC130	10/30/2008	12	12:01:00	12	7.1	7.3	3.5
GVC130	11/20/2008	12	11:35:00	12	6.74	7.2	5
GVC130	12/18/2008	5	11:42:00	7	8.75	7.7	4.07
GVC130	01/15/2009	11	11:44:00	10	8.1	6.5	2.96
GVC130	02/26/2009	12	11:31:00	12	9.3	6.3	3.49
GVC130	03/26/2009	9999	11:25:00	9999	9.3	7	1.42
GVC130	04/16/2009	10	11:32:00	10	9	7.8	2.14
GVC130	05/28/2009	18	11:45:00	13.5	8.57	8.1	2.09
GVC130	06/25/2009	15.5	11:27:00	13	9999	7.7	2.33
GVC130	07/23/2009	19	11:30:00	14	6.4	7.2	6.76
GVC130	08/27/2009	22	11:45:00	13.5	6.14	7.9	7.42
GVC130	10/22/2009	17	10:42:00	14	5.8	6.9	7.12
GVC130	12/17/2009	10	11:39:00	11	8.1	6.4	7.37
GVC130	01/28/2010	10	11:30:00	11.5	10.7	6.5	6.5
GVC130	02/25/2010	13	11:22:00	11.5	11.2	6.3	5.58
GVC130	03/25/2010	12.5	11:33:00	12	11.1	6.5	3.08
GVC130	04/22/2010	12.5	11:32:00	11.5	9.62	8	3.6





Appendix 5. Average annual precipitation over the previous 10 years and previous five years, as recorded at Graton, CA.

Appendix 6. Purrington Creek Geomorphic Assessment

PURRINGTON CREEK GEOMORPHIC ASSESSMENT

Prepared for

Gold Ridge Resource Conservation District
P.O. Box 1064
Occidental, California 95456
Contract OESSCC#101

Prepared by

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April 2010

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Introduction

This document describes geomorphic assessment and hydrologic modeling of Purrington Creek conducted by O'Connor Environmental Inc. (OEI) in March 2010 under contract with the Gold Ridge Resource Conservation District (GRRCD). This assessment is an element of the watershed plan prepared by GRRCD under contract with the California Coastal Conservancy for Green Valley Creek, a tributary of the Russian River within which coho salmon reside. Purrington Creek is a principal tributary of Green Valley Creek located between Graton and Occidental in western Sonoma County.

The geomorphic assessment focused on evaluating fluvial processes affecting habitat conditions for anadromous fish, (e.g. coho salmon) in order to provide guidance regarding future management of Purrington Creek and its watershed. This assessment may also provide perspective on aquatic resources and watershed management issues in Green Valley Creek. The assessment emphasizes specific geomorphic processes of importance to these species as identified by the GRRCD including channel incision, bank erosion/stability, and associated hydraulic conditions. These processes were evaluated with respect to their potential impacts on critical habitat elements for anadromous fish (e.g. abundance and quality of pools and spawning sites). A comparison was made between present habitat conditions as determined by this study and historical conditions as documented in a 1994 survey by the California Department of Fish & Game (CDFG 2006).

A spatially-distributed watershed hydrologic model is being constructed for Purrington Creek using the MIKE SHE model developed by the Danish Hydraulic Institue. The model utilizes available climate, topographic, land cover, soil, and hydrogeologic data for the watershed and provides estimates of the annual and seasonal water balance, streamflow hydrographs, and groundwater levels throughout the watershed. The model has been constructed to characterize critical elements of the current hydrologic system and to evaluate the potential effect of changing land use and cover types on watershed hydrology. The model provides the RCD with a means to evaluate watershed management scenarios on critical hydrologic characteristics affecting aquatic habitat such as peak flow magnitude, flood hydrographs, and base flow.

Watershed Description

Hydrologic Characteristics

The Purrington Creek watershed has a drainage area of about 3.65 mi^2 (2,333 acres) and is a tributary watershed to Green Valley Creek. The headwaters of Purrington Creek lie about two miles east of Occidental; its confluence with Green Valley Creek lies about one mile west of Graton. Elevations range from approximately 100 ft above sea level near the confluence with Green Valley Creek to 900 feet above sea level in the upper watershed (Figure 1). A significant precipitation gradient occurs across the basin with precipitation increasing to the west (roughly following topography) from 41 in/yr near the confluence to 54 in/yr in the headwaters (Figure 1).

Land Use and Cover Types

The majority of the watershed area (52%) is forested, particularly in the upper watershed. Agricultural areas comprise the next largest land cover category, accounting for approximately 25% of the watershed area. Vineyards are the primary agricultural use (17% of the watershed area) and are concentrated in the downstream portion of the watershed and to a lesser extent in the south-central and northwestern portions of the watershed (Figure 2). The remainder of the agriculture in the basin is primarily orchards. Rural residential development accounts for approximately 21% of the watershed area and is scattered throughout the watershed. Although there are numerous roads in the basin, hardscape surfaces (buildings and roads) account for only 2.5% of the watershed area. Vineyard cultivation has increased substantially in the watershed over the past few decades with many areas being converted from orchards to vineyards and some conversion of forested lands.

Geology

The majority of the watershed is underlain by the Wilson Grove Formation which consists of fine-grained loosely consolidated sandstone with layers of beach or dune sand (Figure 3). Maximum thicknesses on the order of 120 ft have been estimated for this formation north of the watershed in the vicinity of Green Valley Road (Boudreau, 1978). Aside from the alluvium in the downstream reaches of the creek, the Wilson Grove Formation is the primary water-bearing material in the watershed and is expected to be the most significant source for providing baseflow to tributary streams in the basin.

Underlying the Wilson Grove Formation and exposed along a large swath running roughly along the course of the main-stem of Purrington Creek are a series of rocks of the Franciscan Formation and the Great Valley Sequence (Figure 3). The serpentinite component of the Franciscan Formation is expected to be particularly erosion prone. The siltstone of the Great Valley Sequence that is exposed along the creek in the western portion of the watershed appears to be very erosion prone as well. These two rock types are likely responsible for a large proportion of the sediment production in the watershed. The fractured bedrock comprising these formations is generally considered marginal as aquifer material, and these formations are expected to contribute less to base flow than the Wilson Grove Formation.

The lower-most 1.7 river miles of Purrington Creek flow through medium-grained Holocene alluvium. The alluvium lies adjacent to the creek and varies in width from between 200 and 1800 ft. Alluvium thicknesses of 20 to 30 ft were observed in the valley between the Dutton Ranch Bridge and the upper Graton Road Bridge. Along this reach and elsewhere in the valley, the creek has incised through the alluvium into the underlying Wilson Grove Formation. Just upstream of the confluence with Green Valley Creek, Purrington Creek exits the alluvial deposits and flows directly over the Wilson Grove Formation over an ~0.5 mile reach (Figure 3). Field observations indicate that the channel intersects this downstream-most exposure of the Wilson Grove Formation from a point about 200 ft upstream of the Dutton Ranch bridge to a point about 1000 ft downstream of the Dutton Ranch bridge below which the channel is incised in alluvium. This suggests that the creek has migrated to the northwest in this vicinity sometime after the deposition of the alluvium. This may have resulted from tectonic uplift that would also be consistent with the pattern of stream incision observed throughout the watershed.

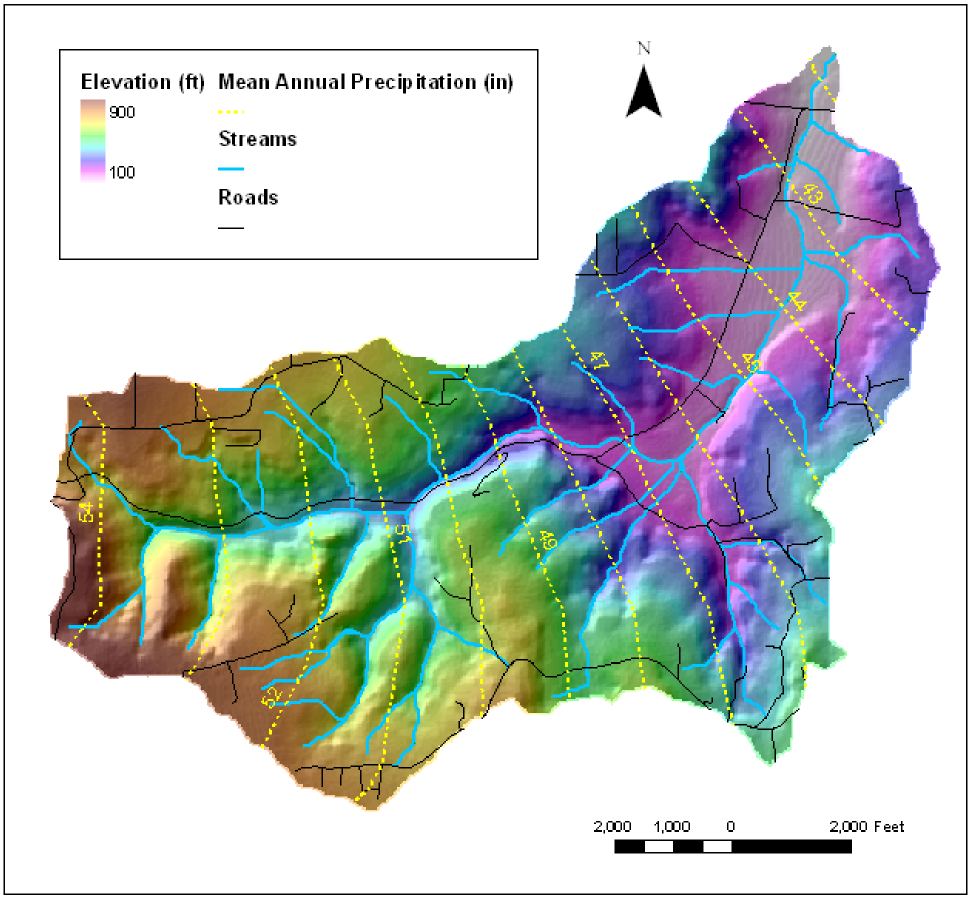

Figure 1: Topography and mean annual precipitation in Purrington Creek watershed

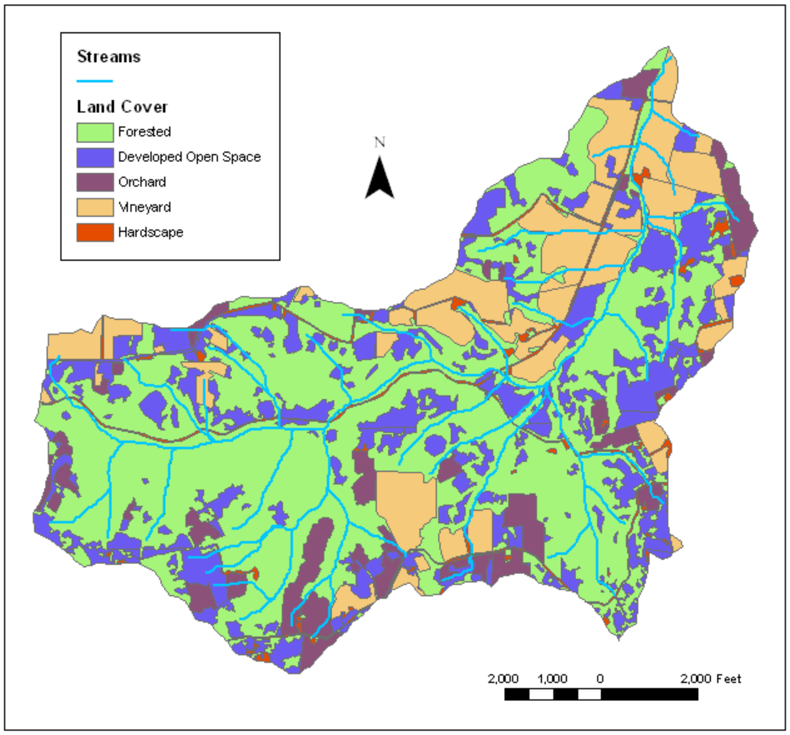

Figure 2: Land cover map of Purrington Creek watershed

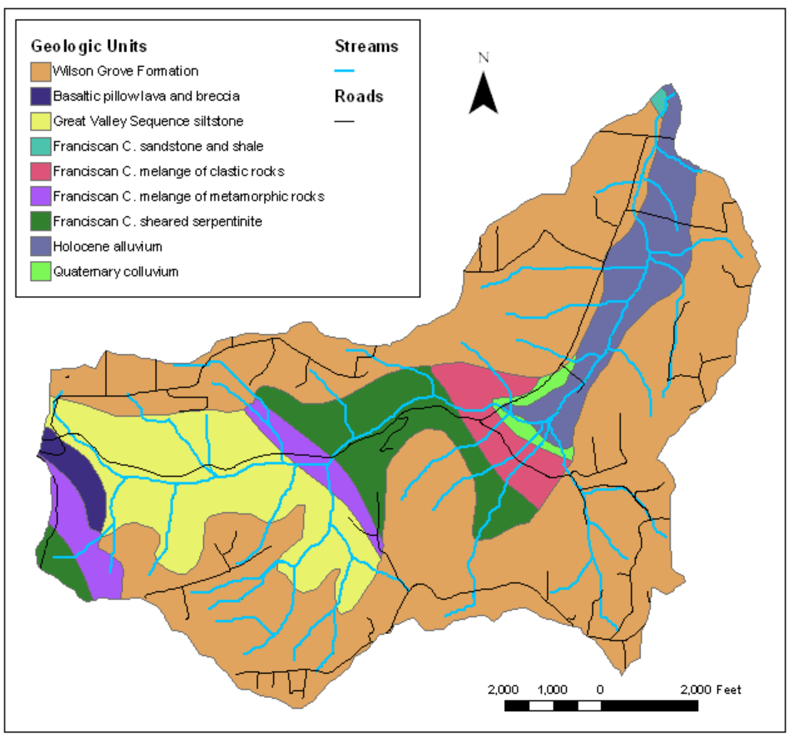

Figure 3: Geologic map of Purrington Creek watershed

Previous Watershed Assessment

The Purrington Creek watershed was included in the Atascadero Green Valley Watershed Preliminary Assessment (Laurel Marcus and Associates 2002). This assessment considered large scale patterns of land use, roads, slope, vegetation and geology. Historic maps were compared to current air photos to see assess changes in land use over time. Salient details of the preliminary watershed assessment regarding Purrington Creek are discussed below.

The Atascadero assessment referenced the CDFG 1994 Purrington and Green Valley Creek Survey stating that "Fish and Game surveys indicate excess sediment in Purrington and Green Valley Creeks that can be generated from roads and impervious surfaces increasing stormflow and causing channel incision as well as from agricultural land uses" (p. 23). Dominant land use types for Purrington Creek were agriculture and forest, frequency of roads on steep slopes was high, and impervious surfaces comprised less than 10% of the total watershed area.

Within the framework of watershed assessment and the conclusion that sediment supply to streams is of concern, stream monitoring was proposed to focus on two objectives: documenting changes in the amount and type of sediment supplied to the streams, and documenting sediment routing through the channel system. The preliminary assessment suggested specific monitoring parameters including composition of the channel bed, condition of channel banks, pool characteristics (location, size and depth), channel cross sections, photos of the channel and composition of the riparian forest. Additional stream monitoring suggestions included observation of timing and locations where surface flow disappears, macroinvertebrate sampling, longitudinal channel profiles, and various water quality tests.

The preliminary assessment suggested delineation of streams based on channel form and composition of the stream bed as an element of the proposed monitoring. Channel slope and confinement can be used as predictors of channel geomorphology (e.g. Washington Forest Practice Board 1997). The preliminary assessment of the Atascadero Green Valley watershed suggested estimating channel slope from topographic maps and assigning slope classes to channel classification types: regime, plane-bed, forced pool-rifffle, step-pool, cascade and colluvial as described by Montgomery and Buffington (1997). The degree of channel confinement by valley walls can influence a stream channel's response to changes in sediment load. A highly confined channel has valley walls very close to the channel banks or that actually form the channel banks, and rising stream flow tends to be accommodated by increasing depth rather than increasing width of flow. An unconfined channel has a well defined floodplain which is a broad flat area adjacent to the channel that is frequently flooded; response to increasing flow tends to be dominated by changing width more than depth of flow. Channel confinement may be expressed as the ratio of the channel width to the valley width, or by the entrenchment ratio (Rosgen 1994, CDFG 1998).

This geomorphic assessment of Purrington Creek is consistent with the recommendations of the preliminary assessment of the Atascadero Green Valley watershed. The geomorphic assessment includes field surveys of many of the stream parameters proposed for monitoring, however data collection was not intended to provide the level of accuracy and repeatability needed for monitoring. The geomorphic assessment is a reconnaissance process that distinguishes between channels with significant differences at the reach scale, and should be considered a necessary precursor to process based watershed assessment, planning and monitoring efforts. Furthermore, the process of distinguishing among channel reaches with distinctive geomorphology provides perspective on the types and locations of stream restoration and enhancement activities that could improve fish habitat.

Geomorphic Assessment

Overview

The geomorphic assessment focused on evaluating fluvial processes affecting fish habitat in the mainstem of Purrington Creek. The assessment was based on systematic field surveys that describe key geomorphic characteristics of the channel, including channel geometry, pool forming processes, and characteristics of the bed, banks, riparian zone and floodplain. These surveys, together with interpretation of channel conditions observed in the field, were used to stratify the channel into reaches with similar characteristics and geomorphic processes. Based on this stratification, it is possible to evaluate specific geomorphic processes of interest, including channel incision, bank erosion/stability, and associated hydraulic conditions. These processes were evaluated with respect to their potential impacts on critical habitat elements for anadromous fish (e.g. abundance and quality of pools and spawning sites).

This geomorphic assessment focused on the main-stem of Purrington Creek (Figure 4), as did the Stream Inventory Report (CDFG 2006) based on field surveys conducted in 1994. The CDFG survey was conducted using habitat inventory methods of the California Salmonid Stream Habitat Restoration Manual, which describe fish habitat based on low-flow channel morphology. The CDGF analysis of 1994 survey data provides some data that can be compared to some of the data collected in this geomorphic assessment. The purpose of this comparison is to evaluate whether, over the past 16 years, there is evidence of significant changes in geomorphic processes that affect fish habitat or in the abundance or quality of fish habitat. Data on pool abundance, depth and morphological classifications that describe hydraulic mechanisms that form pools were collected in this geomorphic assessment for comparison with 1994 conditions.

Field surveys were conducted in late February and early March 2010, including some periods of high runoff following substantial rains in the preceding days. The main-stem of Purrington Creek was initially divided into an upper and lower reach with distinct geomorphic characteristics as indicated by the CDFG analysis, evaluation of map data, and field reconnaissance. These two initial reaches were separated at the upstream Graton Road bridge at the boundary between the alluvial valley terraces and the upland hillslopes of the upper watershed (Figure 4).

Field survey time was limited, and less emphasis was placed on surveying in the upland canyon due to the relatively stable channel substrate and somewhat lower geomorphic sensitivity to potential changes in watershed conditions compared to the channel traversing the valley floor.

About 8,900 feet of the lower reach was surveyed, beginning at the confluence with Green Valley Creek extending nearly continuously to a point where access was not permitted (Figure 4). The survey of the upper reach covered about 1,300 feet, including a geomorphically-distinct reach in an unnamed tributary south of Graton Road in the upper canyon (Figure 4)

Methodology

Within the broadly differentiated upper and lower reaches of the main-stem of Purrington Creek, geomorphically-distinct sub-reaches were identified based on the extent and character of streamside mass wasting and bank erosion, changes in the channel substrate (bedrock, boulders and cobbles, gravel), breaks in channel slope, and channel morphology. Geomorphic data collected for each reach are described in detail in Appendix A.

Channel Geometry

Channel dimensions were measured at a representative cross section within each geomorphically-distinct sub-reach and recorded in a field sketch. The slope of the left and right banks was measured using clinometers. The width of the "bankfull" channel was defined by high-water marks to represent the elevation of a 2-yr recurrence interval flood indicated by strand lines, changes in sediment deposits, and vegetation differences at the channel margin thought. Bankfull depth was also measured at each of the representative cross-section locations. The depth measurements represent the average depth of flow at bankfull stage.

Flood prone width was measured at each cross section as the width of the horizontal surface across the channel at twice the bankfull depth. Flood prone width divided by bankfull width forms the metric "entrenchment ratio". Terrace heights were measured relative to the average elevation of the channel bottom. Terraces were defined as flat surfaces above the flood prone elevation, and are distinguished from the active floodplain. The relative positions of terraces were typically represented in a cross-section sketch of the valley, and terrace heights for left bank and right bank terraces were recorded separately. Channel slope was measured at representative cross section locations using clinometers or rod, level and tape.

Sediment Size Distribution

At selected gravel bars representative of the mobile bed material carried by the stream, streambed surface sediment size distributions were estimated by sampling surface sediment in a systematic random pattern. Six such "pebble counts" of one-hundred particles each were conducted; the diameter of the intermediate length axis of each particle was measured. In other locations, experienced observers selected sediment particles thought to represent the approximate median diameter (D_{50}) and 84^{th} percentile diameter (D_{84}) of the bar surface; these observations were then averaged to represent an estimate of the percentile of the size distribution of interest. Two bulk samples were collected from representative bars in the lower reach of Purrington Creek. These samples were composited to a single container and processed by a geotechnical laboratory to determine the grain size distribution.

Pool Characteristics

The criteria used to define pools in the field were similar to those used by CDFG for habitat inventory. Pools must have a surface dimension (length or width) of at least one-half the bankfull channel width and have a residual depth greater than one foot. Residual depth is the maximum pool depth less the depth above the channel bed elevation control point that defines the downstream end of the pool. This downstream control point is typically a riffle, and such bed features distinguish pools from other flatwater habitat types such as glides or runs.

Pools were identified during channel surveys and counted. Pools were classified by morphologic types that describe the pool-forming process. Pool classifications were adapted from the CDFG habitat classification system. The pool types surveyed were Lateral Scour Pool (Bedrock/Bank), Plunge Pool, Dam Pool, Log-Enhanced Lateral Scour Pool, Mid-Channel Pool and Step Pool, as defined in the California Salmonid Stream Habitat Restoration Manual (CDFG 1998).

Pools were also classified qualitatively by the quality of instream cover as Poor, Fair, or Good. For reference, these cover characterizations can be correlated to the CDFG's instream shelter complexity values and overall CDFG instream cover scores as follows. Poor cover classification correlated to a complexity value of 1 and 0-15% cover, with an overall shelter score range of 0-15. Fair cover classification correlated to a complexity value of 1 or 2 and 16-20% cover, with an overall shelter score range of 16-40. Good cover classification correlated to a complexity value of 2 or 3 and >21% cover, with an overall shelter score of >41.

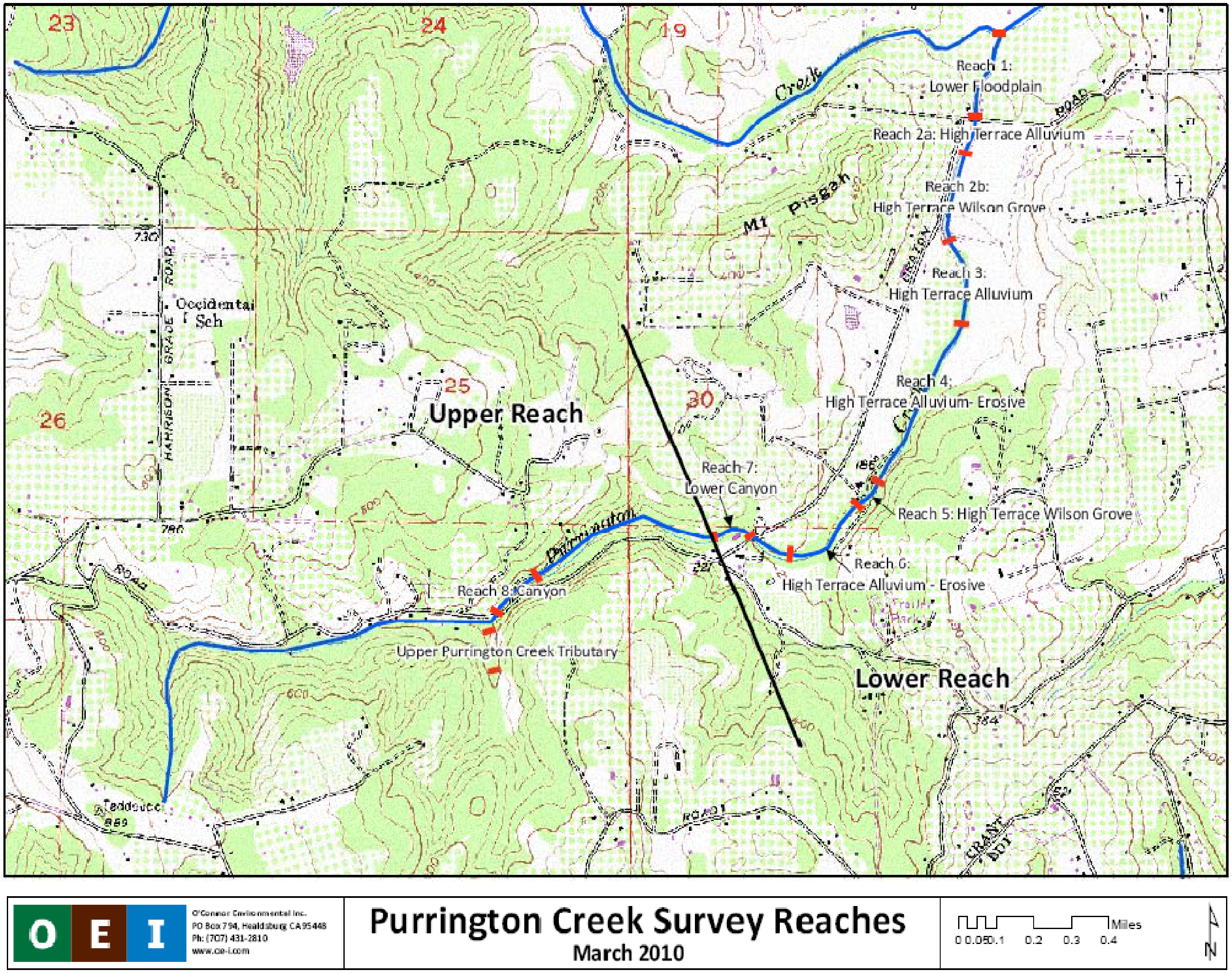

Figure 4: OEI Survey Reaches

Supplemental Geomorphic Data

The following qualitative and ordinal data pertaining to floodplain, riparian zone, streambank, woody debris, and geomorphic conditions were collected. Additional details pertaining to measurements and criteria for these data are presented in Appendix A.

Observed disturbances that may have affected the condition of the channel or the riparian zone were recorded for the left and right banks separately.

The longitudinal continuity and presence or absence of an active floodplain was assessed and recorded as follows: continuous (or nearly so), discontinuous but locally significant floodplain, or floodplain absent. Evidence used to characterize the presence and extent of the floodplain included the presence of side-channels and strand lines, and changes in sediment characteristics and vegetation patterns.

The character of riparian vegetation was noted for the left and right banks within each sub-reach.

Relative abundance of streamside mass wasting features was observed for each reach and the size of these features was estimated as a ratio of the height of the feature relative to the average bank height (as scaled by bankfull depth). Abundance of streamside mass wasting features were recorded as follows: None, Sparse = erosion features <5% of reach length, Common = erosion features 5-20% of reach length, or Abundant = erosion features >20% of reach length.

Large woody debris (LWD) was observed with respect to abundance and function. Abundance was a relative measure described as sparse, common or abundant. LWD function was described as minimal, functional or dominant. For example, "sparse functional" LWD would indicate that there were relatively few pieces of LWD, but that where present, LWD tended to interact with flow to create scour and deposition.

The abundance of gravel bars (few, common or abundant) was noted along with the typical bar morphology (see Appendix A). For example, "common forced" bars would indicate bars occupying a substantial portion of the channel developing in response to flow interaction with stable channel features such as bedrock protrusions of LWD jams.

Channel roughness elements that provided flow resistance at bankfull stage were recorded in descending order of importance; the dominant element was listed first. Channel roughness elements were as follows: B = Boulders, V = Live woody vegetation, Bk = Bank irregularities and Roots, F = Bedforms, C = Cobbles, R = Bedrock, and W = Large woody debris.

Dominant channel geomorphic class was determined according to criteria proposed by Montgomery and Buffington (1997). The principal types relevant to Purrington Creek are pool-riffle, plane bed, forced pool-riffle, and step pool.

Results

For this assessment, 8,900 linear feet of the lower reach and 1,300 linear feet of the upper reach of Purrington Creek were surveyed. The survey completed by CDFG in 1994 covered 15,072 linear feet of the lower reach and 4,299 linear feet of the upper reach. To facilitate comparisons, the boundary between the lower and upper reaches was located at the same point used by CDFG in 1994: about 500 feet upstream of Graton Road at its crossing of Purrington Creek at the head of the valley (Figure 4). Survey data are summarized in Table 2.

Pool Frequency

This survey found about 1.15 pools per 100-ft of stream surveyed. This is a substantially greater pool frequency than that computed from the 1994 CDFG survey (0.67 pools per 100-ft). While these differences may in part represent an increase in pool frequency over time, it more likely results from differences in flow conditions during field surveys and the inherent subjectivity involved in defining individual pools. The recent surveys were conducted during a relatively wet winter, hence flow levels were substantially greater than summer base flow conditions when these types of surveys are typically conducted. These conditions may have increased the likelihood of classifying deep portions of the channel as pools that may be classified as flat water habitat (e.g. glides or runs) during summer base flow conditions. Glides and runs comprise one-third of the habitat units (by length) as reported by CDFG from 1994 surveys.

In the lower reach (Figure 4), the percent of pools in each depth class coincided closely with what was recorded in the 1994 survey (Table 1). The most abundant pools were less than two feet deep comprising about 55% of the total pool count. Two to three foot deep pools accounted for about 35%, and pools greater than three feet deep accounted for about 10% of the total pool count. In the upper reach, the distribution of pools by depth class were also comparable to the 1994 survey, with the vast majority of pools having depths less than two feet (Table 1). The similarities of the distribution of pool depth between the two surveys suggest that pool forming processes and pool conditions have not changed significantly.

Table 1: Percentage of pools as a function of residual pool depth class

	Current Conditions		1994 Conditions	
	Lower Reach	Upper Reach	Lower Reach	Upper Reach
% of pools <2 ft deep	54.2	79.3	57.0	86.4
% of pools 2-3 ft deep	36.1	17.2	33.3	13.6
% of pools > 3 ft deep	9.6	3.5	9.7	0.0

Pool types found under current conditions are summarized in Figure 5. The data are combined for the entire survey reach to facilitate comparison with the 1994 data. The predominant pool type was lateral scour caused by bedrock outcrops or erosion-resistant stream banks, followed by log enhanced lateral scour and step pools. Step pools were formed primarily by bedrock or boulders, and occasionally by woody debris. Perhaps one-fourth of pools are formed in association with woody debris in or adjacent to the stream. Overall, cover was rated as good in 17% of pools, fair in 46% of pools and poor in 37% of pools. In contrast, log-enhanced lateral scour pools had cover rated as good in 33% of pools, fair in 53% of pools and poor in 14% of pools.

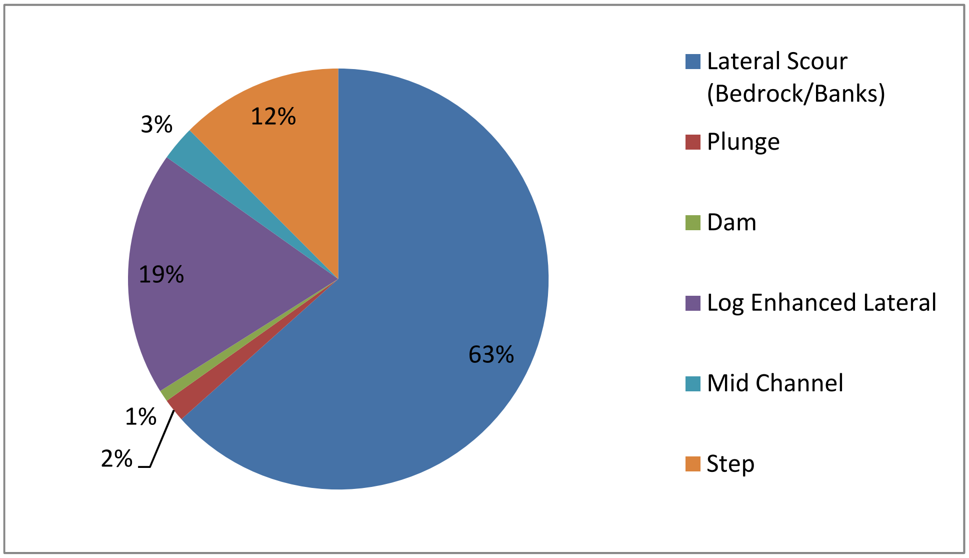

Figure 5: Percentage of pools by type

Geomorphic Reach Descriptions

Six geomorphically-distinct reach types were identified during the survey: Lower Floodplain, High Terrace-Wilson Grove, High Terrace-Alluvium, High Terrace- Alluvium (Erosive), Canyon, and Tributary (Figure 4). Each reach type is described below with respect to distinguishing geomorphic characteristics and critical factors pertaining to potential management objectives.

Lower Floodplain

This portion of Purrington Creek lies within about one-quarter mile of the confluence with Green Valley Creek where valley width increases (Figure 4). This reach is characterized by low terrace elevations which potentially permit extreme flood flows to overtop the stream bank (Figure 6). Overbank flooding is not common here, but is not excluded by extreme terrace height and channel entrenchment found upstream. A lower floodplain surface inset within the valley terrace (Figure 6) along this reach is discontinuous but locally significant within the channel banks throughout the reach. Relative to upstream reaches, the Lower Floodplain reach is distinguished by a wider channel with bankfull width ranging up to about 40 ft and an entrenchment ratio of about 2.4. Banks in this reach are relatively stable with a few local revetments of broken concrete. The Lower Floodplain has a relatively gentle stream gradient of about 0.4%. The dominant channel morphology is pool riffle and forced pool riffle. Woody debris is common and functions in the stream bed. The riparian forest includes mature hardwoods that grow near the stream bed and on along the upper and lower banks. Live alder stems interact with bankfull flows function to promote scour. Pools in this reach tend to have greater residual depths and to be more well-defined by downstream riffles relative to upstream reaches. Buried stems of alder trees, growing bars, and abundant deposition of sand in pools provide substantial evidence of significant sedimentation and bed aggradation within the channel. This reflects both upstream sediment supply and the channel grade change associated with the confluence with Green Valley Creek downstream and the decline in channel confinement relative to upstream reaches.

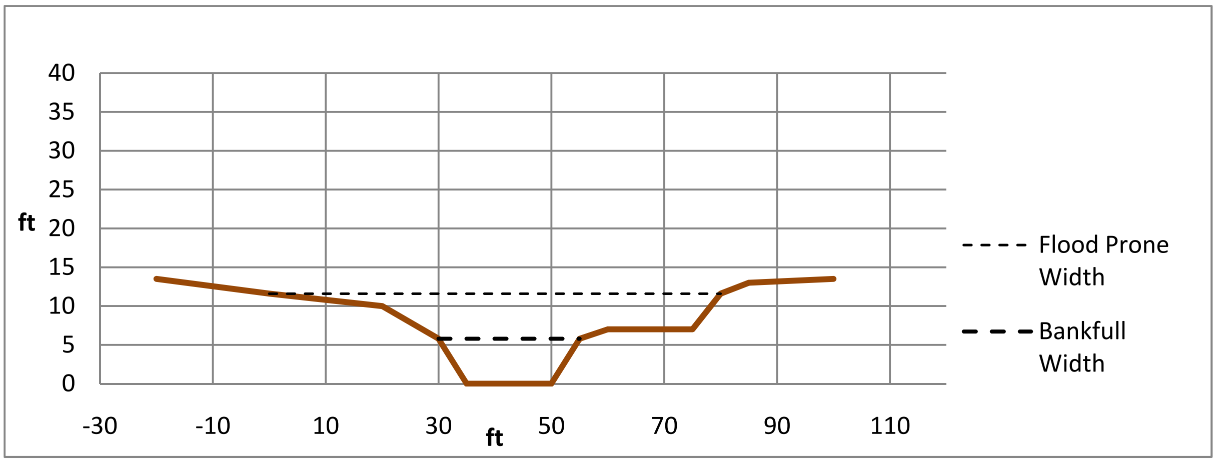

Figure 6: Cross Section Reach 1- Lower Flood Floodplain

High Terrace Wilson Grove

Reaches 2b and 5 were characterized as High Terrace Wilson Grove (Figure 4). The terrace heights were 25 to 30 ft above the channel floor (Figure 7) indicating a degree of channel incision sufficient to prevent overbank flow under current conditions. The channel has incised the sandstone of the Wilson Grove Formation that underlies the valley alluvium. Channel banks are steep, often vertical where bedrock forms the bank, and relatively stable. Nevertheless, sandstone of the Wilson Grove Formation is relatively soft, and stream flow is capable of gradually eroding it. Recent evidence of active erosion processes demonstrate potential for ongoing channel incision through the sandstone. Channel width varies, but is typically narrower (bankfull width about 20 ft) with a high degree of degree of entrenchment indicated by a low value of entrenchment ratio (≈ 1.5). The typical gradient along these reaches was only slightly steeper than adjacent reaches, but can increase significantly in a few locations caused by bedrock outcrops that form local knickpoints in the channel profile. The dominant channel morphology is forced pool riffle and plane bed. Deep and long pools are common in trench-like rectangular sections of bedrock channel. These pools tend to be characterized by low complexity and poor cover. Woody debris is sparse and its function is limited owing to bedrock morphology. Riparian forest trees are hardwoods, but are typically found rooted above the contact between bedrock and overlying alluvium, and are therefore limited to the upper banks and rarely affect channel morphology. The stream bed surface in these deeper water bedrock-dominated channel reaches is typically sand. The confined channel geometry and locally steep gradients promotes sediment transport and permits only transient sediment storage in pools and gravel bars found where the channel expands locally or form in the lee bank irregularities.

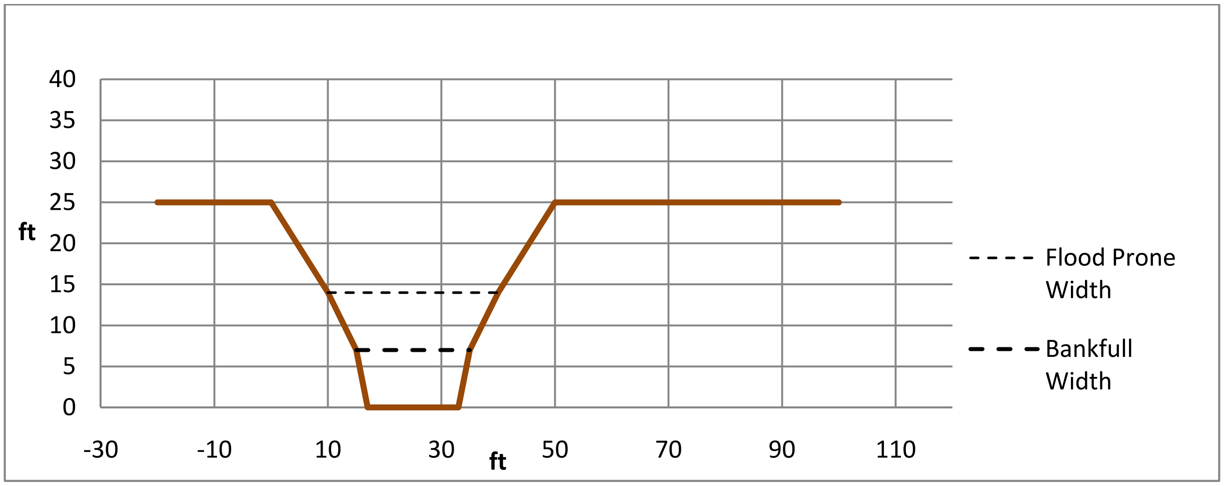

Figure 7: Cross Section Reach 2b- High Terrace Wilson Grove

High Terrace Alluvium and High Terrace Alluvium - Erosive

Reaches 2a and 3 were characterized as High Terrace Alluvium, and reaches 4 and 6 were characterized as High Terrace Alluvium – Erosive (Figure 4). In these reaches, the Wilson Grove bedrock does not outcrop in the bed or banks, and the stream banks are composed of alluvium. Portions of the lower stream bank in some locations are composed of erosion-resistant clay. Terrace heights are at least 20 and typically over 30 ft above the channel floor (Figures 8-11). Overbank flow does not occur under current conditions. Observed bankfull width ranged from 22 to 30 ft; the entrenchment ratio ranged from 1.3 to 2.4 and averaged 1.8. The entrenchment ratio appeared to be greater where the upper banks had previously slumped ultimately allowing development of a narrow terrace surface inset within the taller valley terraces (Figure 10). The non-erosive reaches (reaches 2a and 3) have relatively stable banks under current conditions; substantial bank revetments of rock and broken concrete occur in these reaches. The “erosive” reaches in the upper valley (reaches 4 and 6) have banks prone to slumping (mass failures of bank material in rotational landslides extending into the upper terrace surface). Where slumping occurs, local sediment supply is increased significantly and accompanied by an increase in channel complexity. Channel gradient is about 0.5% in reach 2b, and elsewhere is about 1%. The dominant morphology is forced pool riffle, particularly in sections affected by relatively recent bank slumps. Plane bed morphology is more common where banks are more stable. Woody debris abundance ranges from sparse to common, but is relatively functional creating local scour and sediment deposition site in these sandy-gravel bedded reaches. Riparian forest trees are hardwoods, with some areas of more abundant willow growth on the channel bed and lower banks. Larger trees are typically found rooted on the upper banks and rarely affect channel morphology except in reach 2a. Sediment the stream bed surface is predominantly gravel (Figure 15), with some local variability (e.g. Reach 6). Sand deposits were observed in some pools. Bars commonly form in response to channel irregularities, but also develop an alternating pattern of bars within a relatively straight channel alignment. The variable channel geometry and discontinuous floodplain inset within the valley terraces permits some sediment storage, however, the bankfull channel remains largely confined and most sediment storage is in transient bars and the bed alluvium. Pools tend to be more frequent and complex in areas affected by relatively recent slumping, however, these pools are typically formed by lateral scour and are not typically well defined by downstream riffles.

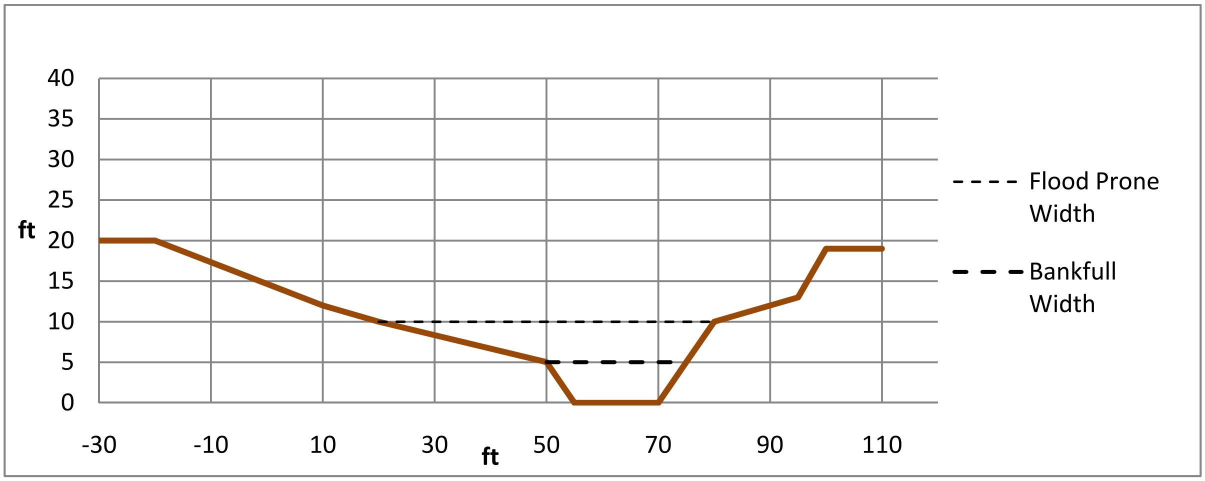

Figure 8: Cross Section Reach 2a- High Terrace Alluvium

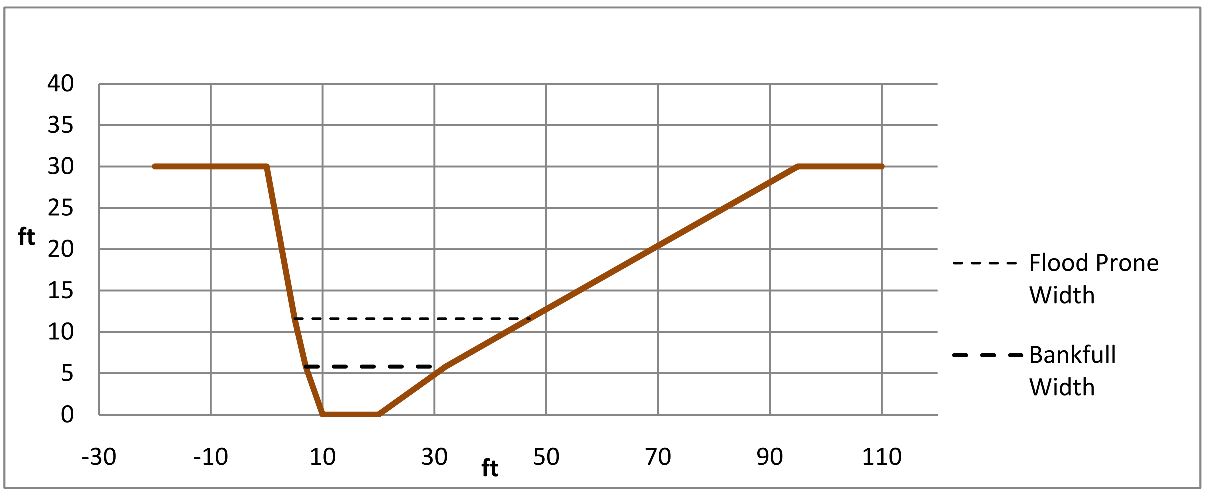

Figure 9: Cross Section Reach 3- High Terrace Alluvium

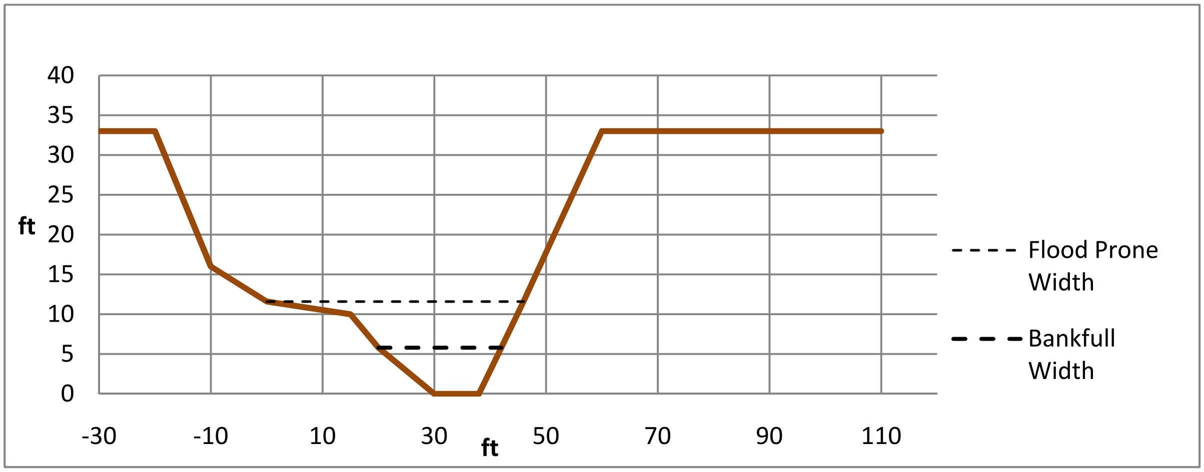

Figure 10: Cross Section Reach 4- High Terrace Alluvium- Erosive

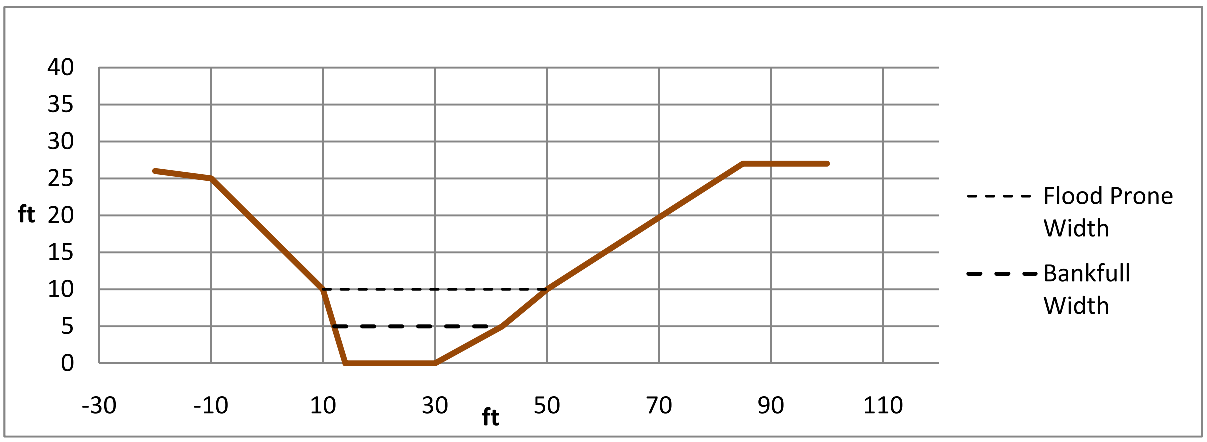

Figure 11: Cross Section Reach 6- High Terrace Alluvium- Erosive

Canyon

Reaches 7 and 8 were characterized as Canyon, with steep valley walls associated with upland hillslopes (Figures 12 and 13). Mass wasting features (landslides) are associated with the steep hillslopes and unstable bedrock in some locations. Hillslopes in stronger bedrock may be steeper (e.g. Figure 12), while hillslopes in weaker bedrock (e.g. serpentine, Figure 13) may be substantially less steep, but both are naturally susceptible to mass wasting. These features are locally abundant, and may contribute significant quantities of hillslope sediment to the channel network, including boulders and cobbles. Channel width is in a range (21 to 30 ft) similar to the downstream reaches, but the degree of confinement is typically high (entrenchment ratio ≈ 1.3) with infrequent and narrow segments of floodplain. Stream gradients were the steepest of the various geomorphic reach types that were surveyed, ranging from as low as 1% near the valley floor to at least 6% in Reach 8 which is more typical of the Canyon reach. The dominant channel morphology is step pool and forced pool riffle with plane bed observed in Reach 7 at the lower end of the canyon. Woody debris is sparse, but functions in the channel bed to create scour and sediment storage sites. The hillslopes include coniferous forest typical of the

Coast Range, dominated by redwood and Douglas-fir. The bed material is much coarser with abundant cobbles and boulders not typically observed in downstream reaches; nevertheless, well-sorted gravel bars representing the mobile portion of the bedload sediment have size distributions similar to those observed downstream. Sediment is transported through this reach, with local sediment inputs associated with landslides, and transient storage occurs in bars within the channel, increasing in frequency as slope decreases. Pools formation is related to channel roughness elements such as bedrock exposed in the bed and banks and boulder steps. Pools are relatively abundant, but tend to be shallow with inconsistent development of downstream riffles.

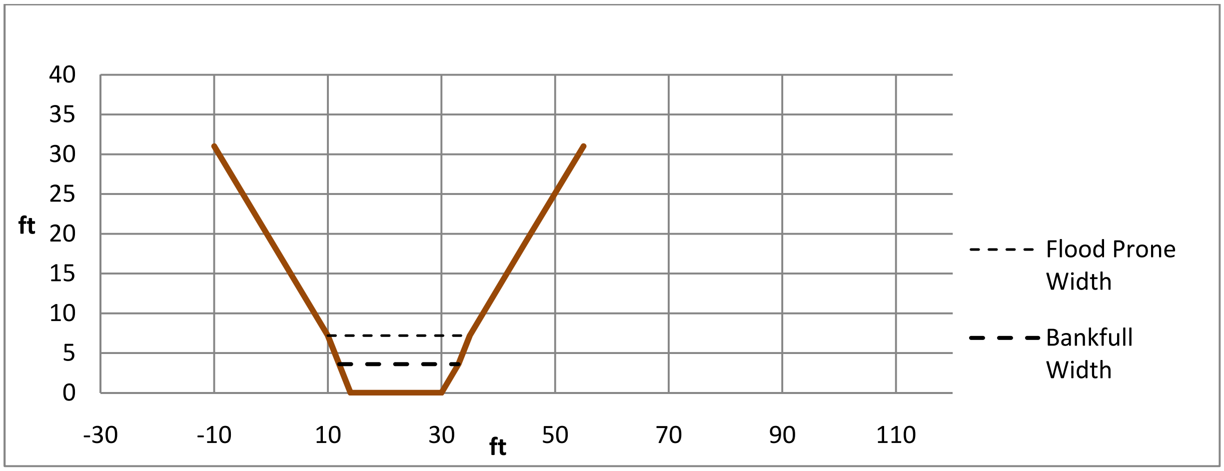

Figure 12: Cross Section Reach 7- Lower Canyon

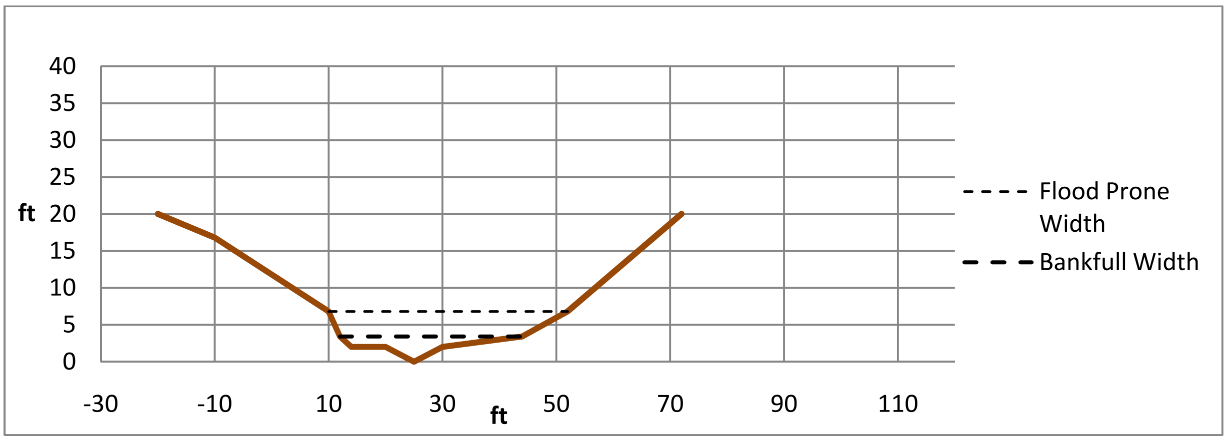

Figure 13: Cross Section Reach 8- Canyon

Tributary

One unnamed tributary was surveyed in upper Purrington Creek above the Canyon reach (Figure 4). This tributary reach was set within a narrow valley with terraces about six feet or more above the channel floor (Figure 14). The valley floor slopes gently to the foot of steeper hillslopes, but tends to separate the channel from hillslopes, reducing the potential for direct delivery of sediment from landslides originating on hillslopes. Nevertheless, slump-type landslides are present along portions of the stream adjacent to steeper hillslopes, including active recent features that contribute sediment to the channel. The channel is confined within terraces with no significant floodplain development observed. Stream gradients are variable, typically about 1.5% but locally up to 3%. Bedrock and boulder pools are abundant and the dominant morphology is forced pool riffle and step pool. Bed material is composed of mobile gravel sizes that are comparable to those found in downstream reaches. Gravel bars are common and represent sediment storage elements for material in transit to the lower watershed. Large woody debris was fairly abundant and appeared to be effective at creating pool habitat conditions.

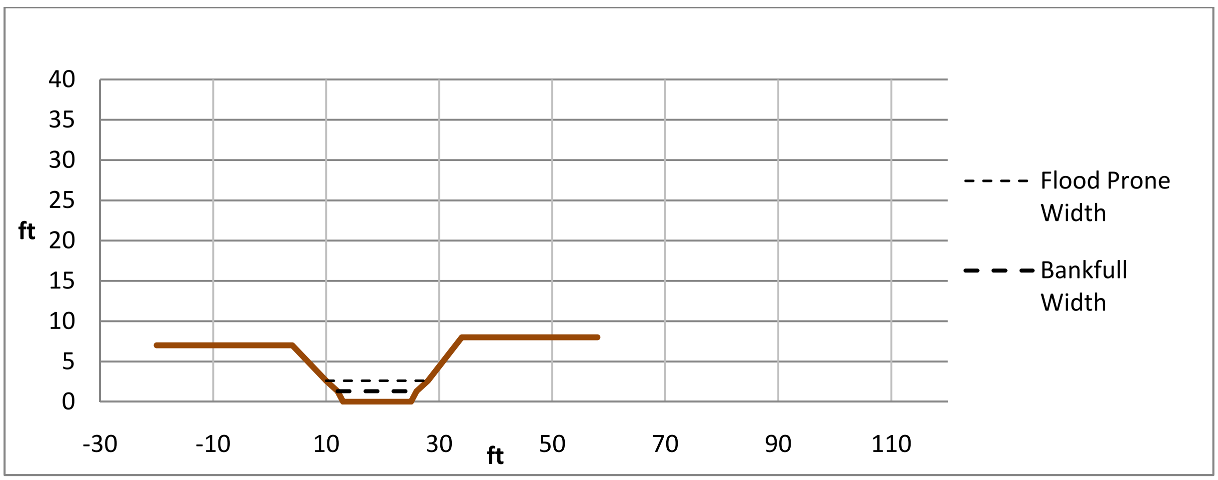

Figure 14: Cross Section Upper Purrington Tributary Reach

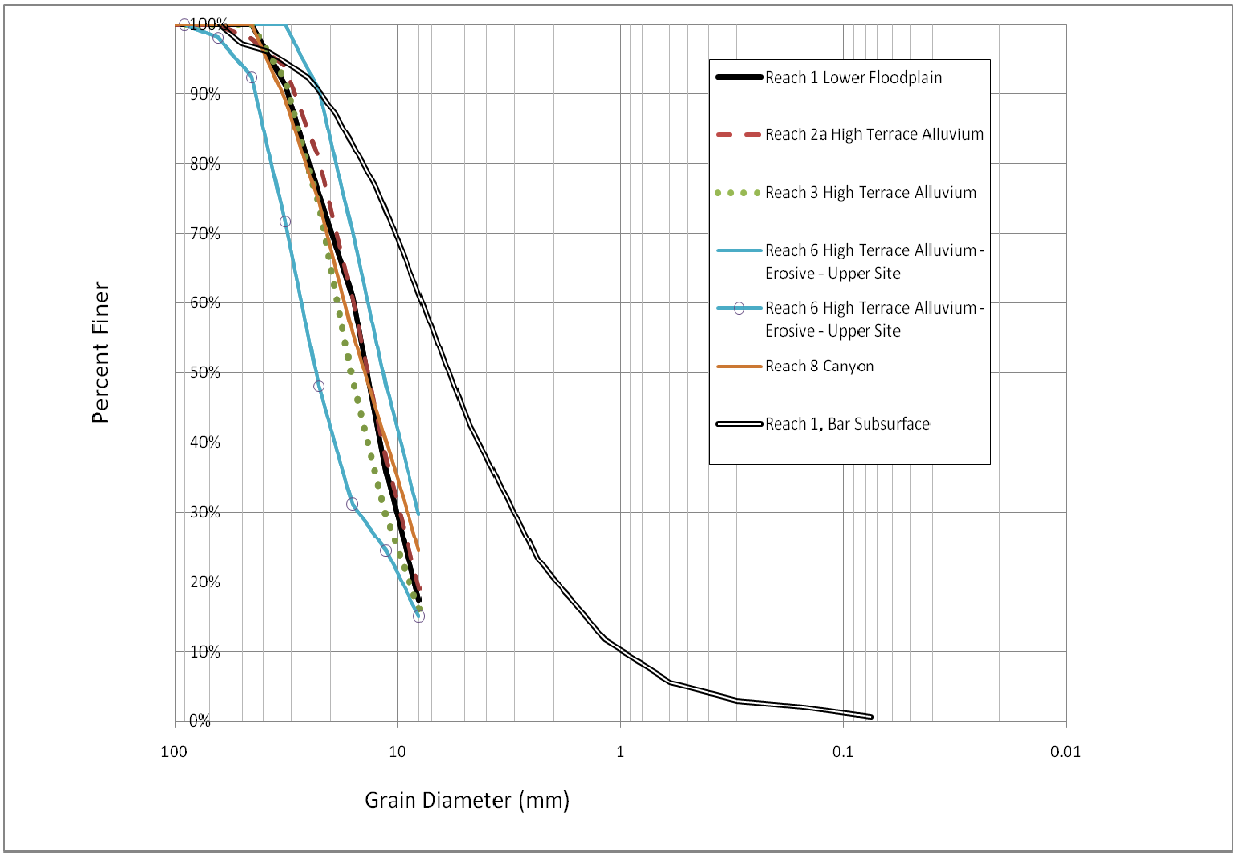

Figure 15: Pebble Count Results for All Reaches

Table 2: Survey Data Collected by OEI March 2010

	LOWER REACH							UPPER REACH	
Reach	**Reach 1 Lower Floodplain**	**Reach 2a High Terrace Alluvium**	**Reach 2b High Terrace Wilson Grove**	**Reach 3 High Terrace Alluvium**	**Reach 4 High Terrace Alluvium - Erosive**	**Reach 6 High Terrace Alluvium - Erosive**	**Reach 7 Lower Canyon**	**Reach 8 Canyon**	**Tributary**
Survey Date	3/8/2010	3/9/2010	3/9/2010	2/24/2010	2/24/2010	3/8/2010	2/24/2010	3/8/2010	2/24/2010
Length Surveyed Ft	1200	540	1200	1200	2500	1300	560	760	540
Channel Slope (%)	0.4	0.5	0.5	1	1	0.9	1	6	1.5
Hillslope % LB	ND	ND	ND	200	50	70	120	58	35
Hillslope % RB	ND	ND	ND	75	100	60	120	65	35
Flood Prone Width (ft)	85	60	30	42	46	40	25	42	17
Bankfull Width (ft)	40	25	20	30	22	30	21	30	14
Entrenchment Ratio FPW/BW	2.1	2.4	1.5	1.4	2.1	1.3	1.2	1.4	1.2
Bankfull Depth (ft)	5.8	5.0	7.0	5.8	5.8	4.5	3.6	3.4	1.3
Terrace Ht #1 (ft)	7	9	25	30	31	11	NA	NA	8
Terrace Ht #2 (ft)	12	19	NA	NA	NA	32	NA	NA	NA
Floodplain	Discontinuous	Discontinuous	Absent	Discontinuous	Discontinuous	Discontinuous	Absent	Discontinuous	Absent
Disturbance LB	NA	None	Rip Rap	Revetment and agriculture	Agriculture	Rip Rap	Rip Rap	Inner Gorge Mass Wasting, Road	Historic Logging
Disturbance RB	Agriculture	None	Rip Rap	Revetment and agriculture	Agriculture	None	Rip Rap	Inner Gorge Mass Wasting, Road	Historic Logging
Riparian LB	Hardwoods, Medium (30-50cm DBH), Dense	Hardwoods, Medium (30-50cm DBH), Dense	Hardwoods, Medium (30-50cm DBH), Dense	Bay, willow, alder, blackberry	Alder, Willow	Hardwoods, Medium (30-50cm DBH), Dense	Ivy, blackberry, suburban, mixed forest canopy	Hardwoods, Medium (30-50cm DBH), Dense	Bay, Redwood, Doug Fir
Riparian RB	Hardwoods, Medium (30-50cm DBH), Dense	Hardwoods, Medium (30-50cm DBH), Dense	Hardwoods, Medium (30-50cm DBH), Dense	Bay, willow, alder, blackberry	Alder, Willow	Hardwoods, Medium (30-50cm DBH), Dense	Ivy, blackberry, suburban, mixed forest canopy	Hardwoods, Medium (30-50cm DBH), Dense	Bay, Redwood, Doug Fir, Closed Canopy

	LOWER REACH							UPPER REACH	
Reach	**Reach1 Lower Floodplain**	**Reach 2a High Terrace Alluvium**	**Reach 2b High Terrace Wilson Grove**	**Reach 3 High Terrace Alluvium**	**Reach 4 High Terrace Alluvium - Erosive**	**Reach 6 High Terrace Alluvium - Erosive**	**Reach 7 Canyon**	**Reach 8 Canyon**	**Tributary**
Stream Side Mass Wasting: Abundance	None	Sparse	None	Sparse	Abundant	Abundant	Sparse	Abundant	Common
Stream Side Mass Wasting: Size	NA	1-5 x Bank Height	NA	1-5 x Bank Height	5-10 x Bank Height	5-10 x Bank Height	5-10 x Band Height	5-10 x Bank Height	1-5 x Bank Height
Bedrock/ Parent Material	Alluvium	Bedrock present but minimal	Bedrock Dominant	Clay alluvium, 1 bedrock outcrop	Clay, alluvium	Bedrock Significant First 200ft Above Bridge	Common bedrock and weathered bedrock	Bedrock Present but minimal	Clay and weathered bedrock, sandstone
LWD Presence	Common, Functional	Common, Functional	Sparse, Minimal	Sparse, Functional	Sparse, Functional	Common, Functional	Sparse, Functional	Sparse, Functional	Sparse, Functional
Bars	Abundant, Forced	Common, Forced	Few, Forced	Few bars (mobile bed material)	Common, Alternate/ Forced	Common, Forced	Common, Alternate	Few, Forced	Common, Alternate
Roughness	Live woody Vegetation/ Banks and Roots, LWD	Bedrock, Live Woody Vegetaion/Banks and Roots, LWD	Bedrock	Bed, riparian veg, banks	Riparian Veg and bed	Live woody Vegetation/ Banks and Roots, LWD,Bedrock	bed, banks, riparian vegetation	Boulders/ Bedforms, Banks and Roots, Live woody Vegetation	Bed, Banks, Small LWD
Channel Morphology Type	Forced Pool-Riffle	Forced Pool-Riffle	Forced Pool-Riffle/Plane Bed	Plane Bed/ Forced Pool Riffle	Forced Pool-Riffle	Forced Pool-Riffle	Plane Bed/ Forced Pool Riffle	Step Pool	Forced Pool-Riffle/Step Pool
D50 (mm)	See Fig. 15	See Fig. 15	See Fig. 15	26	20	17	30	See Fig. 15	33
D84 (mm)	See Fig. 15	See Fig. 15	See Fig. 15	94	79	32	94	See Fig. 15	137

Interpretation of Geomorphic Conditions

This section reviews aspects of channel geomorphology that relate directly to salmonid fish habitat. It considers rearing habitat with respect to pool abundance and characteristics and it considers spawning habitat with respect to bed characteristics and size distributions. Finally, the process of stream incision and bank stability is discussed.

Rearing Habitat

Pools are a critical element of rearing habitat needed by juvenile salmonids, particularly coho salmon. As discussed above, pools are reasonably abundant in Purrington Creek but lack depth and cover complexity. The gravel bed of the channel is readily deformed by channel roughness elements such as erosion resistant banks and woody debris. Woody debris abundance is relatively low in the channel. Where woody debris is present in the channel, it is generally associated with increased pool abundance, greater pool depth and complex cover, provided that the size or position of the woody debris allowed it to remain relatively stable during periods of high stream flow. Woody debris in streams also causes bank erosion if it induces scour against a stream bank. Stable woody debris also causes eddies and local backwater effects during periods of high flow that induce deposition of sediment in bar forms and velocity shelter for salmonids during periods of peak flow, an important element of winter rearing habitat. Shelter from high velocity flow is also found on the bed of the Canyon and Tributary reaches where cobbles and boulders are abundant. Overall, current geomorphic conditions produce rearing habitat that could be characterized as fair.

Spawning Habitat

The abundance of spawning habitat could not be easily judged during field surveys owing to relatively high winter flows. Based primarily on the size and geometry of pools and their associated riffles downstream, spawning habitat is present throughout the surveyed reaches in relatively small patches. Larger patches of gravel with well-formed pool tails transitioning to downstream riffles spanning the channel were relatively rare, and were most common in the Lower Floodplain reach and occur locally in the High Terrace Alluvium reaches.

The available data from field surveys pertaining to size distribution of sediment on bars is also generally indicative of spawning habitat availability and quality. The available data on subsurface sediment from bars adjacent to likely spawning habitat for Purrington Creek are extremely limited and should be regarded with caution. The data are generally consistent with similar data from upper Green Valley Creek (OEI 2003).

The median particle size (D_{50}) of bar surface sediments in Purrington Creek ranged from 11 mm to 32 mm and the surface particle size representing the framework gravel (D_{84}) ranged from 20 to 40 mm (Figure 15). The size distribution of sediment in bars was remarkably consistent throughout the surveyed reaches of Purrington Creek. As determined from the bulk sample from the Lower Floodplain reach, the median particle size of the bed material representative of spawning substrate was 6 mm and D_{84} was 17 mm (Appendix B). Given the aforementioned consistency of size distributions observed throughout Purrington Creek, the samples from the Lower Floodplain reach may potentially be representative of Purrington Creek.

The size distribution of sediment from coho redds listed in Kondolf and Wolman (1993) were summarized in order to facilitate a comparison with the sediment samples obtained for Purrington Creek. The median particle size in coho redds ranged from 5.4 mm to 35 mm, with an average of 20 mm (Kondolf and Wolman, 1993). The median subsurface particle size in Purrington Creek was 6 mm which falls into the low end of the range of ideal coho conditions.

Sediment grain sizes that are relatively fine (silt, sand and fine gravel) have been demonstrated to impair the quality of spawning gravels during the salmonid life stage when eggs are maturing in redds by clogging the space between larger framework grains in the bed sediment. Successful incubation of eggs to aelvins requires gravel permeable enough to allow for the flow of water through the redd. This intragravel water flow is important for supplying dissolved oxygen to the developing embryo, as well as for removing metabolic wastes (Kondolf and Wolman, 1993). Larger sediment grains ranging in size from 1-10 mm can block larger pores and prevent emergence from the redds (referred to as entombment).

Various particle size diameters have been used to define fine sediment that impairs flow through redds. Kondolf (2000) concluded that sediment finer than about 1 mm can reduce the permeability of spawning substrate and reduce intragravel water flow. Kondolf (2000) observed that a concentration of fine sediment <1 mm of 12-14% corresponded to an incubation survival rate of 50%, and suggested that this was a meaningful threshold for evaluating spawning gravel quality. The bulk sample for this survey indicated that only about 10% of the sediment was less than 1 mm in size (Figure 15). If representative, this sample suggests that fine sediment in Purrington Creek does not seriously impair spawning habitat with respect to incubation.

Kondolf's (2000) review of studies of coho emergence indicated 50% emergence corresponding with a proportion of sediment <3.35 mm of less than 33%. The data for subsurface sediment size distribution in Purrington Creek (Figure 15, Appendix B) for percent finer than 3.35 mm was about 32%. These data suggest that gravel in Purrington Creek has a sized distribution that is marginally favorable for spawning habitat with respect to emergence.

Field observations in the Canyon reach of Purrington Creek suggest that somewhat coarser grain size distributions may be expected in these steeper reaches. If so, spawning conditions in the Canyon reach might be somewhat more favorable with respect to the influence of finer sediment sizes.

Stream Incision and Bank Stability

The channel of Purrington Creek lies at an elevation substantially below the adjacent valley floor in Reaches 1 through 6. This grade separation prevents flooding in the valley, except possibly in Reach 1 downstream of Graton Road near the confluence with Green Valley Creek where the valley floor is only about 12 ft above the channel bed. Elsewhere the channel bed typically lies 30 ft below the valley floor. Evidence of active streambed erosion was observed in the High Terrace Wilson Grove reaches where bedrock is both abraded and quarried. Fresh exposures of bedrock near the base of the stream bank are contrasted with more weathered and vegetated exposures on the upper bank. Strath terraces (abandoned erosional surfaces adjacent to the channel) are frequently bordered by trench-like segments of bedrock-bounded channel. Bedrock knickpoints in the channel profile were observed in both High Terrace Wilson Grove reaches.

Reaches upstream of the High Terrace Wilson Grove units (Reaches 2b and 5) have been subject to recent bank slumping. In Reaches 2a and 3, some slumps have been repaired or prevented with rock revetments. In Reach 4 and 6, active slumps and bank erosion features are common. Slumps typically extend from the lower stream bank to the top of the terrace. Bank erosion features only affect the lower bank. Both types of erosion are channel widening processes that occurs in conjunction with channel incision. The higher degree of bank slumping in Reaches 4 and 6 suggests that the locus of active widening in response to incision has migrated upstream from the lower reaches of the creek. These zones of active slumping might also result from valley morphology affecting subsurface water conditions in the stream banks. The valley narrows upstream of Reach 3, and bedrock contacts underlying valley alluvium are closer to the stream channel in both vertical and horizontal space. This could cause the water table adjacent to Reaches 4 and 6 to be higher, potentially resulting in more extensive zones of saturation in the stream banks. This would increase susceptibility to slumping, particularly when combined with bank erosion that undercuts the toe of the banks. In addition, the texture of the bank material and the valley alluvium is relatively fine grained and sandy, and this material is vulnerable to failure after periods of high stream flow that saturates the banks. When flows recede, pore pressure in the soil in the stream bank is high and is no longer counterbalanced by the pressure of the water in the stream, greatly increasing potential bank failure.

The causes of channel incision in Purrington Creek are likely manifold. Tectonic uplift in the region is likely responsible for creating generally incised channel forms throughout the upland areas of western Sonoma County. Historic management practices are likely to have contributed to incision, particularly during the early periods of settlement by European immigrants and the development of agriculture. Forest vegetation was likely cleared in some areas which would increase runoff, and stream channels were likely managed to improve drainage and decrease susceptibility to flooding. The removal of woody debris from stream channels likely occurred, and this may have been sufficient to initiate a cycle of channel incision. In Purrington Creek, it is also possible that disturbance of local channel elevation controls in the lower watershed near Green Valley Creek could have been sufficient to induce channel headcuts that have migrated upstream. It is also possible that early agricultural development motivated efforts to confine and deepen the channel.

The rate of incision has not been previously documented. Estimates of the ages of trees on the lower banks provide some evidence regarding rates of channel downcutting. In addition, at one location in Reach 5 a living tree root spans the channel high above the bed. Based on the approximate age of trees and the elevation difference between the bed and the tree, channel incision rates appear to be on the order of one foot per decade. Associated rates of channel widening and bank retreat would likely add substantially to sediment supply to Purrington Creek, potentially affecting channel conditions in Purrington Creek and the Green Valley Creek watershed.

Hydrologic Modeling

The hydrologic model for Purrington Creek is expected to be capable of predicting streamflow and groundwater conditions over a variety of temporal and spatial scales based on daily rainfall records. The availability of groundwater and streamflow data is likely to limit the degree of model calibration and the spatial scale at which useful simulations can be developed. Model calibration will be made possible by the new stream gauging station put into operation by the GRRCD in early 2010. The initial version of the model will evaluate the magnitude of potential change in streamflow and groundwater levels in relation to changes in land use, and will be used to investigate factors that influence summer baseflow levels in Purrington Creek.

Recommendations

This section identifies supplemental data collection, hydrologic analyses, monitoring activities and stream restoration and management that may contribute to improvement of aquatic habitat and other watershed management objectives. The recommendations are presented without particular regard for priority, however all recommendations are considered to be feasible. The recommendations pertain to the chief geomorphic issues affecting Purrington Creek and its aquatic resources: channel sedimentation, particularly by fine gravel and sand, channel incision and bank stability, and pool development and quality.

Additional Research

As discussed in the preceding section, evaluation of watershed hydrologic conditions through further model development and calibration are expected to identify critical factors affecting runoff patterns, groundwater and summer base flow conditions. Hydrologic modeling may also prove useful in evaluating bank stability conditions that could be affected by water table position. Analysis of base flow hydrology is likely to be the element of the hydrologic model of most relevance to fish habitat condition.

Further field surveys of the stream channel network should be conducted to characterize the tributary channels with respect to potential fish habitat and erosion and sedimentation. Significant fish habitat appears to be present in the upper watershed upstream from the reaches surveyed by CDFG in 1994 and in this assessment. All tributaries should be considered potential sediment sources, particularly areas underlain by in the Wilson Grove Formation. Tributary channels may also play an important role in routing sediment from upland areas to the mainstem channels. A sediment budget for the watershed should be developed to identify the chief erosion processes likely to control channel sedimentation.

Channel bed monitoring would be appropriate if management plans for the watershed target erosion and sedimentation. Additional detailed channel surveys would be necessary for a monitoring program pertaining to channel and habitat conditions. Channel sedimentation status might best be monitored by sampling and analysis of surface and subsurface size distributions to evaluate trends over time and to more accurately characterize habitat conditions for fish (e.g. OEI 2003, OEI 2006). The volume of fine sediment in pools can be monitored in some channel systems, and this approach should be considered in Purrington Creek. Channel incision and bank erosion processes can be monitored by repeated cross-section or topographic surveys. These types of monitoring provide perspective on processes over periods of years.

Channel Incision and Bank Stability

Based on field reconnaissance conducted in this assessment, channel incision processes appear to be active in Purrington Creek. Bank slumps and bank erosion features are common in Reaches 4 and 6, and are likely related to channel incision. Regardless of the causes, bank slumps and bank erosion add substantial amounts of sediment directly to reaches of Purrington Creek believed to be occupied by salmonids and contributes to sedimentation problems in the Upper Green Valley Creek watershed. Bank stabilization in Reaches 4 and 6 should be considered a high priority for watershed management to reduce sedimentation impacts and to protect property. A variety of approaches to bank stabilization are possible. Stabilization of failed banks has been accomplished with rock revetments. Alternatives include bioengineering techniques that utilize riparian plants (typically willow) to stabilize banks, with or without grading to lay back bank slopes to stable angles. It should be noted that many recent bank slumps were vegetated, and that further investigation of the species, age and density of riparian vegetation in relation to bank stability in Purrington Creek may be warranted. Hydrogeologic factors that drive bank slump processes might also be manipulated to reduce bank instability. This approach would seek to reduce soil saturation in stream bank material, however, the feasibility of reducing water table elevations in stream banks would require further study.

Channel incision processes could potentially be arrested or reversed by installation of channel grade controls in the stream bed. This type of stream engineering requires careful planning to avoid potential unintended consequences. Given the strong evidence of channel incision, its likely association with bank erosion processes, and the vulnerability of the channel bed to further erosion, serious consideration should be given to development of a program of channel grade control in lower Purrington Creek (Reaches 2 through 6). The use of natural materials, such as wood and rock, would be strongly preferred to concrete in order to promote habitat complexity over the long term, as well as for aesthetics. Design criteria for grade control structures should include fish passage, local habitat development (pools downstream of structures), and avoiding locations and designs that could destabilize stream banks. In stream structures that would reduce local stream energy by lowering the water surface gradient would also accumulate sediment upstream, which could affect the extent of stream habitat available for salmonids. Substantial sediment accumulation within the channel banks could potentially reduce the extent and severity of bank erosion if thoughtfully planned and carefully managed. Consequently, planning for grade control should anticipate the need to manage channel morphology to maintain or expand rearing habitat for fish. This is discussed further in the following section.

Pool Development and Enhancement

As noted in the geomorphic assessment, bed conditions are responsive to woody debris, and woody debris abundance in Purrington Creek is limited. Woody debris is often identified as a critical component of fish habitat known to be associated with high quality rearing habitat. Woody debris (logs, rootwads, whole trees and branches) forms complex pools and bars in stream channels, either as single stable pieces or in larger accumulations and debris jams. These types of channel features may also cause local bank erosion. Prior to settlement of the Purrington Creek watershed, it is likely that woody debris was more abundant in the channel, and would have been expected to include numerous decay resistant redwood and douglas fir logs in addition to other riparian species, in a variety of sizes and states of decay.

Habitat restoration efforts in many coastal streams in northern California include placement of logs in channels to create or enhance pool habitat. This appears to be an appropriate strategy in Purrington Creek as well, however, consideration should be given to its potential effect on bank stability. In addition, the channel geometry and hydrology of Purrington Creek creates relatively high water depth and locally high velocity that could affect the stability of wood structures. Structures should be designed to remain stable during peak flow periods and to avoid creation of scour zones that would be likely to affect bank stability. These constraints suggest that relatively large wood structures that focus scour energy near the center of the channel or against stable banks would be most appropriate. If grade control structures are to be developed, the design of wood structures should be incorporated in areas upstream of grade control to maintain or enhance desirable habitat.

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APPENDIX A: Stream Channel Characterization Protocol

PURRINGTON CREEK WATERSHED ASSESSMENT

STREAM CHANNEL CHARACTERIZATION PROTOCOL

The following definitions describe a channel survey protocol based on systematic quantitative and qualitative observations of channel conditions at a given survey reach. It is comparable to versions of Form E-4 presented in the Washington Department of Natural Resources methods (Washington Board of Forestry, 1997), but has been streamlined for efficiency. It differs from the WDNR standard protocol in form, but provides equivalent descriptors of channel conditions pertaining to the streambed composition, form and process in the active channel, and the interaction between the channel and its banks and flood plain.

These survey data will be collected in reaches that are geomorphically distinct as determined by observations made during the field survey.

In this protocol designed for Purrington Creek watershed assessment, we have added significantly to quantitative data collection pertaining to large woody debris, gravel bars, and sediment size distribution. When combined with the fish habitat assessment data including quantitative data on pools, the data set will characterize quantitatively the key parameters of relating stream morphology to fish habitat. In addition, most of the qualitative data can be statistically analyzed as ordinal data. These data typically express the relative magnitude of a process or channel characteristic (e.g., floodplain continuity, bedrock abundance in the bed). Ordinal data are identified as such in the protocol. Other types of qualitative data are descriptors that do not have an ordinal sense (e.g., roughness elements, historical channel disturbance).

CHANNEL AND VALLEY GEOMETRY

Channel geometry will be characterized based on a scale cross-section sketch of a representative location in the channel, typically in a relatively straight portion of the channel with few obstructions at a riffle where bankfull flow hydraulics are expected to be relatively uncomplicated. Following is a description of the specific data to be collected; except for channel slope and pool count, the data will be collected at the representative cross-section location as determined in the field. The term “bankfull flow” in this context corresponds to flow levels that occur at recurrence intervals of 2 year or less.

Channel Slope: [%] Will be collected using a clinometer. Slope will be measured in a representative stretch of stream with two people holding clinometers. One person will measure the slope looking uphill and the other person will measure the slope looking downhill for the same stretch of stream. The average of the two observations will be recorded.

Hillslope Angle Left Bank and Right Bank: [%] Number is the maximum and/or average observed stream bank hillslope angle measured in the field with a clinometer. The angle of both streambank slopes is recorded in a valley cross-section sketch in field notes.

Flood Prone Width: [#] Defined by Rosgen (1994) as the width of the horizontal surface at an elevation twice the "bankfull" depth. The flood prone zone is defined by the intersection of the horizontal plane at 2 times bankfull depth and the ground surface of a hillslope or terrace. The valley width does not always coincide with the flood prone width. This information is typically provided in a valley cross-sections sketch.

Bankfull Channel Width: [#] Number is the measured width (ft) of the "bankfull" channel, defined by high-water marks indicated by strand lines, fluvial sediment deposits, and the boundary formed by vegetation at the channel margin. This width is intended to approximate stream stage corresponding to "effective discharge" proposed by Wolman and Miller (1960). This width is often somewhat less than the width defined by a horizontal line connecting the tops of opposite banks. When a portion of the bankfull width of the channel contains riparian vegetation, the bankfull width is apportioned into "vegetated" and "active" components.

Bankfull Channel Depth: [#] Number is the measured average depth (ft) of flow at "bankfull" stage corresponding with field evidence defining bankfull width (i.e., "effective discharge") at the representative cross-section location. Not normally equal to the top of the bank, which is often the elevation of the low terrace or flood plain.

Terrace Heights: [#] Average measured height of terrace surfaces above average elevation of channel bottom. Includes an observation for the flood plain, and an observation for any terrace surfaces present. A zero indicates that the given terrace was absent. The relative positions of terraces are typically represented in a cross-section sketch of the valley in field notes. Terrace Heights for left bank and right bank are recorded separately.

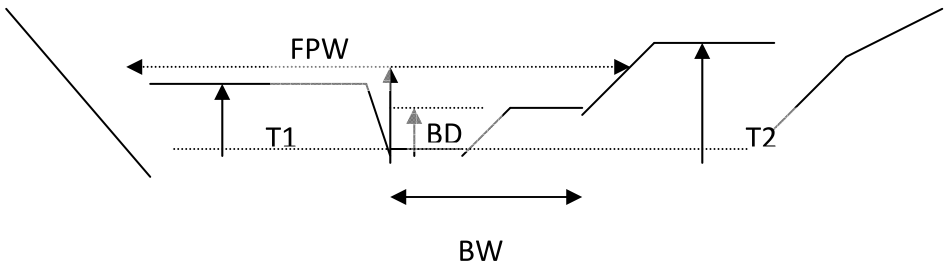
Definition Sketch for Channel and Valley Geometry

Legend

BD = bankfull depth BW = bankfull width

T1 = height of terrace 1 T2 = height of terrace 2

FPW = flood prone width (measured @ twice BD)



RIPARIAN, FLOOD PLAIN, AND BANK CONDITIONS

The following qualitative data supplement data collected in the California Rapid Bioassessment Protocol pertaining to riparian zone and streambank conditions. Similar data collected in the channel protocol were eliminated to avoid duplication of effort.

Flood Plain: [Ls] Letter represents the observed distribution of vegetated flood plain that is occupied during periods of peak flows substantially greater than bankfull flow. For purposes of this survey, the floodplain considered here is substantially higher than the bar top elevations that are often formed during bankfull flows (2 year recurrence interval or less). Evidence indicating flood plain extent includes side-channels, strand lines, sediment deposits, and vegetation; when prominent evidence of overbank flow is observed, the lowercase "ob" is included. Where overbank side-channels are observed, the lowercase "sc" is added. The longitudinal continuity and presence or absence of an active flood plain are assessed. In channels steeper than about 4% slope, the "flood plain" may consist of poorly sorted coarse sediment and debris laying in bars adjacent to the channel deposited during episodes of peak flow. The descriptors below are ordinal with respect to extent of flood plain.

N = No flood plain or terrace (i.e., a severely confined channel)

T = Terrace (no evidence of historic flow **)**

D = Discontinuous but significant flood plain

C = Continuous or nearly continuous flood plain

ob = significant evidence of overbank flow; e.g., deposits, strand lines

sc = side-channels, overbank/overflow channels present

Disturbance: Descriptions of the observed disturbances that may have affected the condition of the channel or the riparian zone. *These are given in no particular order* , are not ordinal in character, and are intended merely to note historic disturbances that could be influential. Disturbances are noted separately for left and right banks.

Streamside Mass Wasting: [LL] Criteria similar to those for bank erosion. It should be acknowledged that the distinction between bank erosion and streamside mass wasting can be difficult to determine. However, streamside mass wasting is usually associated with a landform (e.g., inner gorge) or material type (e.g., lacustrine clay), and appears to be caused by at least one mechanism other than bank erosion. This observation can be important to assessment of sediment supply to channels. These features are of a scale that rarely can be seen in aerial photography, and are unlikely to be recognized in other assessment modules. The size of streamside mass wasting features is scaled by the ratio of their height relative to average bank height (bh) as defined below.

Abundance (ordinal):
None
Sparse = erosion features <5% of reach length
Common = erosion features 5 to 20% of reach length
Abundant = erosion features >20% of reach length
Size (ordinal):
Small = height > bh, up to 5(bh)
Medium = 5(bh) ≤ height ≤ 10(bh)
Large = height > 10(bh)

POOL COUNT, TYPE AND INSTREAM COVER RATING

Pools: Pools will be tallied for each geomorphically distinct reach surveyed. Pools will be categorized by type. Pool types are: Lateral Scour Pool (Bedrock/Bank), Plunge Pool, Dam Pool, Log Enhanced Lateral Scour Pool, Mid Channel Pool and Step Pool. Pool categories are defined in the California Salmonid Stream Habitat Restoration Manual, Third Edition published by the California Department of Fish Game. See aforementioned stream manual for explanations of pool types. Each pool was recorded by type and by quality of instream cover. Instream cover was categorized qualitatively as Poor, Fair, or Good. For reference these cover characterizations can be correlated to the CDFG instream shelter complexity values and overall CDFG instream cover scores as follows (again the CDFG descriptions of instream shelter complexity scores and % cover are in the Stream Habitat Restoration Manual mentioned above). A Poor cover classification correlates to a complexity value of 1 and 0-15% cover, with an overall shelter score range of 0-15. A Fair cover classification correlates to a complexity value of 1 or 2 and 16-

20% cover, with an overall shelter score range of 16-40. A Good cover classification correlates to a complexity value of 2 or 3 and >21% cover, with an overall shelter score of >41.

Pools will be defined in the field as occupying at least ½ of the width of the low flow channel and be as long as the low flow channel width. They will also be defined as having some downstream definition to distinguish them from flatwater or a glide.

STREAM CHANNEL AND STREAMBED CHARACTERISTICS

The following qualitative data supplement data collected in the California Rapid Bioassessment Protocol pertaining to riparian zone and streambank conditions.

Bedrock/Parent Material: [L...] Letter (and additional notes) represents the presence, absence, and extent of bedrock exposed in the channel bed and channel margins observed in the field. If other types of parent material (e.g., indurated glacial till, lacustrine clay, saprolite, etc.) are observed, this is noted; the key observation is exposure of nonalluvial material and the bedrock type, either a descriptive note (e.g., competent sandstone) or an abbreviation for the geologic formation, if known. These are ordinal data.

N = None observed

M = Present but minimal

C = Common

D = Dominant

Channel Roughness Elements: [LLLLL] Letters represent the channel elements that provide resistance to flow at bankfull stage in descending order of importance; the dominant element is listed first. If elements are equally influential, they are separated by a "/". These data are not ordinal.

B = Boulders

C = Cobbles

V = Live woody vegetation

R = Bedrock

Bk= Banks and Roots

W = Large woody debris

F = Bedforms (large gravel bars or step-pool sequences)

Channel Type: [LL/LL] Letters indicate the dominant and subdominant (or co-dominant) channel reach types as defined by Montgomery and Buffington (1997), and briefly described in the main text). Two types are often necessary to characterize the morphology of a given location. These data are not ordinal.

C = cascade **SP** = step-pool **PB** = plane bed **(f)/PR** = (forced) pool-riffle

R = regime **Co** = colluvial **BR** = bedrock

WOODY DEBRIS, GRAVEL BARS AND SEDIMENT SIZE DISTRIBUTION

LWD: A qualitative survey of LWD will be collected to provide data on the abundance of LWD that would be expected to contribute significantly to the quality of fish habitat. LWD will be counted when a piece at least 1 ft (0.3 m) diameter and 6 ft (1.8 m) long is encountered within the bankfull channel.

[LLjL] Letters describe the relative abundance and effectiveness of LWD in the bankfull channel. The first letter refers to abundance. The second letter refers to the degree of function of LWD that is present; the subscript 'j' refers to LWD that is functional primarily in LWD jams rather than as isolated pieces.

Abundance: **S**parse **C**ommon **A**bundant

Function: **M**inimal = LWD present in the channel has insignicant effect on local channel processes. **F**unctional = LWD present in the often has significant effect on local channel processes. **D**ominant = LWD exerts an overwhelming influence on channel function and morphology.

Bars: A qualitative survey of gravel bars will be collected to provide data on the abundance of sediment being actively routed through the channel. Bars are recognized in the field by their topographic relief relative to the thalweg and the finer distribution of sediment on the bar surface relative to the framework sediment found in riffles and the thalweg. In other words, it is expected that bars represent a depositional sediment facies with bar median size finer than channel thalweg/riffle median size, excluding pools. Where sand is abundant, the size criterion may be relaxed. Abundance of bars will be noted for each reach, as well as their distinguishing features and the dominant geomorphic processes forming them.

[LLLL] Letters represent the relative abundance and type of bars (accumulations of mobile sediment) in and adjacent to the channel. The first letter in the sequence indicates the abundance; subsequent letters indicate the type of bar. If different types of bars are present in substantial numbers, then sub-dominant bar types are indicated with subsequent letters in descending order of relative abundance. A "/" separating letters indicates that the bars are of equivalent abundance; similarly, if two different bar types are present and they have different levels of abundance, then a letter code for abundance appears associated with each bar type.

Abundance: **F**ew = present, but comprise an insignificant portion of the surface area within the bankfull channel. **C**ommon = bars frequently occur and occupy a significant portion of the surface area within the bankfull channel. **A**bundant = bars are nearly continuous and occupy the majority of the surface area within the bankfull channel.

Bar Types: **F**orced = bars formed upstream and downstream of channel obstruction such as boulder or LWD steps. **P**oint = point bars formed in alluvial settings opposite pools at outsides of meander bends; reserved for low gradient riffle-pool morphology where helical flow at meander bends is present. **M**edial or Multiple = bars forming in center of channel or in a braided channel or in a complex pattern such as might be found at a LWD jam. **I**solated = bars are isolated to patches with low relief on the bed formed in the lee of small channel obstructions that do not span the channel such as boulders; typically used in plane-bed morphology. **A**lternate = Lateral linear bars on channel margins, typically on alternate sides of channel, often with relatively low relief

Surface Sediment Size Distribution: Surface sediment size will be characterized using 100 point pebble counts conducted at geomorphically distinct locations. These pebble counts are expected to specify the median size for each location within 15% of the true median. At each surveyed cross section the D50 and D84 will also be visually estimated.

Sediment particles will be categorized according to the sieve mesh diameter upon which the particle would be captured by measuring the intermediate axis of the particle with a ruler. The minimum size discriminated for this survey will be 8 mm; the diameter classes in millimeters will be 8, 11, 16, 22, 32, 45, 64, 90, 128, 180, 256, 360, 512, 720, 1024 etc.

Bulk samples will be collected and processed at a qualified lab to determine the percent fines in the stream bed. Bulk samples will be collected at the riffle crest or adjacent to riffle crest, whichever is the more representative substrate. Samples will be collected 1 foot deep with a shovel. Samples will then be dried out and sent to a lab for analysis.

APPENDIX B: Bulk Sample Lab Analysis

Sieve analysis

ASTM C 136

Analyst name: SCL
Test date: 3/16/2010
Sample: PUR Reach 1

Total sample mass = 18692.5 g

US sieve number	Sieve opening (mm)	Mass retained (g)	Cummulative % Finer
3.5	90	0.0	100.0
3	75	0.0	100.0
2.5	63	0.0	100.0
2	50	512.6	97.3
1.5	37.5	213.2	96.1
1.0	25.0	716.7	92.3
3/4	19.0	961.6	87.1
1/2	12.5	1959.5	76.7
3/8	9.5	1755.4	67.3
4	4.75	4631.9	42.5
8	2.36	3587.2	23.3
16	1.18	2139.6	11.8
30	0.6	1160.9	5.6
50	0.3	509.0	2.9
100	0.15	177.8	2.0
200	0.075	260.6	0.6
PAN		106.7	0.0

Sieve analysis

ASTM C 136

Analyst name:
Test date:
Sample:

Total sample mass = g

US sieve number	Sieve opening (mm)	Mass retained (g)	Cummulative % Finer

ASTM C 136: Standard Method for Sieve Analysis of Fine and Coarse Aggregates

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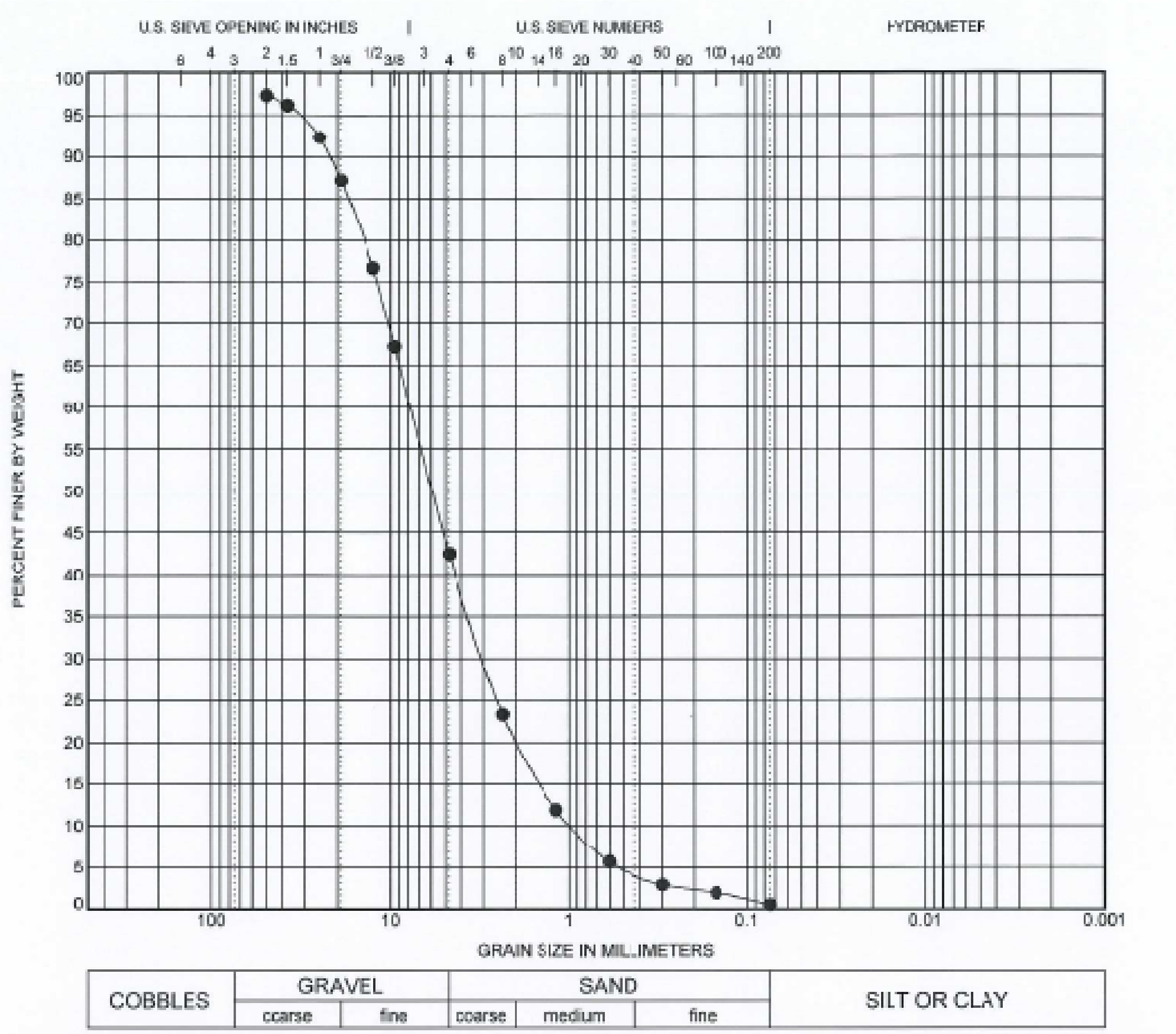
1



	Specimen Identification	Classification	LL	PL	PI	Cc	Cu
●	PUR-Reach 1	GRAY WELL-GRADED GRAVEL (GW) WITH SAND				1.21	8.04

	Specimen Identification	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	PUR-Reach 1	50	7.753	3.013	0.965	54.8	41.9	0.6	

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Appendix 7. Coho and Steelhead Life Histories

Coho Salmon (*Oncorhynchus kisutch*)

Coho salmon, historically known as silver salmon, is federally and state listed as endangered. Coho salmon, as well as other salmonids, are anadromous fish[1]. They reach about 55 – 70 cm in fork length[2]. Spawning males usually have dark green on the head and back, with intensely dark red sides. They are characterized by strongly hooked jaws and slightly humped backs. Females are typically paler than males with dull, dark pink sides and only slightly hooked jaws. Small black spots can be found on both sexes in the back, dorsal fin[3], and upper lobe of the caudal fin[4]. The gums are generally whitish at the base of the teeth in the lower jaw (Moyle 2002). Juveniles generally have narrow, widely spaced parr[5] marks centered along the lateral line[6]. Juveniles can be identified by sickle shaped dorsal and anal fins. These fins usually have a leading edge of black and white. They are silver in color and have thinner parr marks than steelhead trout.

Populations were once found in California in most coastal streams from the Smith River in Del Norte County, south to the San Lorenzo River in Santa Cruz County. Today, the southernmost populations are found in Scott and Waddell Creeks in Santa Cruz County, although a small run is maintained in the San Lorenzo River by artificial propagation (Moyle 2002). While the Russian River falls within the range of coho salmon, wild coho salmon are currently extirpated in this watershed, including Green Valley Creek.

Spawning generally occurs from November to January, although when drought conditions occur, the spawning period can extend through February or March. Eggs incubate in gravels from November to April and hatch out after about 40 days. Alevins remain in the interstices[7] of the gravel for two to ten weeks until their egg sacs have been absorbed. At this point, they are considered fry and they emerge from the gravel between March and May. Fry seek out shallow water and can usually be found along

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[1] Anadromous fish live a portion of their life cycle in the ocean and a portion in fresh water.
[2] Fork length is the distance from the snout to the middle of the fork of the caudal fin.
[3] The dorsal fin is the fin located on the midline on the back of fish. It is used to help maintain balance.
[4] The caudal fin is tail fin of the fish and is usually forked.
[5] Parr marks are vertical, oval shaped bands on sides of fish.
[6] The lateral line runs along the sides of fish from the branchio-stegal rays to the caudal fin. This line functions to help the fish detect vibrations and disturbances in the water.
[7] Interstices refers to the space between particles or gravels.

stream margins. By July and August they are termed parr[8] (juveniles) and usually inhabit deep pools (CDFG 2004). Parr rear in streams throughout fall and winter and begin emigration to the ocean in the spring around March or April. At this stage, they are called smolts[9]. Smolts spend a few weeks in estuaries before entering the ocean. The time spent in an estuary allows smolts to build up a tolerance to saline ocean conditions and also gives them time to grow, increasing their chances of survival in the ocean. After spending two years in the ocean, adults return to their natal[10] streams to spawn.

Coho salmon have different habitat requirements during their various life stages. They are highly temperature sensitive, requiring cold water and mature riparian vegetation and low velocity pool habitats associated with complex stream channels. While migrating upstream to spawn, coho require frequent deep pools to provide refuge from predators and places to rest. Deep pools also provide them with the ability to leap over obstacles – pools need to be 25% deeper than the height of the jump to allow fish to attain the necessary velocity for leaping (Flosi et al. 1998). During spawning, females generally select sites at the head of a riffle[11] where there is good water circulation. Most redds[12] are located in areas where the substrate is comprised of gravel 15 cm diameter or smaller. The amount of fine sediment in the interstitial spaces of the gravel must be minimal to ensure adequate circulation of oxygenated water for the eggs to survive (see *Chapter II, Section F*). Fry and juveniles rear in low-gradient coastal streams and tributaries of larger rivers. They prefer streams with abundant deep pools formed by large woody debris (CDFG 2004). Adequate canopy cover is necessary to keep water temperatures cool in the summer and provide detritus for macroinvertebrate prey. Adequate winter rearing habitat in the form of deep pools with large woody debris or other cover provides velocity refuges in high flows. During emigration, smolts require adequate flow and instream cover to protect them from predators while they migrate downstream to the ocean.

Steelhead trout (*Oncorhynchus mykiss*)

Steelhead troutare also referred to as rainbow trout. Like Coho salmon, they are anadromous fish. Steelhead trout adults range in size from 35 to 65 centimeters in fork

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[8] Parr is another term used to describe juvenile salmonids. They are characterized by vertical bands on sides of their body.
[9] Smolt refers to the juvenile life stage before entering the ocean. During this period the body chemistry changes allowing the fish to live in salt water.
[10] The natal stream is the stream of origin.
[11] Riffles are shallow sections of stream where ripples are formed by obstructions cobbles and boulders.
[12] Redds are gravel or cobble nests built by salmonids in streams to deposit eggs for fertilization and incubation.

length. Adults usually exhibit a silvery color and an iridescent pink to red lateral band. Black spots are typically found on the tail, adipose fin[13], dorsal fin and back. The young are similar in appearance to the adults except they also have oval parr marks centered on the lateral line (Moyle 2002).

Populations were once found in California from the Klamath River drainage in Northern California south to San Diego County (Moyle 2002). Steelhead trout in the Green Valley Creek Watershed are part of the Central California coast steelhead population. These populations include winter steelhead from the Russian River south to Aptos Creek in Santa Cruz County. Winter steelhead trout are fish that return to freshwater streams from the ocean from November through April.

In the Russian River and its tributaries, spawning generally occurs from January to March (CDFG 2002). Steelhead trout usually return to the ocean after spawning and may repeat their journey to spawn in streams up to three or four times during their lifespan. Eggs incubate in gravels for about 50 to 60 days. Upon hatching, alevins remain in the interstices of the gravel for two to three weeks until their egg sacs have been absorbed. When they emerge from the gravel, they are considered fry. Fry seek out shallow water and can usually be found along stream margins. By July and August they are termed parr (juveniles) and tend to inhabitat deep pools (CDFG 2004). Parr rear in the streams throughout the fall and winter and then begin emigration to the ocean in the spring around March or April – at this stage they are called smolts. Smolts spend a few weeks in estuaries before entering the ocean. Time spent in an estuary allows smolts to build up a tolerance to saline ocean conditions as well as giving them time to grow, which increases their chances of survival in the ocean. After spending two years in the ocean, adults return to their natal streams to spawn. Some steelhead trout return to spawn after spending only one year at sea. These immature fish usually measure 25 – 35 cm fork length and are referred to as "half pounders" (Moyle 2002).

Steelhead trout prefer cool, clear, fast-flowing water where riffles predominate over pools. Adequate cover from riparian vegetation and undercut banks are an important component of preferred habitat. They need diverse and abundant invertebrate life and cool water temperatures, with the optimal being 15-18 degrees celcius. Juveniles can be found in deeper faster water, usually among cover such as rocks. Larger fish stay close to fast water that can deliver drifting invertebrates, such as inflowing water at the head of pools (Moyle 2002). They feed mostly on drifting aquatic organisms and terrestrial

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[13] A type of second dorsal fin lacking supporting rays on the back of fish.

insects and sometimes on smaller fish. For spawning, seven inches is the minimum depth required for the successful migration of adult steelhead. Adult steelhead need pools for resting and holding during their upstream migration.

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Appendix 8. Habitat Inventories Summary

CDFG Habitat Inventories for Green Valley and Purrington Creeks (from CDFG 2006)

Stream	Date of survey	Water temp in °F[1]	% Pools by length	% Pools with max depth[2]		Mean shelter rating in pools[3]	# of low gradient riffles w/ either gravel or small cobble as dominant substrate [4]	% gravel/cobble embeddedness in fine sediment rating of 3 or4 [5]	% of pool tail-outs w/cobble embeddedness < 25%	% canopy[6]
				>3 ft	>2 ft					
Green Valley Creek mainstem	6/95 – 9/95	54°F to 86°F	34%	30%		20	21 of 41	75 – 100% in reaches 1 through 3 and 6	60% in reaches 4 and 5	82%
Purrington Creek	8/94 – 11/94	50°F to 66°F	28%		38%	18	55 of 64	51% in reach 1		90%

[1] Temperatures at or above 65°F are considered above the stress threshold for salmonids.

[2] In first and second order streams a primary pool is defined to have a maximum depth of at least two feet, occupy at least half of the width of the low flow channel and be as long as the low flow channel width. In third and fourth order streams a primary pool is defined to have a maximum depth of at least three feet.

[3] A pool rating of approximately 80 is desired. Log and root wad cover in the pool and flatwater habitats would improve both summer and winter habitat.

[4] High percentages are generally considered good for spawning salmonids.

[5] Cobble embeddedness measured to be 25% or less (rating 1) is considered best for the needs of salmon and steelhead.

[6] Canopy cover of 80 percent or higher is considered good.