Mill Creek
Streamflow Improvement Plan

Prepared by:

The Russian River Coho Water Resources Partnership

Sea Grant California UCCE

cemar rehabilitating California coastal streams

Water Institute Occidental Arts & Ecology Center

Trout Unlimited

Sonoma Resource Conservation District

Gold Ridge Resource Conservation District

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Acronyms

AF	Acre-Feet or Acre-Foot
AWEP	Agricultural Water Enhancement Program
BACI	Before-After Control-Impact
BMI	Benthic Macroinvertebrate
CCC	Central California Coast
CDFG	California Department of Fish and Game
CDFW	California Department of Fish and Wildlife (formerly CDFG)
CEMAR	Center for Ecosystem Management and Restoration
CI	Confidence Interval
CSG	California Sea Grant
DO	Dissolved Oxygen
DPS	Distinct Population Segment
EDSU	Emergency Small Domestic Use Registration
ESU	Evolutionarily Significant Unit
eWRIMS	Electronic Water Right Information Management System
FRGP	Fisheries Restoration Grant Program
GIS	Geographic Information System
GRRCD	Gold Ridge Resource Conservation District
KIBP	Keystone Initiative Business Plan
MWAT	Maximum Weekly Average Temperature
MWMT	Maximum Weekly Maximum Temperature
NCRWQCB	North Coast Regional Water Quality Control Board
NFHAP	National Fish Habitat Action Plan
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NOAA	National Oceanic and Atmospheric Administration
NOAA-RC	National Oceanic and Atmospheric Administration Restoration Center
OAEC	Occidental Arts and Ecology Center
PAD	Passage Assessment Database
PIT	Passive Integrated Transponder
POD	Point of Diversion
PPT	Precipitation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RM	River Mile
SD	Standard Deviation
SDU	Small Domestic Use (Registration)
SCC	State Coastal Conservancy
SCWA	Sonoma County Water Agency

SIP	Streamflow Improvement Plan
SRCD	Sonoma Resource Conservation District
SWRCB	State Water Resource Control Board
TU	Trout Unlimited
UC	University of California Cooperative Extension and California Sea Grant's Russian River Coho Monitoring Program
UCCE	University of California Cooperative Extension
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WDMP	Water Demand Management Program
YOY	Young-of-the-Year (age 0+ fish)

Executive Summary

The Russian River Coho Water Resources Partnership prepared this Streamflow Improvement Plan (SIP) as part of the Russian River Coho Keystone Initiative. The Keystone is an effort led by the Partnership with support from the National Fish and Wildlife Foundation. Since its establishment in 2009, it has grown to include many other funding and conservation partners.

The purpose of the Keystone is to restore a viable self-sustaining population of coho salmon in the Russian River watershed. The Partnership selected five focal watersheds, all sub-basins within the Russian River watershed, in which it aims to (1) restore a more natural flow regime, (2) increase the viability of juvenile coho and numbers of returning adult coho, and (3) increase water supply reliability for water users.

The Partnership applies a systematic, watershed-scale approach that brings together landowner interests, streamflow and fish monitoring, technical, planning and financial assistance, and water rights and permitting expertise to modify water use and management to improve instream flow.

This Streamflow Improvement Plan is a roadmap for prioritizing and implementing streamflow improvement projects with multiple public benefits and a diversity of approaches in the Mill Creek watershed. Mill Creek is the second of five watersheds for which we are developing Streamflow Improvement Plans. The others are Grape Creek, Dutch Bill Creek, Green Valley Creek, and Mark West Creek (though completion is depending upon available funding).

Mill Creek Streamflow Improvement Plan

The purpose of the Mill Creek Streamflow Improvement Plan (SIP) is to identify specific measures that moderate the impact of dry season water demand and improve instream flow for coho salmon and ecosystem function. Our goal is to manage water demand through conservation, storage and modified diversion practices in order to maintain a flow regime that is protective of the various life history stages of salmon.

Section 1 provides an overview of the Russian River Coho Water Resources Partnership, describes our rationale for selecting Mill Creek as a focal watershed under the Keystone Initiative, and describes the purpose of the SIP and its nexus with other watershed planning efforts.

Section 2 describes rainfall and streamflow patterns in the Mill Creek watershed.

Section 3 analyzes human water needs relative to available water supply and streamflow at different temporal scales. Sufficient water is available in Mill Creek to meet human needs on an annual scale. By reducing the disparity between discharge in the rainy versus dry seasons and use in the dry versus rainy season, we can meet human and fisheries needs.

Section 4 summarizes the presence and status of coho salmon in Mill Creek and their relationship to flow and habitat.

Section 5 uses the information in Sections 3 and 4 to provide recommendations and describe permitting considerations. It also provides a preliminary calculation of water availability for permitting purposes (based on the criteria provided by the State Water Board). This Section provides a roadmap for achieving both the physical/infrastructure and social/management changes necessary to ensure streamflow improvement.

Section 6 describes monitoring efforts, long-term threats to the water savings recommended in this SIP, and strategies to ensure durable results.

1 Introduction

1.1 The Russian River Coho Water Resources Partnership

1.1.1 Mission and Partners

The Russian River Coho Water Resources Partnership (Coho Partnership) was established in 2009 to implement the National Fish and Wildlife Foundation (NFWF) Keystone Initiative Business Plan (KIBP) for coho salmon in the Russian River. The Partnership includes the Center for Ecosystem Management and Restoration (CEMAR), Gold Ridge Resource Conservation District (GRRCD), Sonoma Resource Conservation District (SRCD), Occidental Arts and Ecology Center's WATER Institute (OAEC), Trout Unlimited (TU), and University of California Cooperative Extension and California Sea Grant (UC), in partnership with the Sonoma County Water Agency (SCWA). The multi-year KIBP aims to restore a viable self-sustaining population of coho salmon in the Russian River watershed.

The population of coho salmon native to the Russian River approached extinction during the last decade. With the inception of a population augmentation program in 2004, habitat improvements, and changes in ocean conditions, the number of returning adults has increased annually, with estimated returns approaching 500 during the winter of 2012-13. However, the coho recovery program is still far from reaching state and federal targets of self-sustaining runs of over 10,000 adult coho returning to the watershed each year.

Providing streamflow for juvenile coho during the dry season is a critical but often overlooked component of coho recovery in the Russian River. The Partnership was established to fill that gap and to improve instream flow and water reliability for water users in the Russian River watershed. Drawing from state and federal fisheries recovery plans, the KIBP identified five key sub-watersheds in the Russian River basin where near-term changes in water management are critical to restoring coho salmon: Dutch Bill, Green Valley, Mill, Mark West, and Grape Creeks.

The Partnership's goals are to (1) restore a more natural flow regime in five priority watersheds, especially in spring, summer, and fall; (2) increase the viability of juvenile coho and numbers of returning adult coho in the region; and (3) increase water supply reliability for water users in each focal watershed. The Partnership's approach integrates targeted outreach and community support; project development, implementation, and evaluation; support for strategic changes in water rights and policy; and streamflow and fisheries monitoring.

The combination of efforts in the Russian River to restore habitat, augment coho populations with hatchery releases, and conduct coho life cycle monitoring is unique, and the Coho Partnership builds on these efforts to address the survival bottleneck caused by low streamflow in Russian River tributaries. These efforts address the highest priority actions identified in the National Marine Fisheries Service's (NMFS) Central California Coast (CCC) Coho Recovery Plan. Since NFWF established the Keystone Initiative in 2009, the Russian River has become a focus area for complementary efforts: the National Oceanic and Atmospheric Administration (NOAA) selected the Russian River as its first Habitat Blueprint

Area, the Natural Resources Conservation Service (NRCS) included the Russian in its California Salmon Habitat Improvement Partnership, Grape Creek (another priority tributary) was selected as one of the ten national Waters to Watch by the National Fish Habitat Action Board, and NOAA recently named the CCC Coho population as a “Species in the Spotlight.”

1.1.2 Rationale for Selecting Mill Creek

Mill Creek was chosen as a focal watershed because it provided the critical intersection of feasibility of salmon restoration, degree of impairment of stream by diminished flows, landowner interest in collaboration, importance to coho salmon, range of land and water uses with the potential to demonstrate a variety of solutions, and federal and state recovery plan prioritization. NMFS’s CCC Coho Recovery Plan identifies Mill Creek as a Core Area for protection and restoration (See Figure 1).

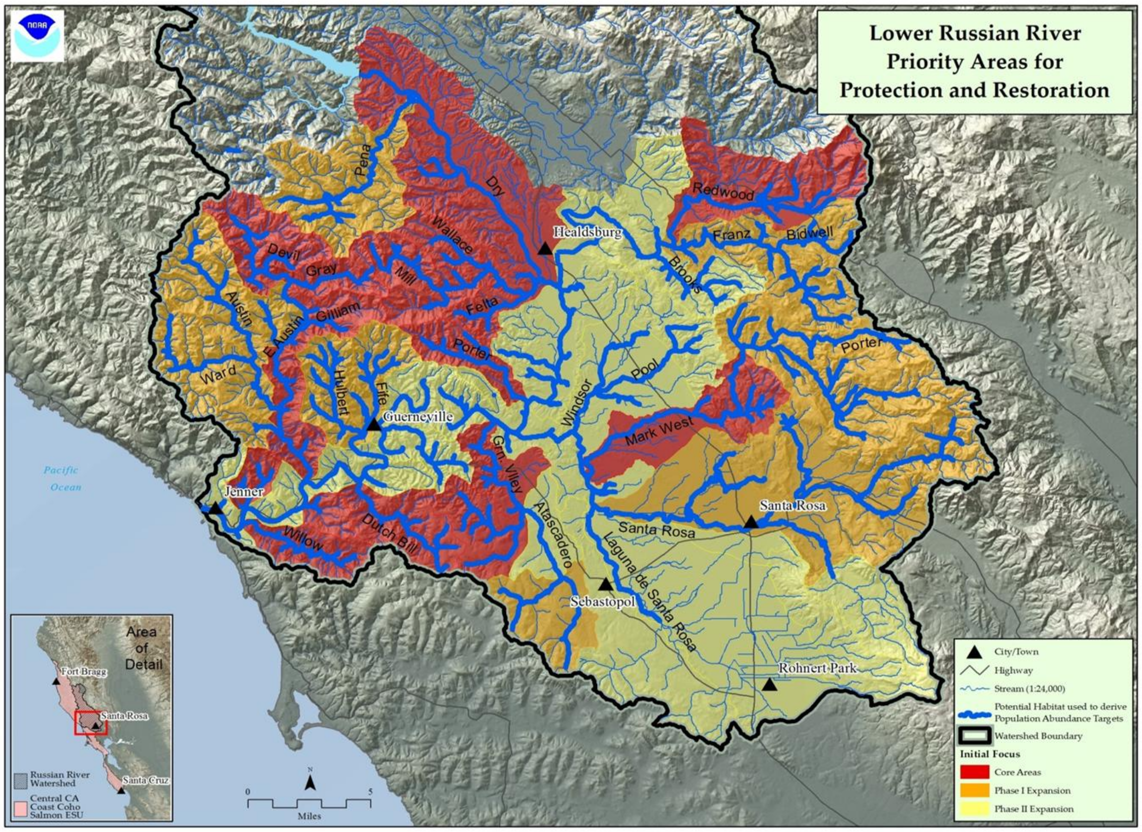

Figure 1. Core Area Identified in the NMFS CCC Coho Recovery Plan (NMFS 2012).

In spring 2015, the California Department of Fish and Wildlife (CDFW) and NMFS identified Mill Creek as one of four Russian River tributaries (and one of nine streams in the state) for a voluntary drought initiative and asked water users along Mill Creek to reduce their reliance on water from Mill Creek and its adjacent shallow aquifer in order to protect native coho and steelhead. In summer 2015, the State Water Board adopted an emergency conservation regulation for Mill Creek and three other Russian River tributary streams.

1.2 Purpose of the Mill Creek SIP

The purpose of this SIP is to provide a foundation and rationale for actions to improve streamflow conditions for salmon and steelhead and water supply reliability for water users in the watershed. The SIP integrates information gathered through the Partnership's activities and recommends future actions in the watershed.

1.2.1 Nexus with the Mill Creek Watershed Management Plan

In 2013, SRCD drafted Phase I of the Mill Creek Watershed Management Plan. The Plan provides information on watershed background, management recommendations, agricultural and rural sustainability, water conservation, water quality, instream and riparian habitat, sediment sources and impacts, and forest lands. One of the Plan's recommendations is to complete this SIP. Because SRCD has already compiled information concerning habitat quality and non-water quantity-related threats and recommendations, the Partnership intends that this SIP be used in conjunction with the Management Plan. The SIP will focus on providing watershed-specific streamflow monitoring information and recommendations based on the (hydrologic and fisheries) data collected by the Partnership. Both are intended to be living documents.

2 Rainfall and Discharge

2.1 Rainfall

The climate patterns of the Mill Creek watershed are, like most of coastal California, characteristically Mediterranean: summers are warm and dry, and winters are wet and cool. Precipitation occurs almost exclusively as rainfall (i.e., snowfall is very rare), and it occurs mostly during winter. Rainfall data over a 50-year period recorded at the nearest city, Healdsburg, CA (approximately 1 mile from the Mill Creek watershed), show that 90 percent of the average annual rainfall occurs during the wet half of the year November through April; less than 2 percent of the average annual rainfall occurs from June through August (Figure 2). While the total amount of rainfall may be variable from one year to the next, the seasonality of precipitation is consistent among all years.

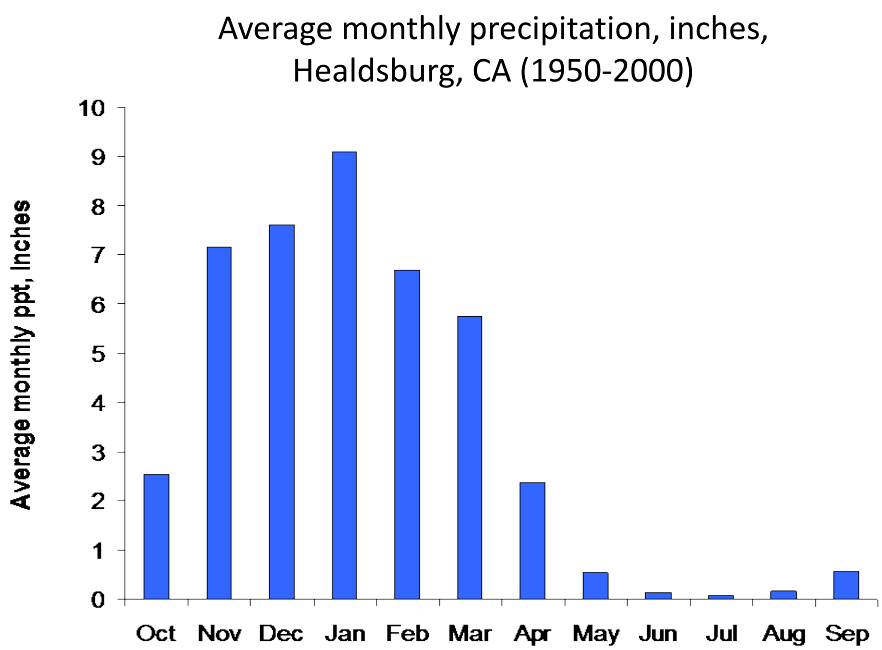

Figure 2. Average monthly rainfall recorded at Healdsburg, CA.

Computer models indicate that the Mill Creek watershed receives 49 inches of rainfall in an average year, with up to 54 inches occurring at higher elevations in the watershed and 40 inches occurring in the lower elevations (Figure 3).[1]

[1] This was estimated using a spatially distributed dataset developed through the Parameter-elevation Regressions on Independent Slopes Model (PRISM), a precipitation model developed by researchers at Oregon State University

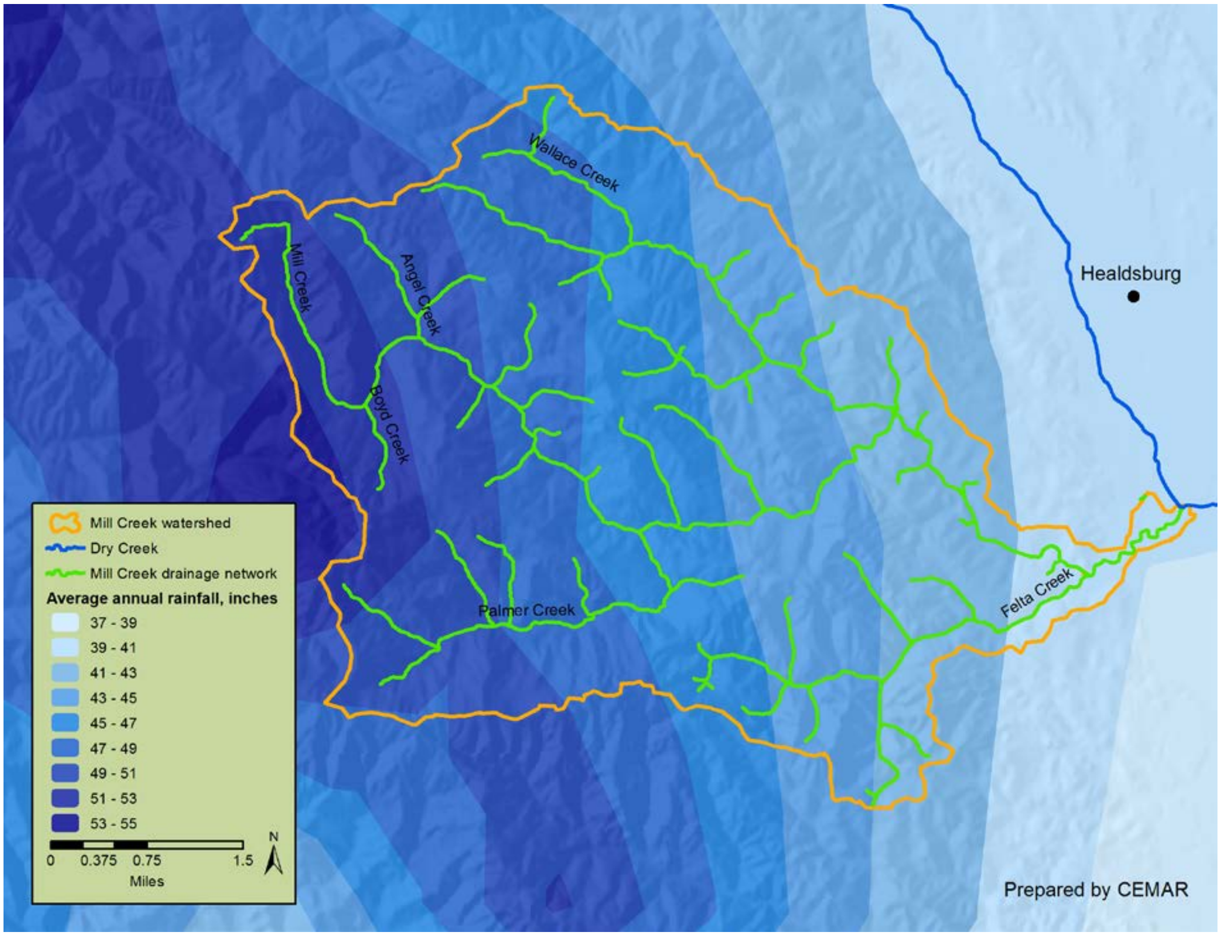

Figure 3. Average annual rainfall over the Mill Creek watershed.

Long-term records from nearby Healdsburg, CA indicate that rainfall can be variable from one year to the next. Over the 65-year period 1951 to 2015, annual rainfall has varied from as low as 16 inches to as much as 83 inches, with extended periods of low and of high rainfall throughout the historical record (Figure 3A). Most notably, the drought of 2012-2015 represents one of three periods of below-average rainfall for four or more consecutive years: the others were 1959-1962 (four years) and 1987-1992 (six years).

(considered state-of-the-art in precipitation modeling in the western United States) and publicly available over the internet. The rainfall dataset was converted into a shape file and used in a Geographic Information System (GIS) to depict the rainfall patterns in the watershed and to perform needed calculations.

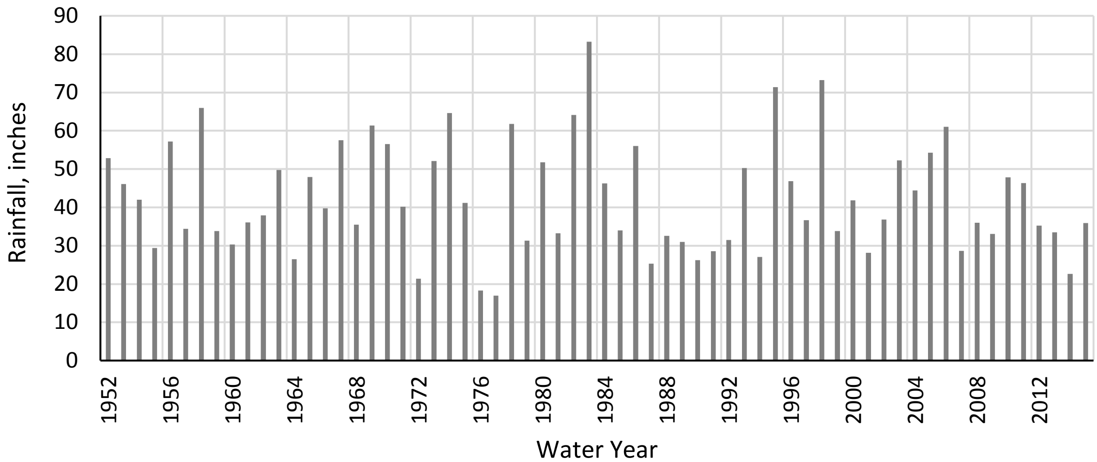

Figure 3A. Annual rainfall recorded at Healdsburg, CA, 1952-2015.

During the dry period 2012 to 2015, rainfall at Healdsburg was not evenly distributed through the winter; rather, it was focused either early in winter or late in winter, and occurred in a few large rainfall events (Figure 3B). For example, in water year 2012 (October 2011 to September 2012), 75% of the rainfall occurred in four storms, all after January 15. In water year 2013, 75% of the rainfall occurred before January 1. In water year 2014, 95% of the rainfall occurred after February 1; and in 2015, 80% of the rainfall occurred in a December storm and a February storm.

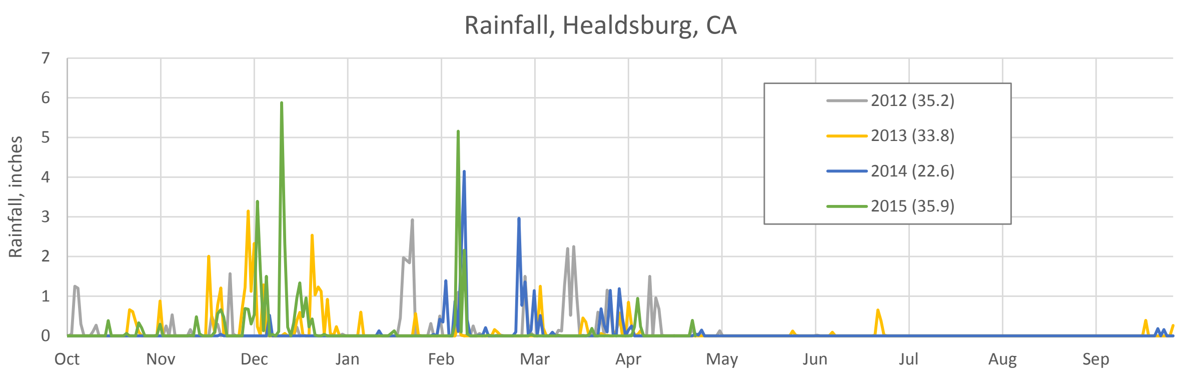

Figure 3B. Rainfall recorded at Healdsburg, CA, water years 2012-2015.

Future climate change scenarios for the Northern San Francisco Bay Area (Micheli et al. 2012) suggest that precipitation in the area will become more variable, with unprecedented annual extremes. Both "wetter" and "drier" climate change scenarios predict a potentially extended dry season, with reduced early and late wet-season precipitation. Rainfall patterns in these recent drought years offer a window into what can be expected more often in the future.

2.2 Streamflow

Streamflow is an essential component for understanding the interaction between humans and the surrounding ecosystem in the Mill Creek watershed. Streamflow data provide the foundation for many applications, such as quantifying the magnitude of the impairment that water use may cause on streamflow and helping to identify reaches that will benefit most from winter water storage. The data also are important for determining the means by which water can be obtained and stored in winter to minimize the impacts to environmental resources such as salmonid habitat. Streamflow data can also provide a baseline condition for flow prior to implementation of streamflow improvement projects and can be used to illustrate benefits of the projects once they have been completed.

We installed six pressure transducers in the Mill Creek watershed to serve as streamflow gauges during the course of the project (Mi01-Mi06 in Figure 4, note the Mi02 gauge on Palmer Creek only operated From June 2010 to October 2011); an additional gauge was installed by the State Water Resources Control Board farther downstream (Mi09 in Figure 4). We also measured streamflow at approximately monthly intervals beginning in water year 2010, following protocols adapted from the CDFW Standard Operating Procedures for Discharge Measurements in Wadeable Streams (CDFW 2013).[2] Using the measured streamflow values, we developed rating curves to correlate streamflow with discharge for each site. In addition, we installed staff plates to account for pressure transducer drift and other factors that may cause phase shifts (i.e., changes in the relationship between stage and streamflow) over the course of the project.

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[2] Rather than using Marsh-MacBirney current meters as described in CDFW (2013), we used a Price mini and Price AA current meters because our experience has suggested the Price mini current meter provides more accurate low-velocity measurements.

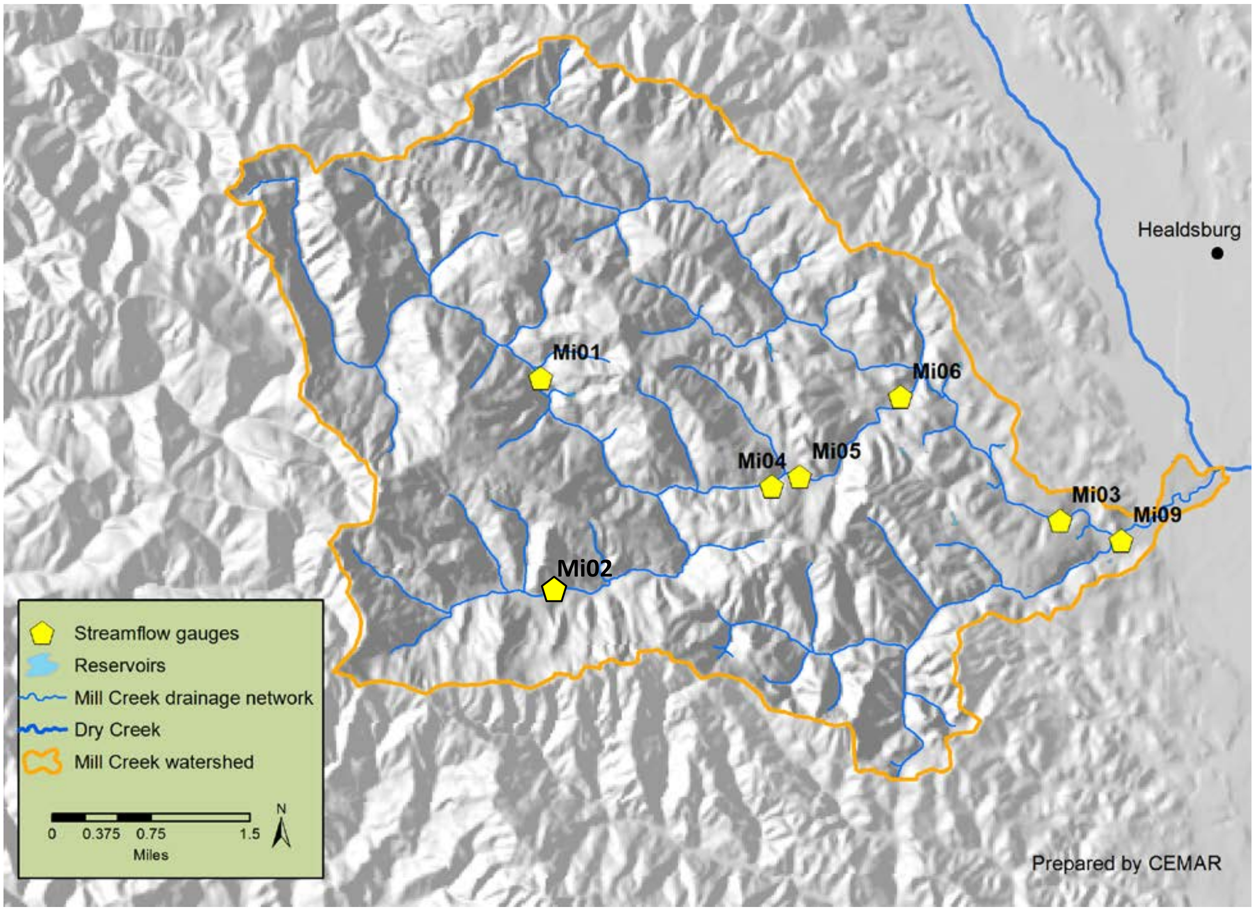

Figure 4. Streamflow gauge locations in the Mill Creek watershed.

2.2.1 Seasonal trends

Streamflow in Mill Creek shows seasonal trends that are characteristic of Mediterranean-climate streams. Like rainfall, the majority of discharge occurs during the winter months; during the period of gauge operation, as much as 95% of discharge occurred between November and April (Figure 5). Similar to rainfall, there may be substantial variability from one year to the next: Figure 5 shows how most discharge may occur in two months as in 2013, or may be spread through the winter as in 2011. However, the seasonality is consistent among years.

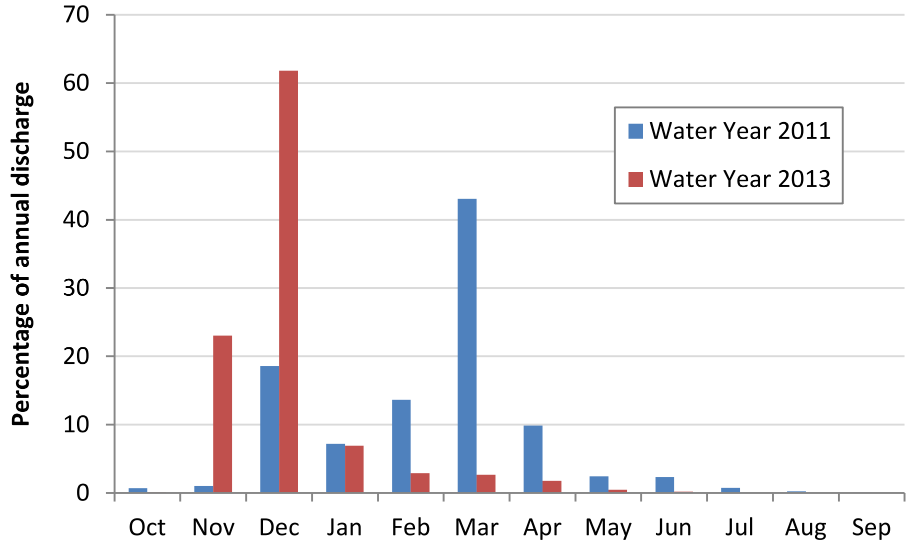

Figure 5. Monthly discharge as a percentage of annual discharge in Mill Creek, 2011.

Within the winter rainy season, streamflow typically occurs as a series of high-flow events during and immediately following rainfall events, and prolonged periods of declining base flow (Figure 6). Streamflow recedes following rainfall events at the onset of the dry season toward (and often reaching) intermittence in summer.

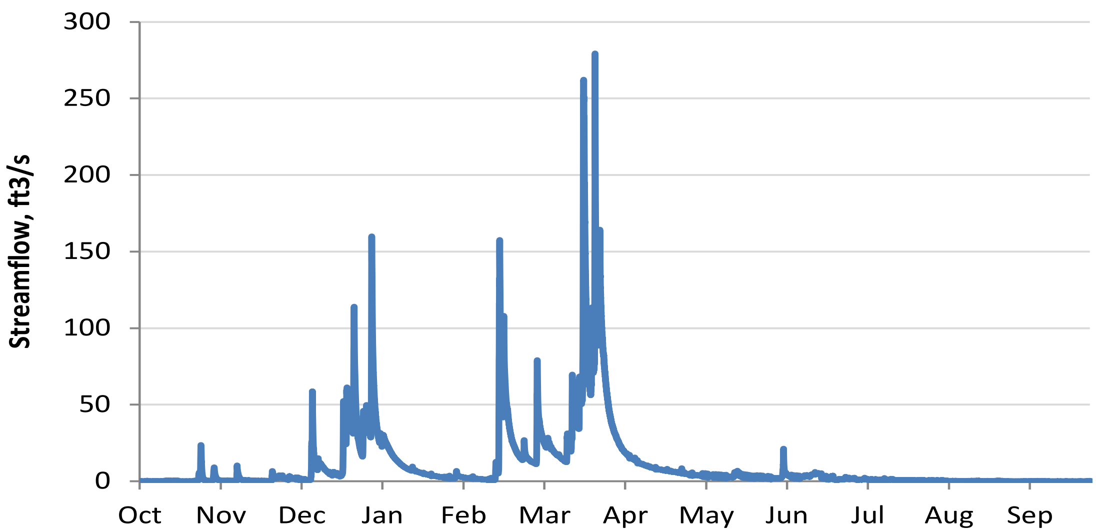

Figure 6. Streamflow recorded in Mill Creek at Bear Flat (Mi01), water year 2011.

This climatic regime poses several significant challenges to people living and working in the region, as well as aquatic organisms that use the Mill Creek drainage network for their life cycles. During the prolonged summer dry season, streams can be an unreliable source of water. Some people turn to springs, wells, and water gathered during the rainy winter for use in summer. Winter water storage may be especially important in dry years, because other water sources like springs and wells may go dry in summer. Additionally, the *variation* in winter discharge also is challenging for water users: if the majority of rainfall and discharge in a year occurs in December, then storage infrastructure must be ready to store water early in the year and maintain it until needed in summer. Aquatic organisms such as steelhead and coho salmon also face challenges; they are exposed to the high-flow conditions that occur periodically through winter, and then must persist in freshwater streams through the summer dry season until the rainy season brings water to streams once again.

Though rainfall occasionally occurs in spring or even summer (e.g., 2011), all streams in coastal California without regulated flow (i.e., dam releases) recede toward intermittence through summer. Gauges at Mill Creek show this trend toward intermittence, with some sites ceasing to flow by September in 2011 and August in 2013 (Figures 7, 8).

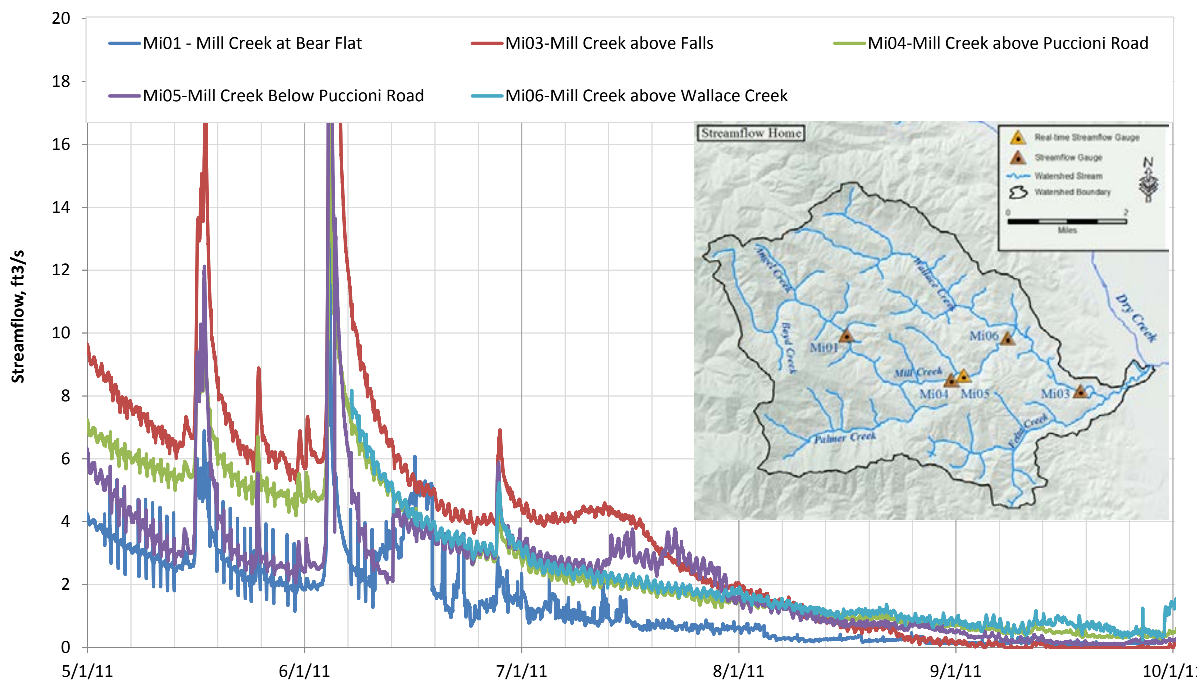

Figure 7. Streamflow at five locations in Mill Creek, May – October 2011.

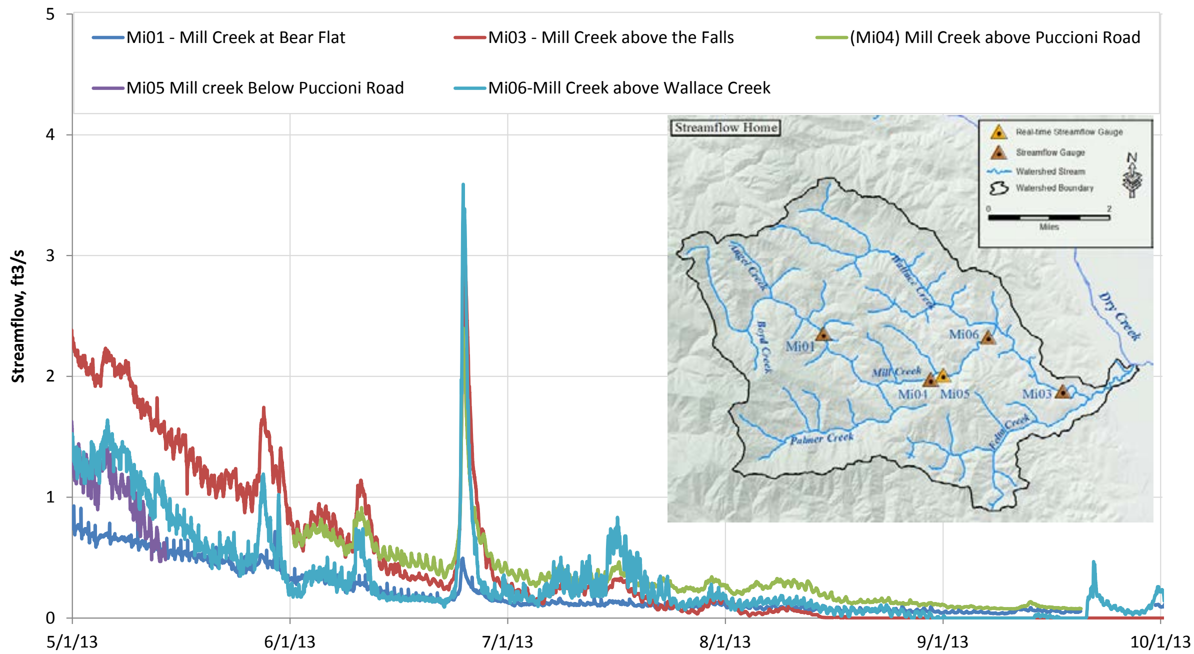

Figure 8. Streamflow at five locations in Mill Creek, May – October 2013.

2.2.2 Dry-season flows and human influence

Streamflow data collected in Mill Creek show the influence of water management practices on streamflow during the dry season. If Palmer Creek in 2011 represents typical flow conditions for an unimpaired stream (showing the consistent pattern of diurnal fluctuations in water level due to evapotranspiration; Figure 9), deviations from that flow pattern illustrate how water management practices along Mill Creek affect streamflow during summer. The Mi05 and Mi06 gauges, located in stretches of several rural residences along Mill Creek, show sudden drops in flow on the order of 0.1 to 0.3 ft^3/s through summer 2011. The sudden flow recessions are not as evident in the most downstream site (Mi03), but flow is lower than at upstream sites, suggesting that the cumulative effects of several small diversions could be causing an overall reduction in streamflow in Mill Creek. Similar patterns of reduced streamflow with distance downstream through the middle of Mill Creek, from Mi04 to Mi06 to Mi03, were measured in summer 2012 and 2013 (e.g., 2013 in Figure 10). In 2013, flow at Mi03 (farthest downstream) became intermittent in mid-August, while sites upstream maintained flow through the month (Mi04 continued to flow through summer and Mi06 became intermittent in early September).

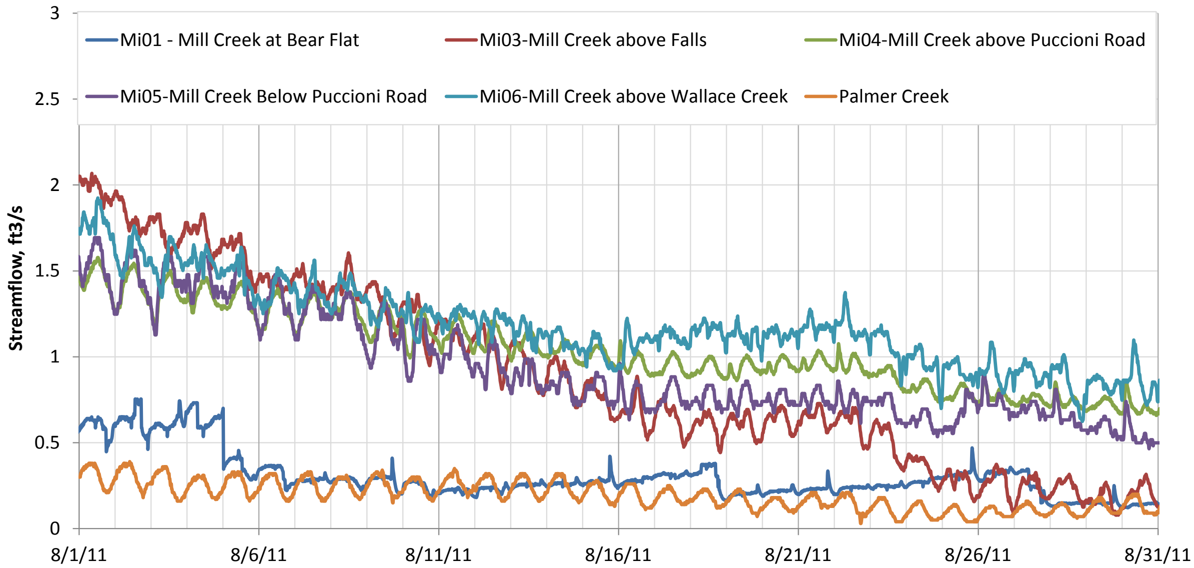

Figure 9. Streamflow at five locations in Mill Creek, August 2011.

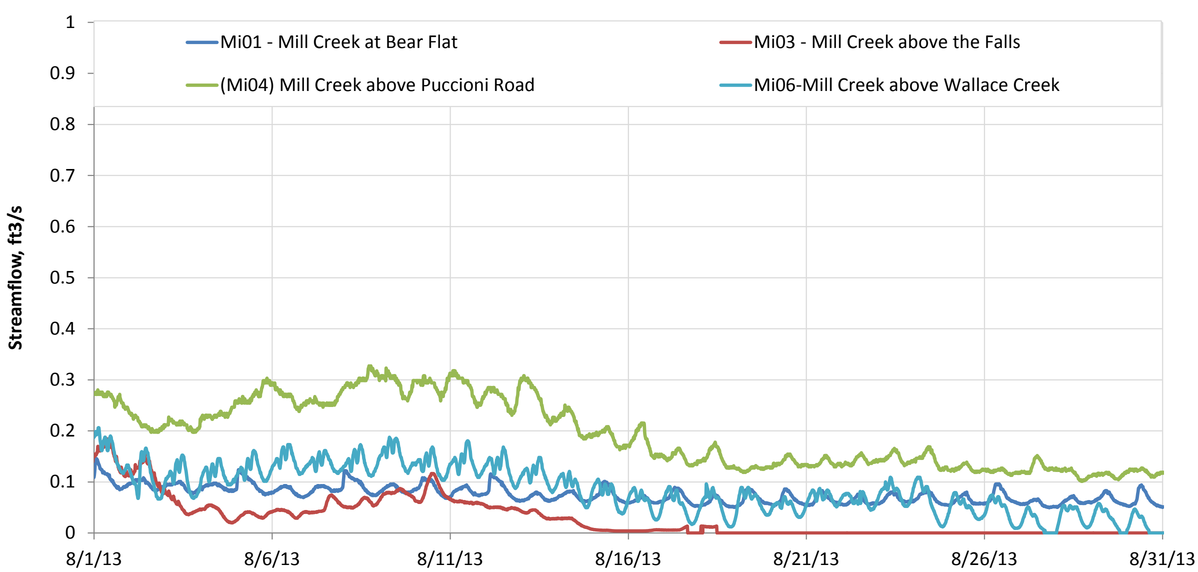

Figure 10. Streamflow at four locations in Mill Creek, August 2013.

Streamflow data during spring also show the influence of water management on streamflow in Mill Creek. Streamflow in May 2011 increased and decreased in unexpected ways beginning at the most upstream site Mi01; this pattern of rising and falling during the day was recorded at three additional sites farther downstream (Figure 11). Similar changes in flow during May were recorded in 2012 and 2013 (though the changes in flow were not as great as in 2011).

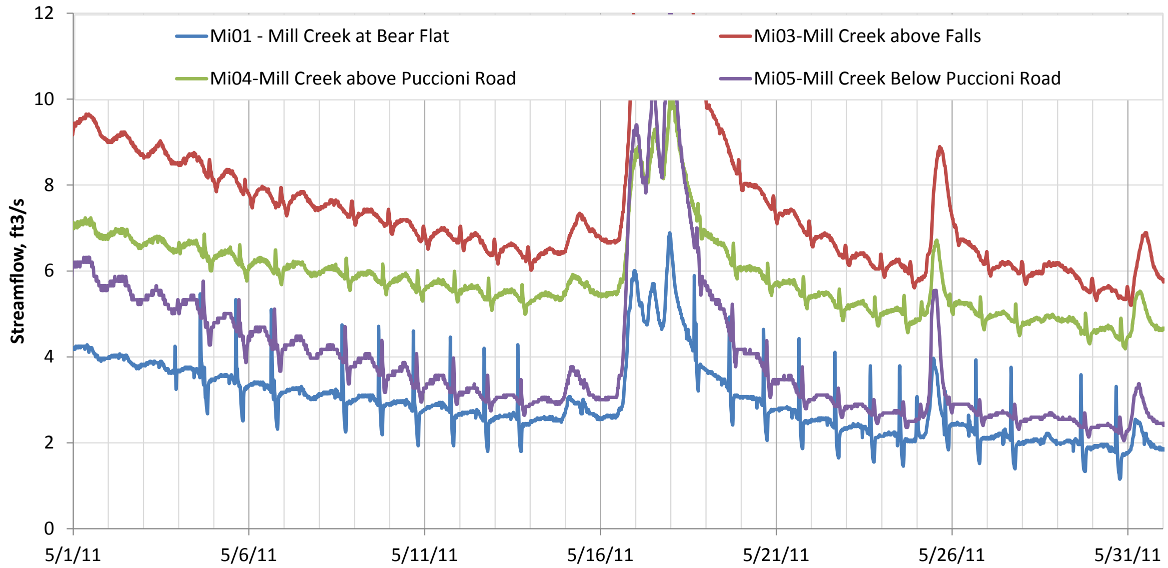

Figure 11. Streamflow in Mill Creek, May 2011.

2.2.3 Influence of 2012-2015 drought

Streamflow data gathered from the Mill Creek drainage network show the effect of the drought over the past few years, and provide valuable insights for potential future conditions. The data show a substantial difference in discharge among wet years and dry years: wet years (2010, 2011) have greater base flow and sustain discharge through the year, whereas dry years often do not. The flow records also show a consistent pattern of less base flow and earlier intermittence in each sequential dry year in Mill Creek. Whereas Mill Creek sustained flow through 2010, 2011 and 2012, it became intermittent in August of 2013 and July of 2014 (the latter resulting in at least three months of zero flow).

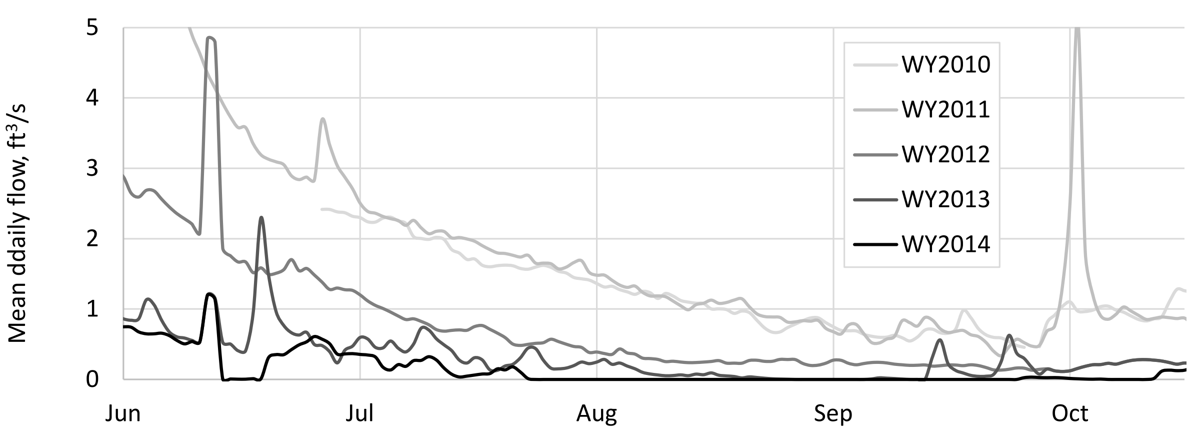

Figure 12. Mill Creek mean daily flow, June-October, 2010 to 2014.

2.3 Summary

The data collected over the past five years in Mill Creek show the typical characteristics of streamflow in Mediterranean-climate regions: flow during winter is punctuated by rainfall-driven high flow events, and flow recedes through spring and summer toward intermittence. Streamflow recedes to less than 0.5 ft^3/s (225 gallons per minute) even in a wet year, meaning that winter peak flows are typically more than one thousand times the magnitude of summer base flow.

Data also indicate that instream diversions can have measurable effects on streamflow throughout the drainage network. These effects may be most ecologically significant in summer, when small diversions can cause flow to drop by as much as 50%. Further, the cumulative effects of many small (i.e., residential) diversions may cause substantial reductions in flow throughout the dry season.

In dry years, many parts of Mill Creek become intermittent. Among our streamflow monitoring sites, those sites that become intermittent earliest tend to be located downstream of clusters of residences, which are common along the middle and lower reaches of Mill Creek. The multi-annual drought of 2012 to 2015 has caused summer flows to consecutively decrease with each subsequent drought year, resulting in streams becoming intermittent earlier with each dry year.

3 Human Needs

3.1 Comparing human water needs to water in Mill Creek

As described above, streamflow data suggest that human water management practices can adversely affect streamflow through spring and summer. A preliminary hydrologic evaluation can help to determine whether there indeed is sufficient water available on an annual scale to meet human water needs with minimal ecological impacts by initiating projects to restore streamflow.

This preliminary hydrologic evaluation compares rainfall, discharge, and human water need on an annual scale. Rainfall and discharge define water availability in a watershed: rainfall provides the overall input of water into a watershed, and discharge describes the portion that reaches streams. Rainfall is typically evaluated as average (or "normal") annual rainfall, which depicts conditions that occur most typically (our interest in long-term project resilience means that we often consider rainfall for "dry" type water years in subsequent evaluations). Rainfall can be captured off rooftops or collected directly in ponds, and it provides recharge of groundwater during winter. Discharge is the cumulative amount of streamflow from the watershed. Watershed discharge at an annual scale is an important component in this framework because it characterizes the amount of water available for stream ecosystem processes and is the source of water for people who divert directly from streams. Discharge integrates several watershed processes such as evapotranspiration and groundwater recharge that affect the fraction of rainfall that becomes converted to streamflow through the year.

3.2 Rainfall and discharge

As described above, the Mill Creek watershed receives considerable rainfall in an average year: we estimate that the annual average rainfall in the watershed is 49 inches, with a range of 54 inches in the headwaters to 40 inches in Dry Creek Valley. Over the 14,260 acre watershed, this results in a total of 58,200 acre-feet of water falling onto the Mill Creek watershed in an average year.

To estimate average discharge in Mill Creek, we modeled discharge using a simple drainage basin area-ratio transfer based on historical streamflow records measured at two nearby streamflow gauges. Data from the USGS gauge on Pena Creek near Geyserville, CA, and the USGS gauge on Austin Creek near Cazadero, CA, guided the discharge estimates used for Mill Creek.

The scaling method entails multiplying discharge recorded at the historical USGS streamflow gauge according to a ratio of catchment area and then by a ratio of average annual rainfall (based on PRISM data) in the Mill Creek watershed to average annual rainfall above the USGS streamflow gauges:

$$Q_{project\ wshd} = Q_{gauged\ wshd}\left(\frac{Area_{project\ wshd}}{Area_{gauged\ wshd}}\right)\left(\frac{Annual\ ppt_{project\ wshd}}{Annual\ ppt_{gauged\ wshd}}\right) \qquad (1)$$

In Equation 1, the terms $Q_{project\ wshd}$, $Area_{project\ wshd}$, and $Annual\ ppt_{project\ wshd}$ refer to discharge, upstream watershed area, and average annual precipitation of the study basin; the terms $Q_{gauged\ wshd}$, $Area_{gauged\ wshd}$, and $Annual\ ppt_{gauged\ wshd}$ refer to discharge, upstream watershed area, and average annual precipitation upstream of a historically gauged watersheds (i.e., Pena Creek and Austin Creek).[3] This equation appears in Appendix B of the State Water Board's North Coast Instream Flow Policy (SWRCB 2014).

This method for modeling streamflow was chosen because of its clarity and simplicity to calculate using GIS, as well as for its regulatory application: the State Water Board advises water right applicants in this region to scale streamflow using this approach to determine if sufficient flow exists to allow a new water right (SWRCB 2014). Further, an evaluation by the USGS (Mann et al. 2004) found that the basin area ratio transfer method of estimating streamflow generally performed better in this region than methods based solely on rainfall. We calculated two discharge values for Mill Creek – one modeled from Pena Creek and one from Austin Creek – and used the average of the two values for this report. The resulting streamflow information is summarized in Table 1.

Table 1. Basin hydrology characteristics, Pena Creek, Austin Creek and Mill Creek.

Stream	Wshd area, acres	Average annual rainfall, inches	Average annual rainfall volume, AF	Average annual discharge volume, AF
Pena	14,300	56	67,200	29,890 (measured, 1979-1990)
Austin	40,400	54	181,700	118,007 (measured, 1960-2013)
Mill	14,300	49	58,200	31,859 (estimated)

3.3 Human Need

Human water need describes the amount of water required for human uses over a period of time such as a year and characterizes the amount of water people can expect to need in the future (Deitch et al. 2009). In the Mill Creek watershed, irrigated agriculture and rural residences are the two most evident forms of water use. In addition, wineries and other commercial industries within the region contribute to the human water need. Irrigated agriculture can have varying water needs depending on the type of crop grown. Wine grapes are the most prevalent crop in watershed, and can require water for both irrigation and frost protection. Domestic water needs typically include requirements for landscaping and household use. Wineries require water for barrel and equipment cleaning, and for dish washing in tasting rooms. Water needs at locations such as schools can include restrooms and landscaping irrigation.

[3] The method used here for extrapolating discharge from USGS gauges does not incorporate other differences in watershed characteristics such as land cover or underlying geological formations, though these features also likely affect discharge.

This study focused on potential streamflow enhancement related to agricultural, industrial and rural residential water use. We identified features such as winery locations, agricultural fields, and building structure locations in the Mill Creek watershed using aerial imagery in ArcMap to construct a model of the human development footprint in the watershed (Figure 13). Of those structures identified as buildings, we distinguished between those that are houses and those that are other types (such as barns and garages) based on proximity to green lawns, driveways, and other residence-associated features, on size, and roof features (such as shingle color and roof lines).

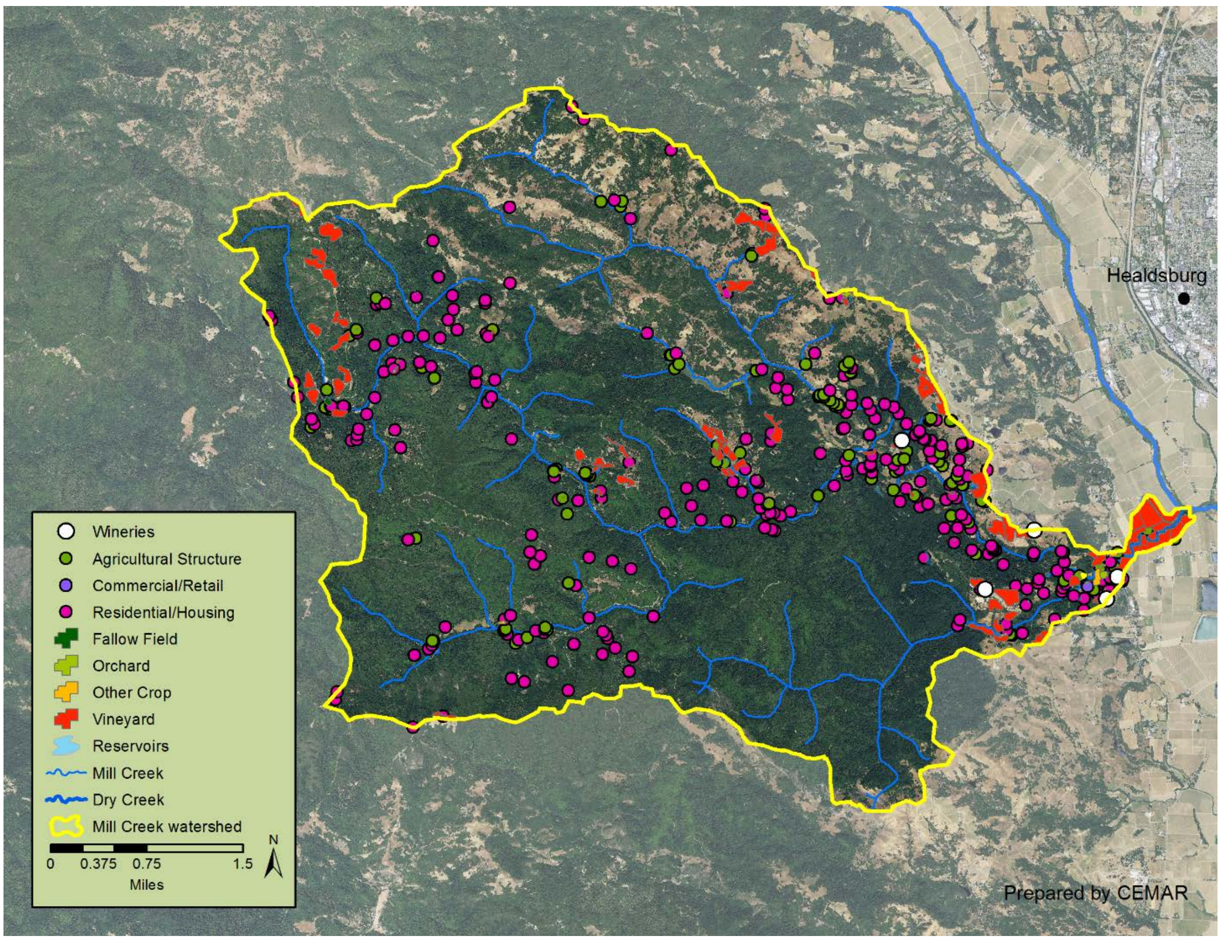

Figure 13. Human footprint in Mill Creek watershed, used to estimate water need.

The information gathered, along with standardized water use estimates, guided our assessment of human water needs in the study area:

Agricultural. We used digitized agricultural coverage to estimate the total acreage of land as vineyards in the watershed, and then calculated total agricultural water need based on regional per-area estimates of water use. For example, vineyard irrigation in coastal Northern California may require up to 0.6 acre-feet of water per acre of grapes annually (Smith et al. 2004). Since our approach is based on average use rates, and many vineyards producing premium wines typically use water at lower rates (especially for fully established vines), our estimates should be considered conservative. For olive orchards, we used per area water use rates derived by researchers at the University of California Davis (i.e., 2 acre-ft. of water per acre).[4]

Industrial (wineries). We used existing data sets to create an estimate of wine production water use in terms of gallons of water per acre of grapes. Winery water needs were only calculated for those vineyards that appeared to be affiliated (based on proximity) with wineries in the watershed. Our approach assumes that wine production is limited to only those grapes grown near the winery, and may underestimate total winery water use. However, our estimates of wine production correspond well with figures provided by the wineries themselves (on their web sites). We relied on various sources to estimate that wineries require approximately 2,750 gallons of water to make wine from an acre of grapes (i.e., 0.008 acre-feet of water per acre of vineyards).

Residential. Residential water use is variable in coastal California. Based on our review of residential water use data in coastal northern California (CEMAR 2014), we estimated rural residential water use at 300 gallons of water per day. This rate was applied to the number of households within each watershed to estimate the annual water need for residences, and thus includes consideration of greater water needs in summer for landscaping purposes.

School. We estimated the annual water use for the West Side Elementary School based on our previous work in a subregion of coastal northern California, as well as USGS determined school water-use rates. We used 4.5 gallons of water per day per person rate for toilet use, hand-washing and drinking; and estimated outdoor irrigation at a 2.5 acre-feet/year per irrigated acre rate based on our work in a nearby watershed. Our approach assumes that the school is only in operation 183 days/year (the California standard).

We estimated the amount of human water need for the Mill Creek watershed based on the water use rate factors described above. Mill Creek has approximately 348 acres of vineyards, requiring 206 acre-feet of water annually for irrigation (Table 2). Five wineries are located within the watershed, with varying amounts of production. Based on individual winery production estimates, the total annual water used by Mill Creek watershed wineries is 0.4 acre-feet. We estimate that the school in Mill Creek has 1.5 acres of irrigated area and 200 people onsite. We count 254 rural residences in the Mill Creek watershed. The total amount of water needed for these residences is approximately 82 acre-feet per year.

[4] Based on deficit irrigation estimates described by Goldhamer (1999).

Table 2. Water need calculation factors and water needs in Mill Creek watershed.

Mill Creek	Residences	Wineries	Schools	Vineyards (acres)	Orchards (acres)	Other Crops (acres)	Total human water need (acre-feet/yr)
Number	254	5	1	348	7	8	
Water need, acre-ft/yr	82	0.4	4.25	206	14	16	322

3.3.1 Annual Scale

Comparing the human water needs in Mill Creek watershed to the average rainfall and discharge provides an initial assessment for whether human water needs can be met through the water resources available on-site on an annual scale. Our analysis indicates that total water needs in the Mill Creek watershed comprise a small fraction of the total water available – 0.5% of the average annual rainfall and 1% of the average annual discharge (Figure 14).

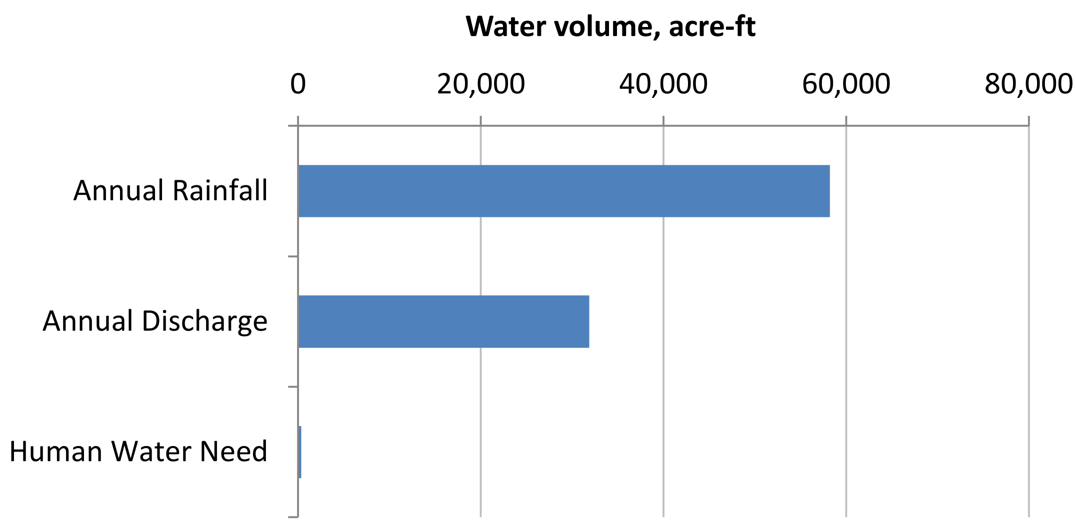

Figure 14. Comparison of average annual rainfall, average annual streamflow and human water need in the Mill Creek watershed.

In a dry year, annual rainfall may be as little as half of the average (data from Healdsburg indicate that annual rainfall was less than half of average twice during the 65-year period 1951-2015, so a year with half the average annual rainfall is atypically dry but not the driest on record). If total water needs are the same in a dry year as a normal-type year, then water needs would comprise 1% of the annual dry-year rainfall. Data from nearby historical streamflow gauges show that discharge in dry-type years is approximately half the rainfall (i.e., annual rainfall is 50% of discharge, regardless of wet year or dry year conditions, possibly because so much of the rainfall occurs in winter and in large events), so total water need would comprise 2% of dry-year discharge.

3.3.2 Summary

The above data provide important insights into the complexities of water management in the Mill Creek watershed. The Mill Creek watershed receives as rainfall approximately 200 times the total amount of water that we estimate people need for residential and agricultural uses in the watershed, even under dry-type conditions. We estimate that average annual discharge is approximately 100 times human water needs. In a dry year (e.g., a year with rainfall that is exceeded by 90% of all years), rainfall is approximately half of the average; rainfall would still greatly exceed the amount of water needed for various human uses in the Mill Creek watershed. All these results indicate that there is ample water in the Mill Creek watershed *on an annual scale* to meet human and environmental needs, even in a dry-type year.

Despite this abundance of water, the timing of its availability is the greatest challenge associated with ecologically sustainable water management. Our streamflow data corroborate this idea: many small diversions from the Mill Creek drainage network and adjacent shallow aquifers can cumulatively reduce streamflow during the dry season. Streamflow enhancement projects are based on the concept that modifying the timing of diversions from summer to winter can lead to increased summer base flow while also maintaining environmental flows in winter and providing water security for human use. By diverting water in winter and storing it for use in the dry season, people would no longer be diverting water from the stream when flow is low in summer. Given changes in rainfall patterns predicted in coming decades (described above), such storage projects will be critical for maintaining reliable water supplies for human water needs and for maintaining ecological processes in the Mill Creek watershed.

3.4 Water Rights in the Mill Creek Watershed

Water rights records provide one view into scale and type of human water needs across the Mill Creek watershed.

3.4.1 Water Rights Overview

There are two basic types of surface water rights in California, riparian and appropriative rights.

A riparian right entitles a landowner with land immediately adjacent to a stream (or other body of water) to a reasonable amount of the natural flow for use on that land. The right is inherent to ownership of the land and cannot be lost through non-use. When water is scarce, riparian owners share the available supply. The use of riparian rights does not require approval from the State Water Board, but users are required to submit Statements of Water Diversion and Use annually. Riparian rights are senior to appropriative rights, but also have significant limitations: water cannot be used on land that is not associated with a riparian parcel and no seasonal storage (generally more than 30 days) is allowed.

Appropriative rights are created by putting a specific quantity of water at a specific location for beneficial use. Unlike riparian rights, appropriative rights allow water to be stored and to be used on non-riparian land. They are junior to riparian rights, and priority among appropriative users is established by date (“first in time, first in right”). Appropriative rights can be lost if they are not used. There are two types of appropriative rights, pre-1914 and post-1914 rights.

Before 1914, a water user could establish an appropriative right by posting a notice, constructing diversion facilities, and putting the water to use. California enacted the Water Commission Act in 1914, which established a comprehensive permit system for appropriative rights. Since then, all new appropriative rights are created by application to what is now the State Water Board. Post-1914 appropriative rights can be approved only after a public process in which the applicant is required to demonstrate the availability of unappropriated water and the ability to place that water to beneficial use. The quantity of the water right is described in a permit, license, or registration. Pre-1914 users are required to file Statements of Water Diversion and Use annually; post-1914 users are required to file permittee or licensee reports annually; registration holders are required to report every five years.

3.4.2 Water Rights in Mill Creek

The Electronic Water Rights Information Management System (eWRIMS) database lists water rights on file with the State Water Board throughout the state of California. For the Mill Creek watershed, eWRIMS lists 27 appropriative rights (21 licensed, 2 permitted, and 4 pending), 1 stockpond registration, 3 domestic use registrations, 15 riparian claims, 2 pre-1914 claims and 1 other claim (Figure 15). Nineteen of the rights allow for storage.

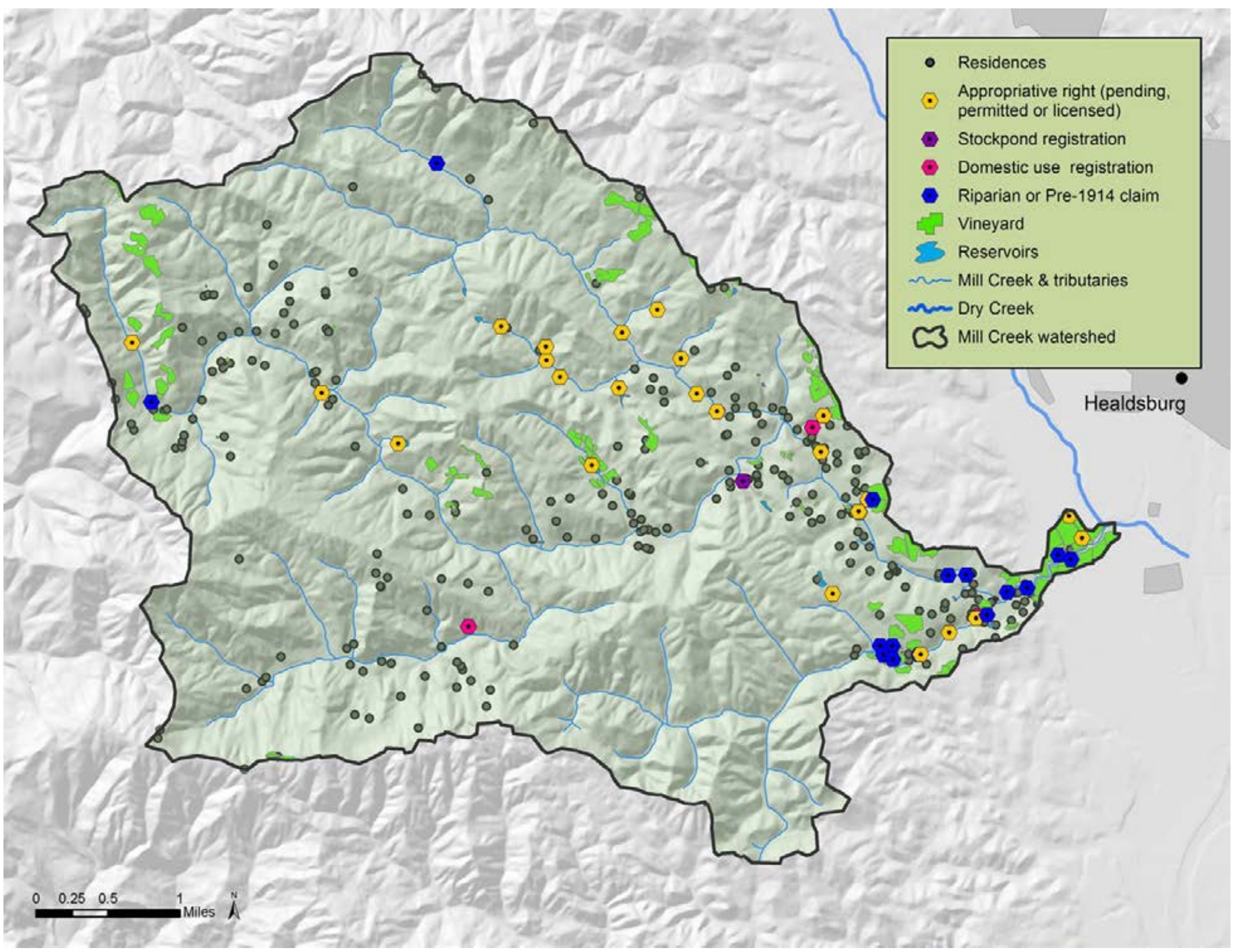

Figure 15. Locations of water rights in the Mill Creek watershed in eWRIMS as of August 2015.

Water rights may not be the most accurate way to estimate water need in the Mill Creek watershed as they under-represent the number of diversions. The eWRIMS database does not capture riparian or pre-1914 water rights if the water user has not submitted a Statement of Water Diversion and Use, uses for which a permit or license is not required (e.g., diversions from springs that meet certain criteria or pumping from percolating groundwater), or illegal water use. In addition, the State Water Board may be processing Statements of Water Diversion and Use that have not yet posted to eWRIMS.

4 Fish and Habitat

4.1 Historic presence

The Russian River watershed once supported native runs of anadromous coho (*Onchorhynchus kisutch*) and pink salmon (*O. gorbuscha*), as well as steelhead trout (*O. mykiss*) (Steiner 1996). Due to a lack of historic survey records, it is unknown whether Chinook salmon (*O. tshawutscha*) were present in the Russian River prior to the first release of hatchery fish in 1881 (Chase et al. 2007), however, a self-sustaining population of Chinook currently exists today.[5] Russian River coho salmon were historically prevalent enough to support a commercial fishery and Russian River steelhead formed the basis of a highly prized game fishery that attracted anglers from around the world until the 1950s (Steiner 1996). Pink salmon are now extirpated from the system and Chinook and steelhead are listed as threatened under the Federal Endangered Species Act. The Central California Coast Evolutionarily Significant Unit (CCC ESU) of coho salmon (including those found in the Russian River), which are estimated to have numbered in the tens of thousands as recently as the early 20th century (Steiner 1996), are on the brink of extinction. The decline of CCC coho has been especially rapid in recent decades, resulting in their listing as endangered under both the State of California and federal Endangered Species Acts.
Coho salmon, steelhead and Chinook salmon are currently present within the Mill Creek watershed. Early documentation of salmonid presence in the Mill Creek watershed is limited, but historic coho salmon presence was confirmed in Mill, Felta and Wallace Creeks (Spence et al. 2005) (Table 3), and steelhead were likely present in all of the major tributaries within the system. Dry Creek had an estimated population of 300 coho before Warm Springs Dam was built and returns of adult coho salmon to the Warm Springs Hatchery were documented every year except for one between 1981/82 and 1999/2000, though in increasingly lower numbers over time (Coey et al. 2002). Chinook have been observed in the lower reaches of Mill and, occasionally, in Felta Creeks (Obedzinski et al. 2009).

Table 3. Summary of coho presence recorded during historic CDFW surveys of Mill Creek and tributaries as noted in Spence et al. (2005) and CDFW's Stream Inventory Reports for Mill, Felta, Wallace and Palmer Creeks.[6]

Stream	Years with documented historic coho presence
Mill	1951, 1952, 1960, 1966, 1995
Felta	1966, 1995
Wallace	1952, 1966
Palmer	not surveyed

[5] http://www.scwa.ca.gov/chinook/
[6] No coho were observed during other survey years.

Over the past century, coho salmon populations in the Russian River watershed have experienced steep declines, along with other populations across the Pacific Coast. Historically, the Russian River had the largest coho population in the CCC ESU but the number of coho salmon smolts migrating to the ocean is estimated to have declined 85 percent between 1975 and 1991 (NMFS 2012). Extensive surveys by CDFW in the early 2000s found coho salmon to be present in only four of 39 historic coho streams within the basin, and only one stream had three consecutive year classes (Conrad 2005, Spence et al. 2005). By the time coho became the focus of local resource agencies in the mid-1990s, coho salmon numbers had dwindled to the point of near collapse throughout the Russian River. After the 1995 documentation of juvenile coho salmon in Mill and Felta Creeks, wild coho were not observed in the Mill Creek watershed again until the spring of 2005, when a small number of young-of-year coho, believed to have originated in Felta Creek, were captured in a smolt trap on Mill Creek (Conrad et al. 2006).

4.2 Russian River Coho Salmon Captive Broodstock Program

Private landowners, organizations and agencies responded to this decline by conserving and restoring critical salmonid habitat within the Russian River Watershed, but that effort in itself was not enough. In 2001, with Russian River coho salmon populations on the brink of extinction, a collaborative effort was formed to restore self-sustaining runs of native coho salmon to streams within the watershed that historically supported them. The Russian River Coho Salmon Captive Broodstock Program (Broodstock Program) represents a broad partnership involving the CDWF, NMFS, U.S. Army Corps of Engineers (USACE), SCWA, UC, and hundreds of private landowners. This multi-year program was built on the use of native coho juveniles as broodstock for the production of juvenile salmon for release into historic coho streams. Broodstock program partners carefully capture wild juvenile coho, rear them to adulthood at the Don Claussen Warm Springs Hatchery, spawn them, release the juvenile offspring into selected tributary streams and monitor their growth and survival until the fish move downstream, into the ocean. This cycle is repeated annually, along with monitoring of adult coho that return to spawn in those same streams two to three years after their release as juveniles.

Broodstock Program partners captured the first coho broodstock from Green Valley and Dutch Bill Creeks (tributaries to the Russian) each summer from 2001 through 2003 and began releasing their offspring as juveniles into designated streams in October of 2004 (Conrad 2005). Mill Creek was one of the first streams stocked in 2004 and has been stocked each year since. Palmer Creek has received annual plantings of juvenile program coho since 2005. A total of 318,850 juvenile coho from the Broodstock Program were planted into Mill Creek and its tributaries from fall 2004 through fall 2014 (Table 4). Releases into the Mill Creek watershed since 2004 have averaged approximately 35% of all releases into Russian River tributaries each year, ranging from 15% to 58% (Ben White, USACE, unpublished data).

Table 4. Total numbers of Broodstock Program juvenile coho salmon stocked into Mill Creek and its tributaries (Ben White, USACE, unpublished data).

Stream	Brood year	Release year	Total release
Mill Creek	2003	2004	3,433
	2004	2005	4,399
	2005	2006	11,599
	2006	2007	33,192
	2007	2008-09	37,610
	2008	2009-10	34,228
	2009	2010-11	36,254
	2010	2011-12	31,933
	2011	2012-13	17,072
	2012	2013	19,168
	2013	2014	19,182
Palmer Creek	2004	2005	4,386
	2005	2006	5,123
	2006	2007	7,847
	2007	2008-09	9,022
	2008	2009-10	7,093
	2009	2010	6,916
	2010	2011	7,059
	2011	2012	7,045
	2012	2013	7,027
	2013	2014	7,204
Angel Creek	2010	2011	2,058
TOTAL			**318,850**

4.3 Coho Broodstock Program monitoring

UC's Russian River Coho Salmon Monitoring Program conducts ongoing monitoring of salmonid populations in tributaries to the lower Russian River in order to evaluate the efficacy of the Broodstock Program, and to apply advances in scientific knowledge to its management. Working in this capacity, they are documenting the abundance, survival, and distribution of wild and program coho salmon throughout the southern portion of the Russian River basin over time. Both wild and hatchery stocks of Mill Creek coho have been the subject of year-round monitoring since the first Broodstock Program planting in 2004, with incidental documentation of steelhead and Chinook. Due to the endangered status of coho salmon and the objective of coho recovery guiding UC and Coho Partnership monitoring efforts, coho salmon will remain the salmonid species of focus for the purposes of this report.

UC biologists maintain Passive Integrated Transponder (PIT) tag antennas on Mill, Felta, and Palmer Creeks to track the movement of PIT-tagged program coho at all life stages (Figure 16). A downstream migrant smolt trap has been operated by UC on the lower reach of Mill Creek each spring since 2005 (Figure 16). Additional fish monitoring activities on Mill, Felta, Palmer and, as of 2013, Wallace Creeks include spawner surveys throughout the winter months to document adult returns and snorkel surveys in the summer to document the presence and abundance of juveniles.

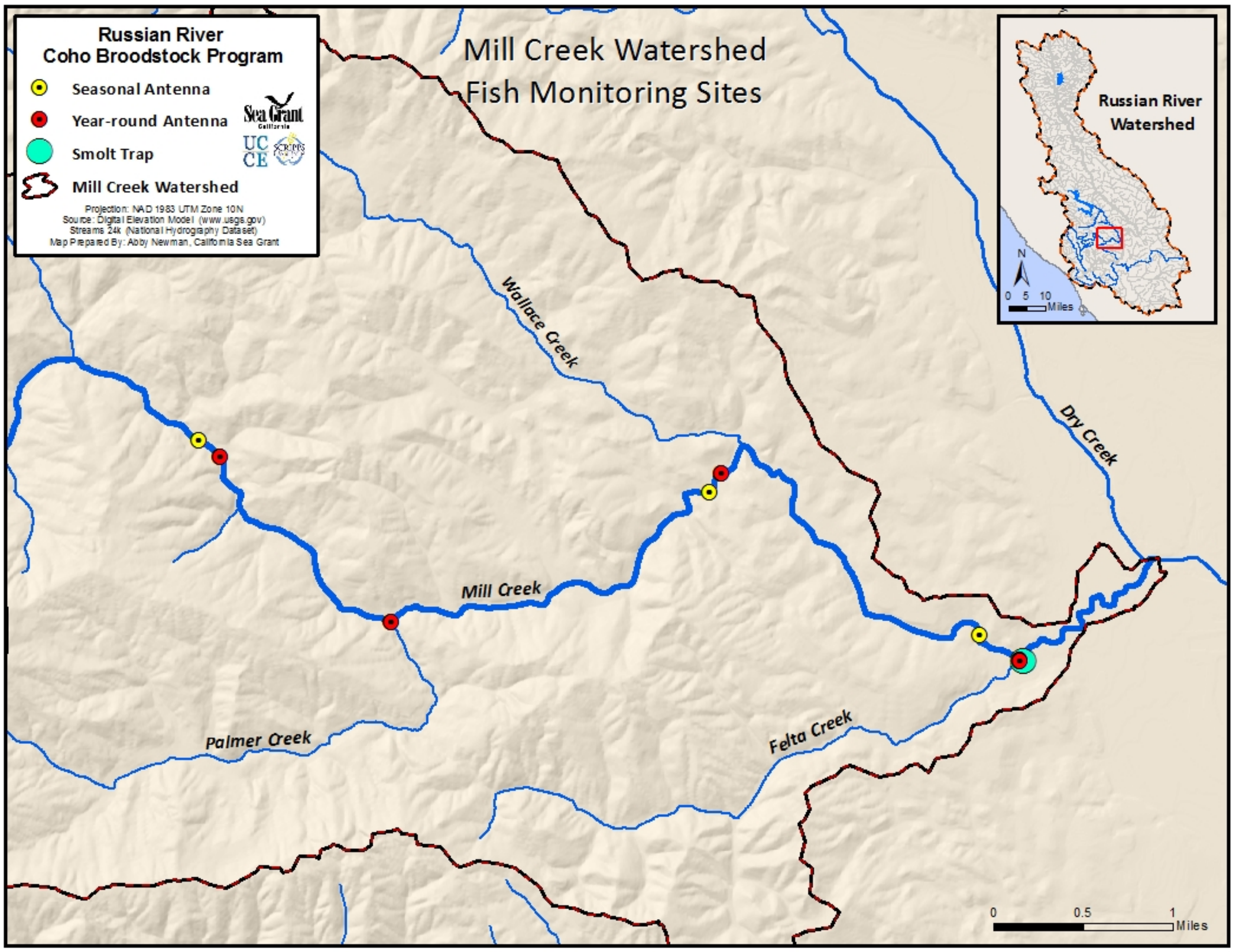

Figure 16. Fish monitoring stations in the Mill Creek watershed, including PIT tag antenna locations and downstream migrant smolt trap site.

4.3.1 Smolt abundance and juvenile survival

Each spring, UC operates a smolt trap and PIT tag antenna array near the mouth of Mill Creek (Figure 16) to estimate the number of smolts migrating to the ocean, estimate juvenile survival and growth of hatchery releases, and document smolt migration timing. Figure 17 shows the estimated number of hatchery and wild coho smolts leaving the Mill system each year, paired with the total number of juveniles released upstream of the traps since the previous spring . Survival of fall-released juveniles to the smolt stage averaged 0.26 (range 0.12 to 0.56) over the last nine years (Figure 18) and falls within rates observed in neighboring wild populations in Marin (Reichmuth et al. 2006, Carlisle et al. 2008). On average, the majority of PIT-tagged juveniles emigrating from Mill Creek are detected between March and June, however, a portion of the fish are detected leaving Mill during the previous fall or winter season (prior to March 1) (Figure 19).

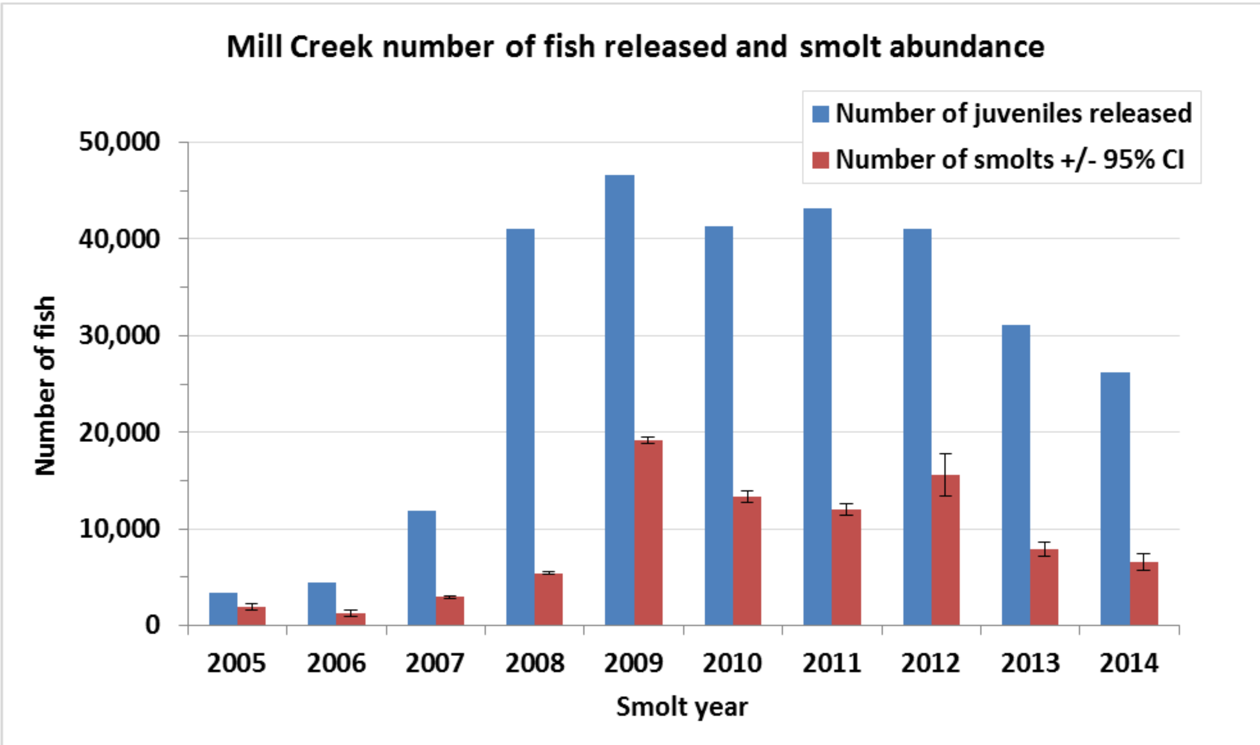

Figure 17. Estimated number of coho smolts leaving Mill Creek each year, along with corresponding number of juvenile coho planted since the previous spring.

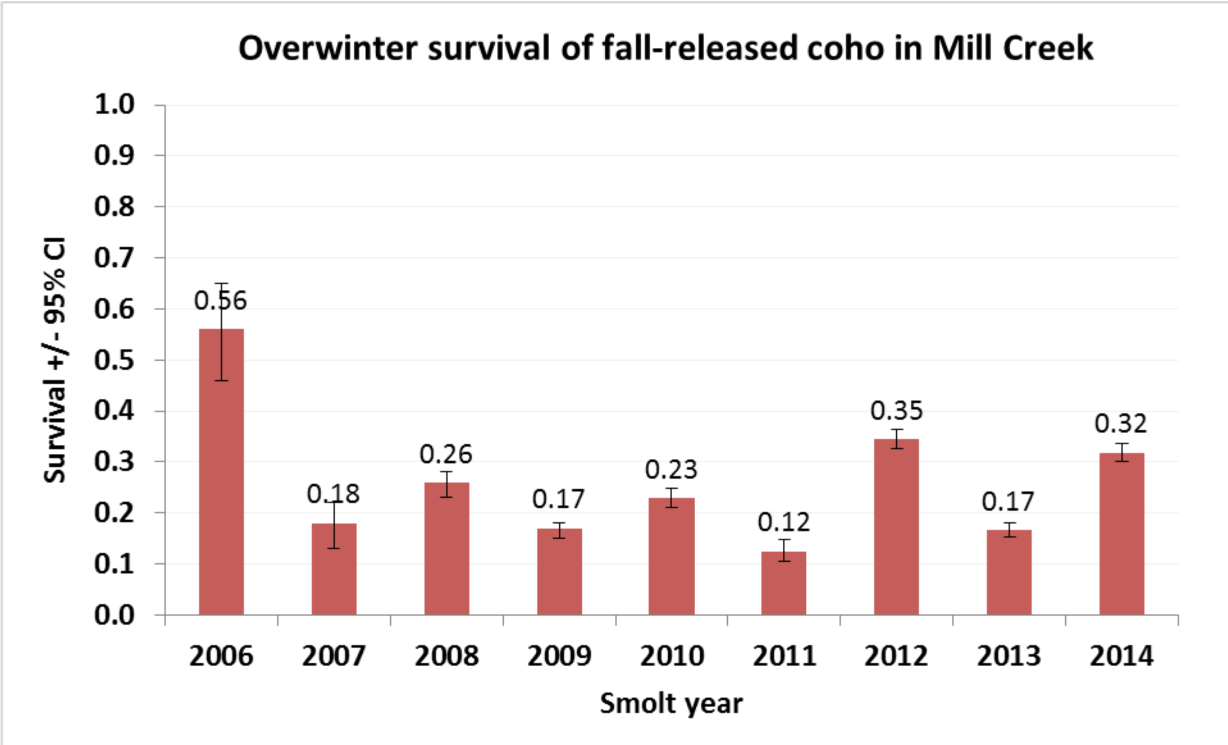

Figure 18. Estimated overwinter survival of juvenile coho released into Mill Creek during the fall season and emigrating as smolts the following spring.

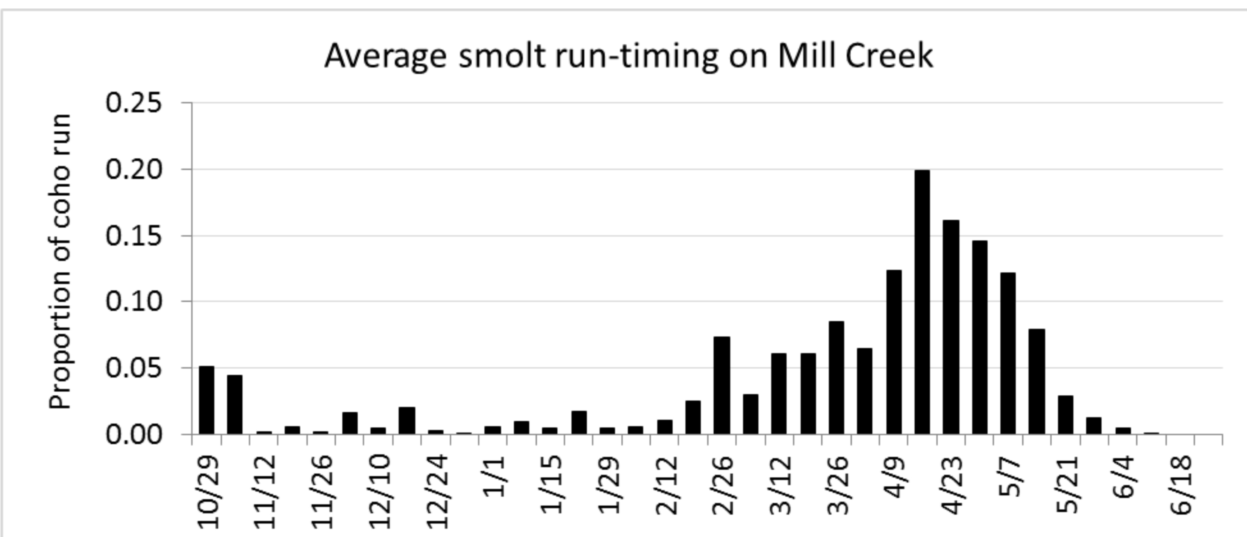

Figure 19. Average proportion of smolts detected emigrating each week from the time of fall release through the end of the smolt migration period. Dataset includes all fall releases between 2007 and 2013.

4.3.2 Adult returns

A combination of spawner surveys (2006-2014), adult trapping (2007-2011) and operation of PIT tag antenna arrays (2007-2014) have been used to estimate the number of adult coho returning to Mill Creek each year, beginning in the winter of 2006-2007 (Figure 20). Comparing the estimated number of smolts leaving each year with the estimated number of adults returning approximately one and a half years later, "marine" survival (survival from the mouth of Mill as smolts, through the river, to the ocean, and back to Mill as adults) averaged 0.3% for the last eight cohorts, ranging from 0 to 0.8%. Figure 21 displays the distribution of redds observed during annual winter spawner surveys conducted from 2006 and 2015. Although spawning has been observed throughout the watershed, the majority of known coho redds were observed in the lower reaches of Mill Creek (Figure 21). While it is possible that some of the unknown salmonid redds were coho redds, it is likely that the majority of them were steelhead redds based on the fact that, in subsequent juvenile surveys, greater numbers of juvenile steelhead than juvenile coho were observed in those locations.

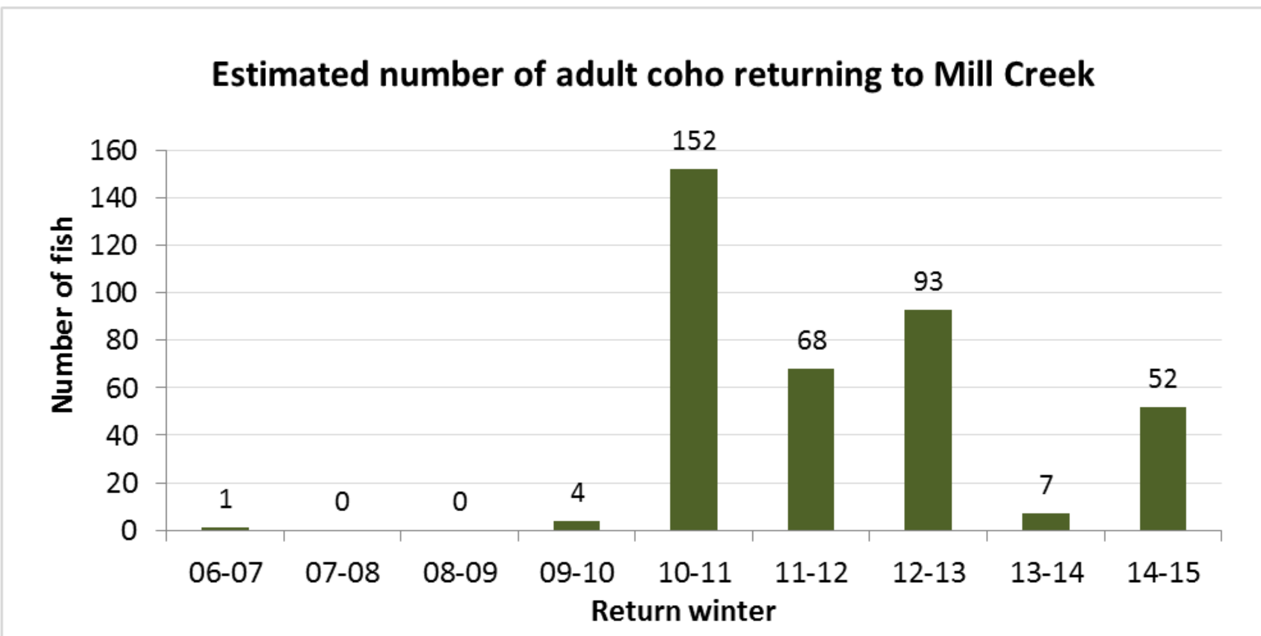

Figure 20. Estimated number of adult coho returning to Mill Creek each winter.

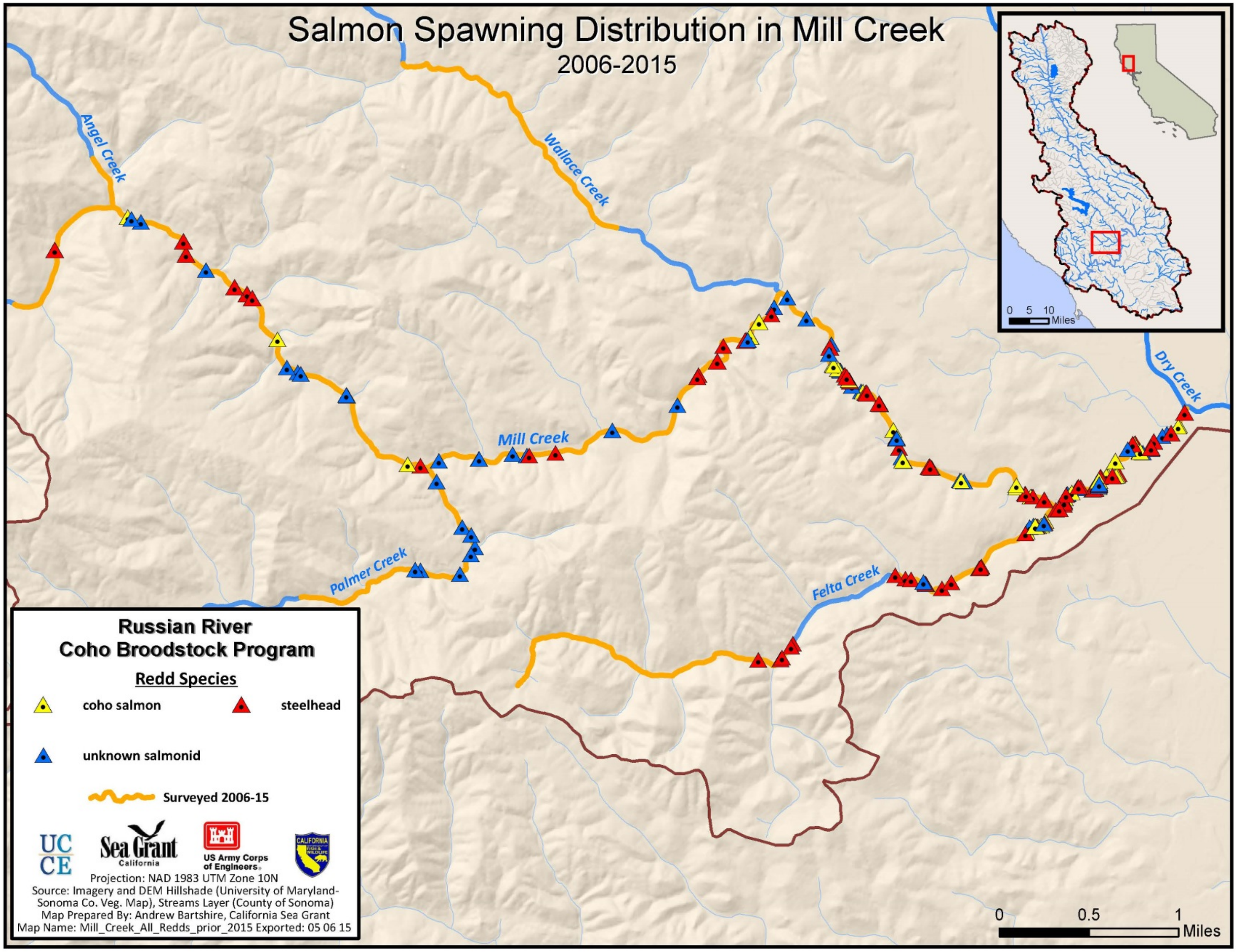

Figure 21. Map showing salmonid redds observed in Mill Creek between 2006 and 2015.

4.3.3 Natural production

Each summer (June-August), UC conducts snorkeling surveys in the Mill Creek watershed to document the presence of wild juvenile coho salmon, which provides evidence that successful spawning of adults occurred the previous winter. Since the inception of the Broodstock Program, the number of wild juveniles observed each year has generally increased, with the exception of 2014 in which no wild juvenile coho were observed (Table 5). The absence of wild juvenile coho in 2014 is likely explained by poorer ocean conditions than in previous years, as well as drought conditions during the winter of 2013-2014 that prevented adult coho from accessing Mill Creek until early February, after the peak spawning months of December and January.

Table 5. Total minimum count of wild coho young-of-the-year observed during UC presence/absence dive surveys, abundance surveys, and in downstream migrant smolt trapping operations in the Mill Creek watershed.

Year	Mill	Felta	Wallace	Palmer	Total
2005	23 [1]	33	n/a	0	56
2006	3 [1]	50	n/a	0	53
2007	2	0	n/a	0	2
2008	35 [1]	366	n/a	0	401
2009	0	n/a	n/a	0	0
2010	394	n/a	n/a	147 [2]	541
2011	1,585	310 [3]	n/a	3	1,898
2012	590	211	n/a	0	801
2013	3,259 (6,518) [4]	78	0	27	3,364 (6,623)
2014	0	0	0	0	0

[1] *These fish were thought to have originated in Felta Creek.*

[2] *Wild offspring of adult coho released into Palmer the previous winter.*

[3] *Limited access to conduct survey.*

[4] *Every other pool snorkeled. Expanded count is double the observed count.*

4.4 Flow-related bottlenecks to survival

Coho salmon need sufficient stream flow in order to complete their life cycle. During the summer season, juveniles need cool, connected pools in which to survive and grow. As one-year-old smolts, they need sufficient flows to migrate out of Mill Creek between March and June, through Dry Creek and the Russian River on their way to the ocean. One and a half years later, they need sufficient flows to migrate back upstream as adults and into Mill Creek to spawn in December through February. In Mill Creek, flow limitations have been documented for juvenile rearing, as well as for smolt and adult migration.

4.4.1 Flow limitations to juvenile rearing

As part of an effort to identify flow-impaired reaches in Mill Creek, in 2012 UC began conducting annual low flow surveys to document the lowest flow conditions fish might experience within a year. Each September, the stream is walked and flow conditions are categorized as dry, intermittent (wet pools but no surface flow), or wet (wet pools connected by surface flow) (Figure 22). The lowest reaches of Mill Creek have gone dry in all survey years and, with progressively drier years, the amount of dry habitat has been extending further and further upstream over time (Figure 22).

In order to understand the impact of these flow conditions on juvenile coho that are rearing in the stream during the summer months, the low flow survey data was overlaid with juvenile snorkeling count data collected earlier each summer to estimate the proportion of juveniles that were observed in reaches that later dried out. For example, Figure 23 shows the 2013 densities and distribution of juvenile coho salmon observed during June and July snorkeling surveys in relation to the low flow conditions that the fish experienced in September. Of approximately 3,819 wild juvenile coho observed in the Mill Creek watershed during the summer of 2013, 2,766 (72%) were found in reaches that became dry in September (Figure 23).

The high proportion of wild juveniles observed in the lower reaches of Mill during the summer is related to the fact that the majority of coho spawning occurs in the lower reaches of Mill Creek (Figure 21). One likely reason for the observed spawning distribution was the presence of two partial passage barriers low in the watershed that were likely preventing adults from accessing the upper watershed in some winters. The lower of the two partial barriers was removed in 2012. Following that removal, a significant increase in the number of redds was observed upstream of that barrier (Figure 24, Figure 25). The second barrier is a high priority for removal to increase access of adults to the upper reaches of Mill Creek that remain wet throughout the summer dry season.

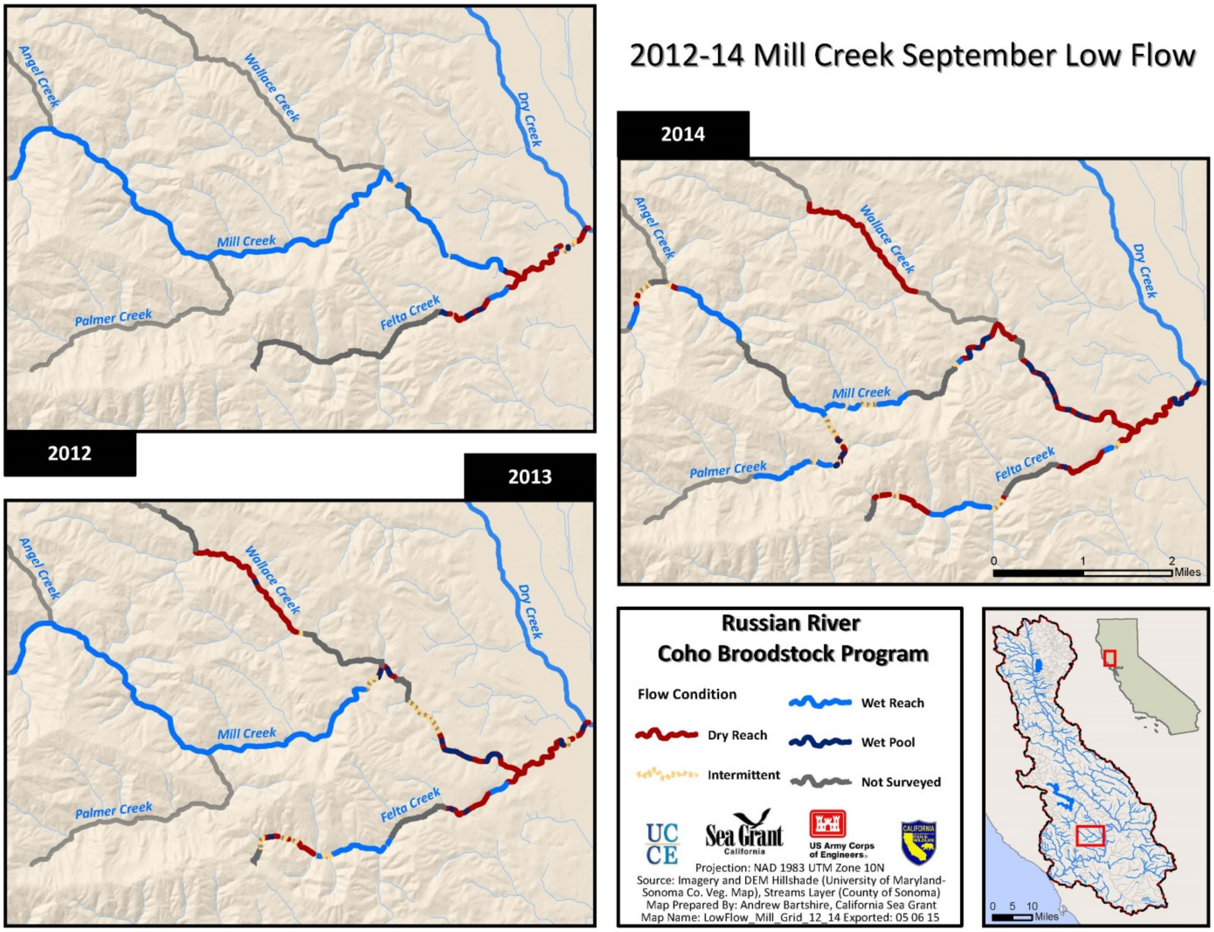

Figure 22. Low flow conditions in Mill Creek each September from 2012 through 2014.

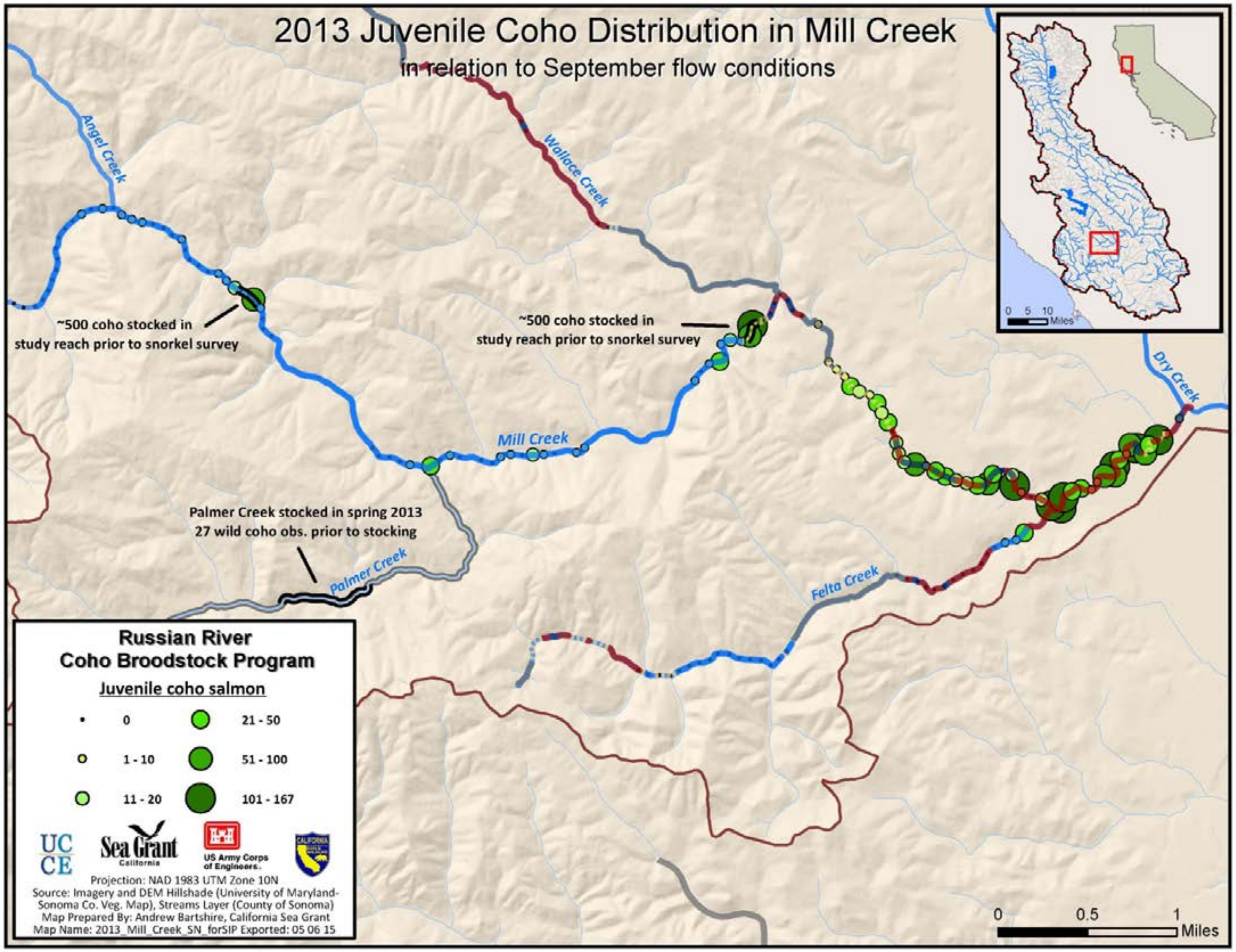

Figure 23. Distribution of juvenile coho observed during the summer of 2013, in relation to low flow conditions in September 2013.

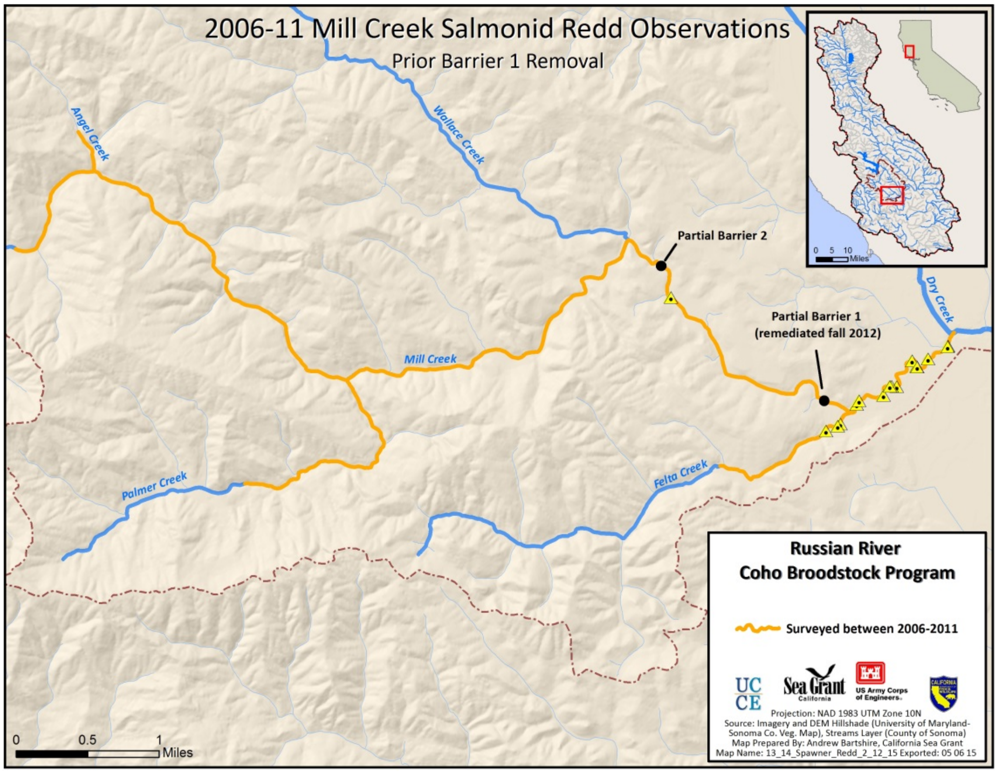

Figure 24. Coho salmon redd observations before partial passage barrier removal in Fall 2012.

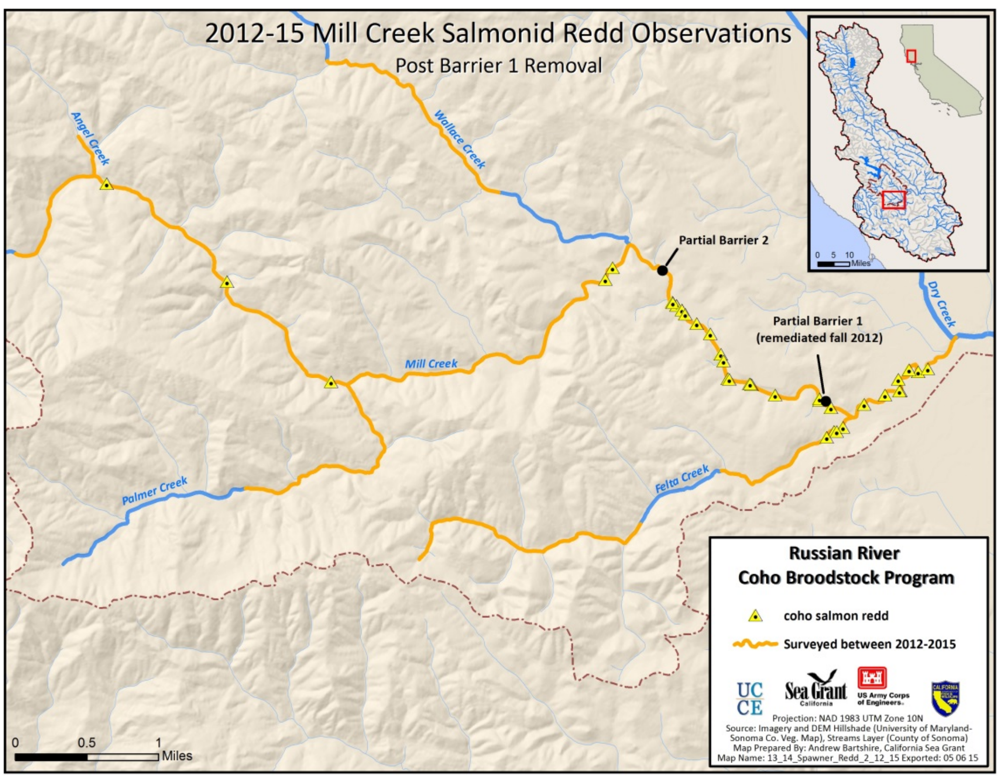

Figure 25. Coho salmon redd observations following partial passage barrier removal in Fall 2012.

4.4.2 Low flow impacts on migration of smolts and adults

In some years, lack of surface flow has cut off the migration corridor for smolts attempting to leave Mill Creek in the spring, as well as adults attempting to migrate upstream during the winter. For example, during the spring of 2008, Mill Creek became disconnected from Dry Creek on May 14, prior to completion of the smolt run (Figure 26). In this year, 1,261 coho smolts (23% of all smolts captured) were unable to migrate to the ocean due insufficient surface flow. Since 2005, such disruptions to smolt migration have occurred in 2008, 2009 and 2014, and are likely to occur in 2015.

During the winter of 2013-2014, coho salmon adults were documented entering the Russian River during October- December 2013 but, due to lack of flow, were not able to access spawning habitat in Mill Creek until February 6, 2014, after the first significant rain event that reconnected Mill Creek to Dry Creek and the mainstem of the Russian River. Although this extreme winter drought event was unique over the last 10 years of monitoring, the flashier nature of winter stream conditions in recent years appears to be influencing access to streams during the winter, as well as exposing redds between storm events.

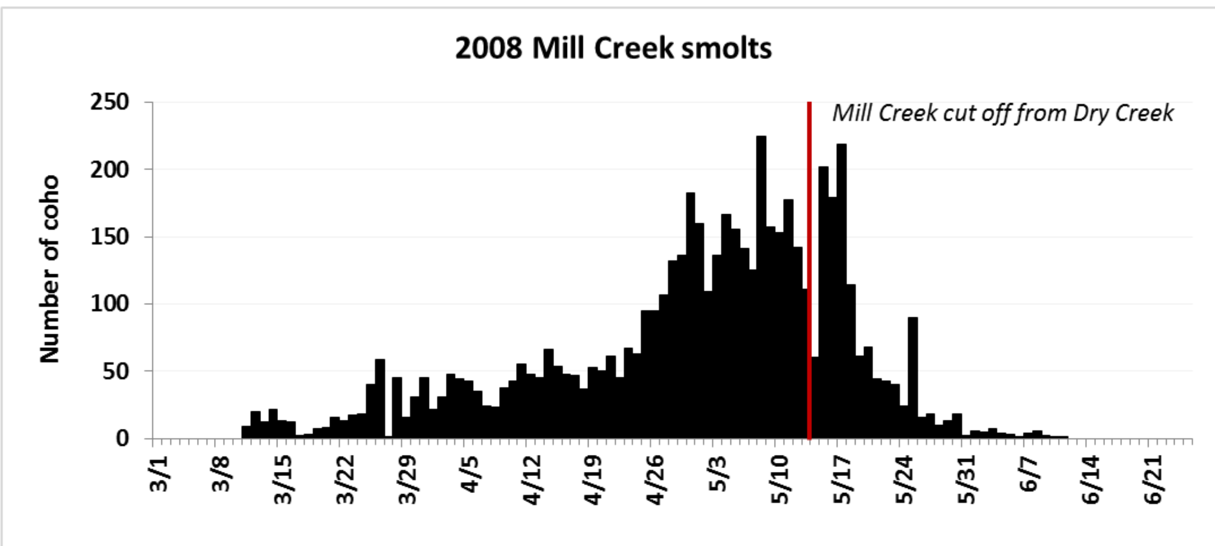

Figure 26. Migration timing of Mill Creek coho smolts in relation to when Mill Creek became disconnected from Dry Creek due to lack of surface flow in 2008.

4.5 Survival and flow monitoring

4.5.1 Overview

Through its work with the Coho Partnership, UC has been conducting an ongoing study of over-summer survival of juvenile coho in relation to flow and other environmental variables in Mill Creek, as well as three other Russian River tributaries (Dutch Bill, Green Valley and Grape Creeks), since 2010. The goal of this study is to describe the relationship between juvenile coho oversummer survival and environmental metrics, and to evaluate the effectiveness of flow enhancement projects at increasing survival of juvenile coho salmon.

The overall study design follows the BACI (Before-After, Control-Impact) framework, which examines conditions *Before* and *After* project implementation, as well as comparing a *Control* site (reference reach) with an *Impact* site (treatment reach). Having a control, or reference, reach allows the effects of restoration actions to be discerned from natural variability, stochastic events, and underlying trends. UC biologists selected treatment reaches—which were likely to be influenced by streamflow improvement projects—and reference reaches—which were unlikely to be influenced by projects—and compared survival at pre-determined intervals during the dry season with environmental variables most likely to impact survival (flow, temperature, wetted volume and dissolved oxygen). Each site has been surveyed over regular intervals (e.g., monthly) through each of the past five summers; at each survey session, juvenile coho salmon were counted, and streamflow, physical channel characteristics (e.g., pool depth, wetted area, total wetted volume) and other environmental metrics (e.g., water temperature, dissolved oxygen) were measured. More detailed descriptions of methods are described below.

The Mill Creek reference reach, in the upper watershed, maintains relatively steady flow through the summer and is located upstream of any prospective future flow enhancement project sites. It begins at river kilometer 12.39 and extends upstream for 240 meters (Figure 27). This reach has been surveyed, as part of this study, from 2010-2014 and ongoing sampling is expected. The Mill Creek treatment reach was originally established at river kilometer 8.65, upstream of the Puccioni Road crossing, and extended for 300 meters upstream (Figure 27). After the first year of sampling, it was determined that this reach was not well-suited as a treatment reach, since it was not notably flow-impaired and was unlikely to be a target location for flow improvement work. In 2011, a more suitable treatment reach was established at river kilometer 6.10, upstream of the confluence with Wallace Creek (Figure 27). This treatment reach,[7] which extends upstream for 210 meters, is located in an area of marginal surface flow. In most years, Mill Creek becomes disconnected, or dries entirely, downstream of this reach, while it remains mostly wet upstream. The reach itself generally has sufficient surface flow but becomes flow-impaired in the driest years, or possibly as a result of withdrawals. Sampling occurred in this reach from 2011-2014 and is expected to continue.

[7] From this point forward, the Mill treatment reach discussed in this document refers solely to the reach established in 2011 at river kilometer 6.10, unless otherwise specified.

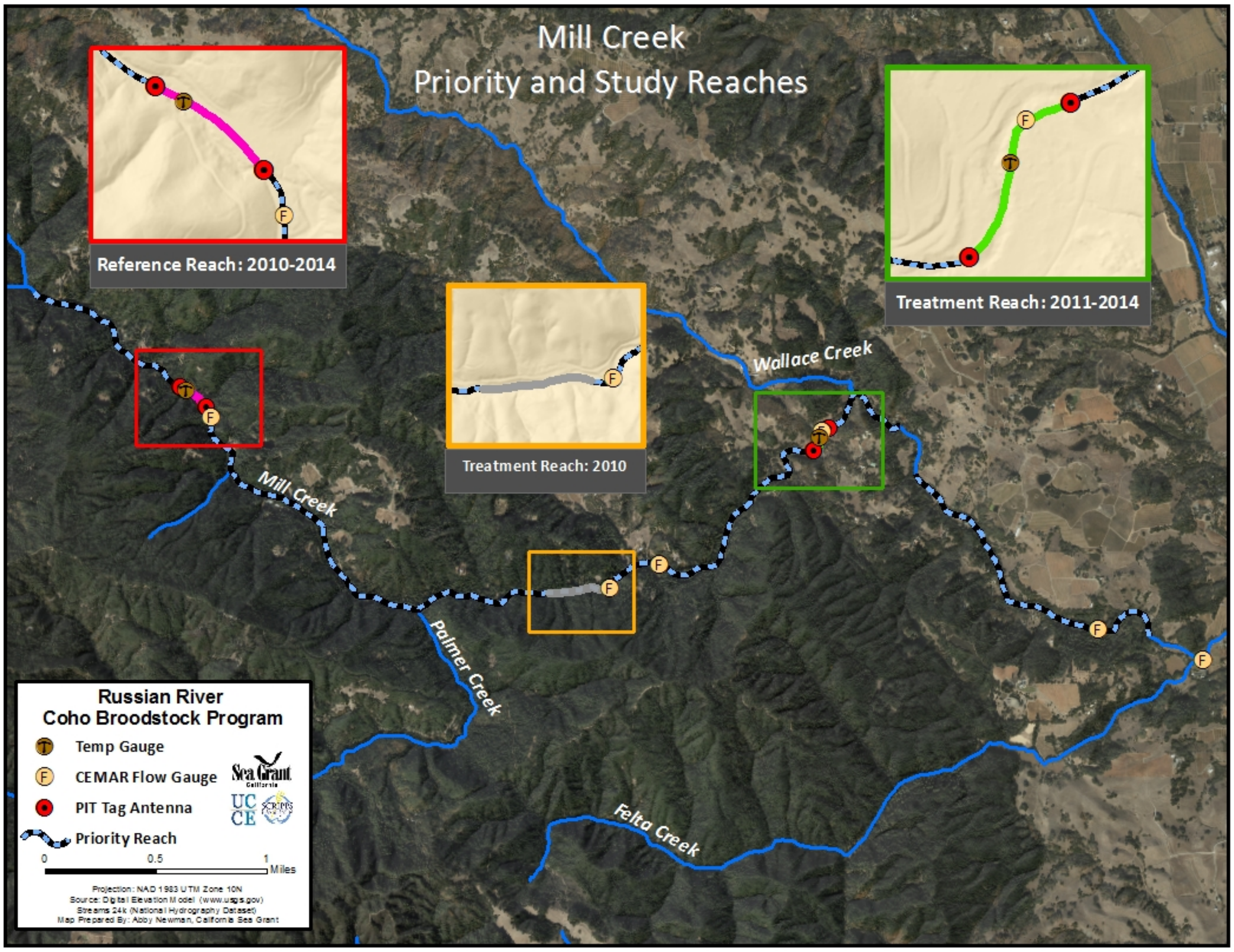

Figure 27. Map of the priority focus reach, reference and treatment reaches in Mill Creek.

4.5.2 Methods

Each year, UC biologists worked with the Russian River Coho Salmon Captive Broodstock Program to implant PIT tags in approximately 1,000 young-of-the-year (yoy) coho produced at the Don Clausen Warm Springs Hatchery and released 500 into each of the Mill Creek study reaches in June. Prior to the release, UC constructed and installed PIT tag antennas at the downstream boundary of the study reaches to document emigration throughout the summer survival interval. An additional antenna was installed at the upstream boundary of the Mill treatment reach in 2013 and at the upstream end of the Mill reference reach in 2014 to account for upstream movements as well.

Habitat surveys and dissolved oxygen sampling were conducted in each reach at pre-established intervals of approximately 4-8 weeks between June and October. In 2012, only June and September surveys were conducted, due to funding limitations. Hourly water temperature data was collected throughout the study period by deploying a continuously recording temperature logger in a representative pool within each reach.

UC biologists conducted paired “wanding” survey at the same intervals as the habitat surveys, using a portable PIT tag detection system, in order to estimate survival of coho over each interval. Approximately one month after planting, an additional wanding survey was conducted above reaches that had no upstream boundary antennas in order to account for fish that had moved out of the study reach. UC biologists relied on streamflow data from the CEMAR gauges in the watershed to correlate fish survival with streamflow. A multiple-day electrofishing survey was conducted on each reach in late September or early October to measure coho in order to estimate oversummer growth.

4.5.3 Results

4.5.3.1 Habitat

Channel type, average over-channel canopy cover, average oversummer shelter rating and pool depth were used to describe basic morphological and habitat characteristics within each of the study reaches (Table 6).

Both the Mill Creek treatment and reference reaches were classified by CDFW as F4 channel types (CDFW 2000). F4 channels are defined as entrenched, meandering, riffle-pool channels on low gradients with a high width-to-depth ratio and gravel substrate (Flosi et al. 1998).

Canopy was assessed each June in order to quantify the amount of vegetation providing shade cover over the stream channel, an important factor in maintaining cool water temperatures and reducing evaporation during the hot summer months. Average percent coniferous cover was also assessed in order to characterize dominant riparian forest composition. Between 2011 and 2014, the Mill Creek treatment reach had an average canopy cover of 90%, with virtually no coniferous cover, while the reference reach had an average canopy of 83%, with 45% of that cover comprised of coniferous trees (Table 6). Average canopy cover in both Mill Creek reaches exceeded CDFW’s habitat benchmark of ≥80% (Flosi et al. 1998).

Shelter was assessed for all pool and flatwater units in order to quantify the amount of instream cover available to fish. For each unit, a shelter rating was derived through an assessment of shelter composition, quality and percent total cover within the stream channel. The shelter rating values listed in Table 6 were averaged for all pool and flatwater units over the survey period of June to October from 2011 to 2014. The average instream shelter rating was 16.5 in the Mill treatment reach and 31.6 in the reference reach (Table 6). CDFW established a shelter value criterion of ≥80 for suitable salmonid habitat (Flosi et al. 1998). Shelter values in both Mill Creek reaches were well below this criterion (Table 6).

Maximum depth was measured in every pool during each habitat survey. When June depths were averaged over all years, 38% of pools in the reference reach and 71% of pools in the treatment reach had maximum depths of >3.0 (Table 6). CDFW has stated that ≥ 40% of pools in a reach (by length) should be ≥ 3.0 feet deep in order to meet the habitat needs of salmonids for third order streams (Flosi et al. 1998). In June, the reference reach nearly met this benchmark and the treatment reach exceeded it substantially (Table 6).

Dominant substrate was recorded for all riffles. When averaged over a two-year period, 87% of riffles in the study reaches were dominated by gravel or small cobble substrate; substrates designated as desirable for salmonid spawning (Flosi et al. 1998).

Table 6. Mill Creek study reach characteristics, averaged from 2011 to 2014. Note that the percentage of pools >3.0' deep reflects measurements of maximum depth, not residual depth, taken during the June survey.

Reach	Channel type[1]	Avg canopy (%) +/- 1 SD	Avg coniferous cover (%) +/- 1SD	Avg shelter rating +/- 1 SD	Avg % pools >3.0'D by length +/- 1 SD
Mill treatment	F4	90.2 +/- 8.9	0.1 +/- 0.4	16.5 +/- 14.0	0.71 +/- 0.04
Mill reference	F4	82.8 +/- 10.8	45.5 +/- 24.9	31.6 +/- 15.9	0.38 +/- 0.12

[1]*Rosgen stream channel classification from CDFW stream reports*

Though habitat characteristics were not quantified for the entire stream, the habitat in our defined study reaches was averaged over all study years and qualified in relation to CDFW's established benchmarks (Flosi et al. 1998). Average canopy cover in both Mill reaches exceeded CDFW's habitat benchmark. The Mill treatment reach exceeded CDFW's benchmark for the proportion of primary pools ≥ 3.0 feet by reach length, while the reference reach was just 5% short of it. The vast majority of riffles in the study reaches met CDFW's criteria for suitable spawning substrate.

By contrast, shelter values were well below CDFW's desired value of ≥80 for salmonids (Flosi et al. 1998). Shelter ratings of ≥80 have not been recorded in any study reaches on Russian River tributaries, where the greatest shelter value documented was 62, in a highly-enhanced reach. In the context of the four streams included in this study, shelter ratings in both the Mill treatment reach (16.5) and the Mill reference reach (31.8) were very close to the average values exhibited across all treatment and reference study reaches for all years (16.5 and 30.8, respectively).

The results of this study, combined with a decade of year-round observations of stream conditions and fish distribution, led UC biologists to characterize the physical habitat in both Mill Creek study reaches, along with the majority of Mill Creek upstream of the Westside Road crossing, as relatively high quality. The available habitat appears sufficient to meet the needs of salmonids occupying those reaches, in the presence of ample surface flow.

4.5.3.2 Temperature

Continuous temperature loggers were deployed in each study reach throughout the oversummer season. Daily water temperature in the Mill treatment reach from June 15 to October 15 of 2011 to 2014 averaged 16.1° C (+/- 0.6° C SD), with an average maximum weekly average temperature (MWAT) of 18.5° C (+/- 1.4° C SD), and an average maximum weekly maximum temperature (MWMT) of 19.8° C (+/- 1.9° C SD). Oversummer daily temperatures in the Mill reference reach from

June 15 to October 15 of 2010 to 2014 averaged 15.2° C (+/- 0.4° C SD), with an average MWAT of 17.2° C (+/- 0.7° SD) and an average MWMT of 18.0° C (+/- 0.9° C SD).

Optimal instream temperatures for coho salmon are between 10° and 15° C (McMahon 1983). Welsh et al. (2001) found that coho salmon were absent from otherwise suitable rearing habitat in the Mattole watershed when MWAT exceeded 16.7° C, and MWMT exceeded 18° C. At 20-20.3° C and above, coho experience significant decreases in swimming speed, increased mortality from disease and cease to grow (McMahon 1983). Temperatures exceeding 25-26°C are lethal to coho salmon (NMFS 2012). CDFW established a benchmark of ≤15.5° C for coho and ≤18.3° C for steelhead (Flosi et al. 1998). This criterion was established for the entire North Coast region, but there is evidence that Russian River salmonids can survive at higher temperatures over the summer months (Obedzinski et. al 2008).

Average water temperatures observed in the Mill treatment reach over the summers of 2011 to 2014 are above the preferred range for coho salmon, but within the tolerance range, and within the suitable range for steelhead. The following graph, however, illustrates that average daily temperatures in this reach exceeded the optimal threshold for coho for the majority of the study period and exceeded the impairment threshold of 20° C in the hottest period during July, 2013 (Figure 28). Average MWAT in the treatment reach was above the avoidance threshold for coho but below the impairment threshold, while average MWMT was above the avoidance threshold and nearly reached the impairment threshold.

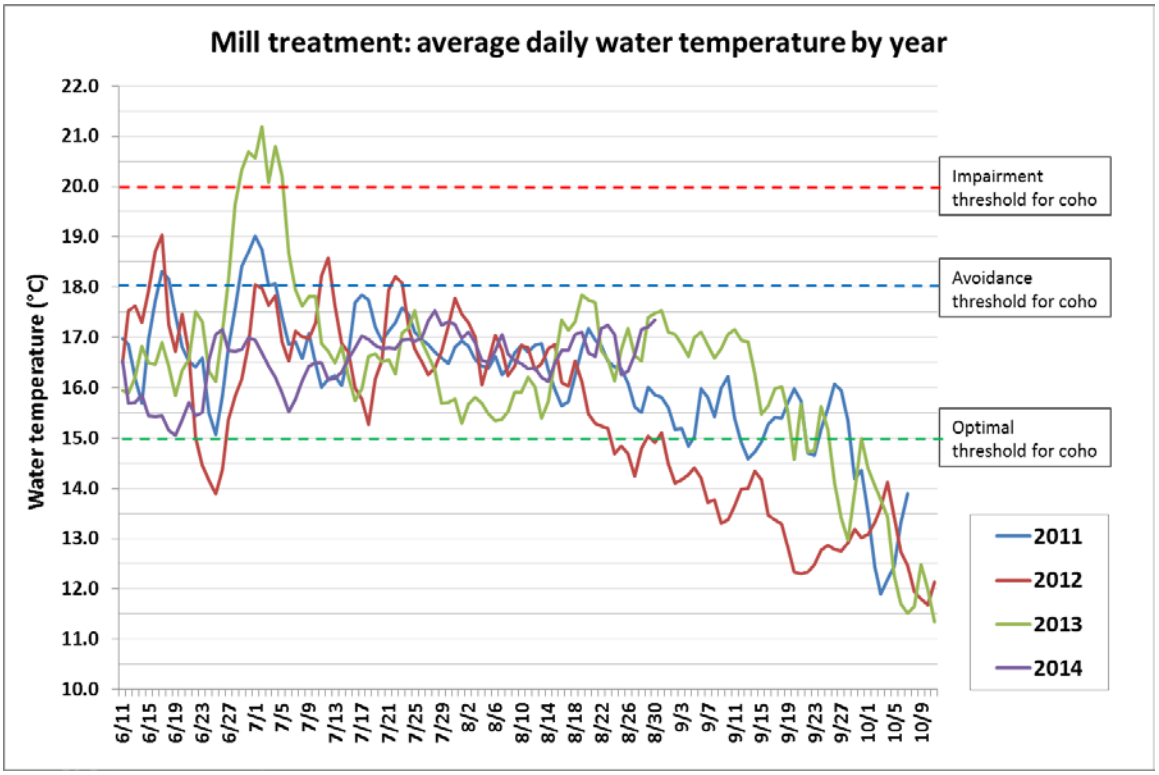

Figure 28. Average daily water temperatures in the Mill Creek treatment reach over the summers of 2011-2014 in relation to thresholds described in McMahon (1983).

Average daily water temperatures in the Mill reference reach over the summers of 2011 to 2014 were at the high end of the optimal temperature range for coho but well within the suitable range for steelhead. A closer look at the entire season by year shows that average daily temperatures in this reach exceeded the optimal threshold for coho for the majority of the study period and exceeded the avoidance threshold of 18° C in the hottest period during July, 2013 (Figure 29). Average daily water temperatures never exceeded the impairment threshold for coho in the reference reach (Figure 29). Average MWAT over all study years in the reference was above the preferred range for coho, but below the avoidance threshold, while average MWMT was right at the threshold level for avoidance, but within the tolerance level.

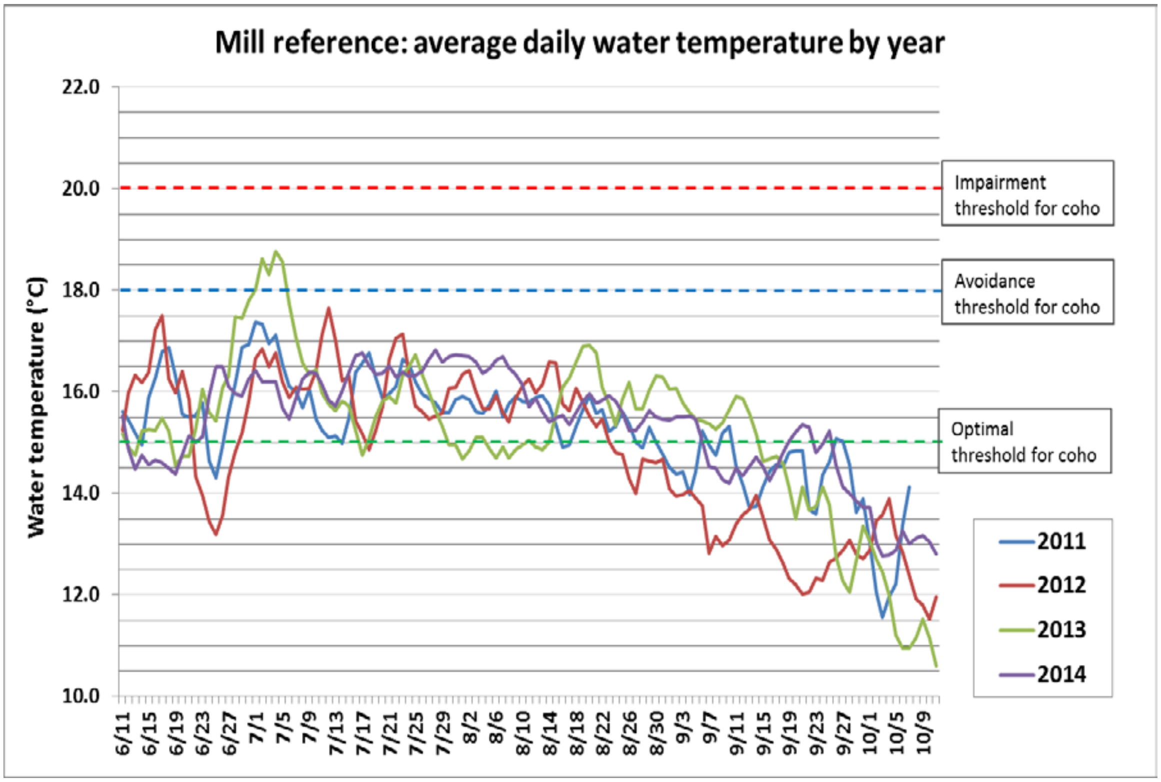

Figure 29. Average daily water temperatures in the Mill Creek reference reach over the summers of 2011-2014 in relation to thresholds described in McMahon (1983).

4.5.3.3 Dissolved oxygen

Dissolved oxygen (DO) data was collected at survival sample intervals in each study reach over the summers of 2011 to 2014, using a YSI 55D and YSI Pro20 handheld DO sensor (model varied by year). All sampling was conducted at the same location and depth (0.9') in every pool within a reach for each study year. DO data was collected within a window of about an hour in late morning (9:00-10:00 a.m.). DO in the Mill treatment reach over all years averaged 7.7 mg/L (+/- 2.0 mg/L SD), while DO in the Mill reference reach over the same period averaged 8.8 mg/L (+/- 0.9 mg/L SD).

The North Coast Regional Water Quality Control Board (NCRWQCB) listed an objective of 7.0 mg/L as a year-round daily minimum DO objective for the Russian River Hydrologic Unit (NCRWQCB 2007). Moderate production impairment is known to occur below 5.0 mg/L (NCRWQCB 2007). Food conversion decreases below 4.5 mg/L, inhibiting growth in juvenile salmonids, who have been documented avoiding waters with DO concentrations this low (McMahon 1983). The lower limit to avoid acute mortality in salmonids is 3.0 mg/L (NCRWQCB 2007).

Average DO concentrations in both Mill Creek reaches over the summers of 2011-2012 met or exceeded NCRWQCB's water quality objective. DO concentrations in the treatment reach fell below this threshold in August and October of 2013, and dropped well below mortality levels in August of 2014 when surface flows were 0.00 ft^3/s (Figure 30). Average DO in the reference reach only fell below 7.0 mg/L in August of 2014 and remained above production impairment levels on every date sampled (Figure 31).

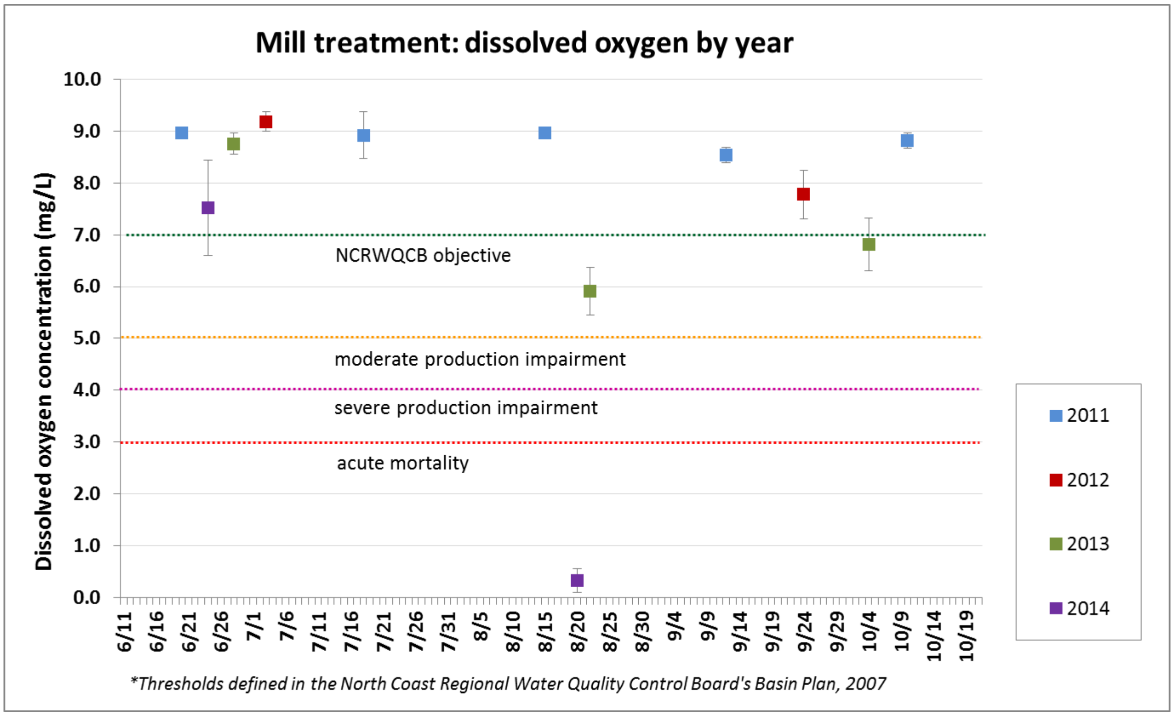

Figure 30. Reach average dissolved oxygen concentration in the Mill Creek treatment reach for all sample intervals, 2011-2014.

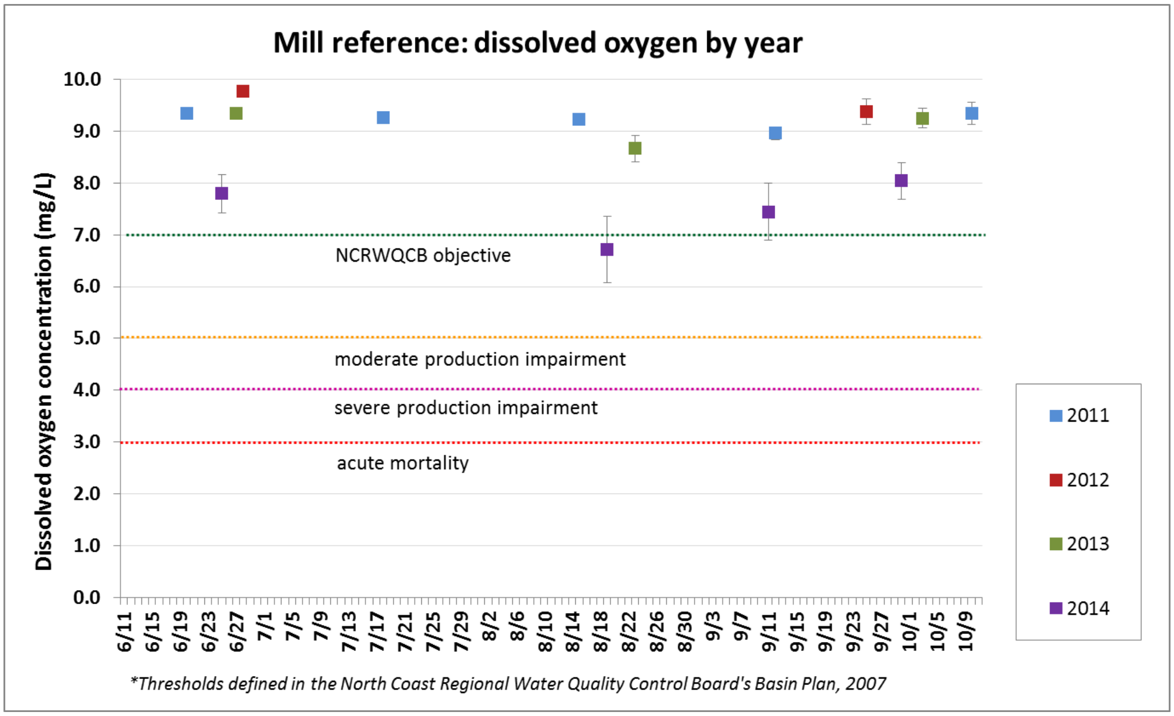

Figure 31. Reach average dissolved oxygen concentration in the Mill Creek reference reach for all sample intervals, 2011-2014.

4.5.3.4 Survival and surface flow

Patterns in oversummer survival between the treatment and reference reach differed during the study period of 2011 through 2014 (Figure 32). In the treatment reach, survival decreased from 0.81 in 2011 to 0.00 in 2014 (Figure 32). In contrast, we observed little variation in survival in the reference reach over the same time period (range 0.62 to 0.81)(Figure 32). In both reaches, we observed a decline in survival from 2011 through 2013, however, the overall decrease in the treatment reach (0.37) was greater than in the reference reach (0.13). In 2014, there was an extreme difference in survival between the two reaches; in the treatment reach no fish survived while, in the reference reach, we observed higher survival than in any other year (Figure 32). In comparison with other study streams, average oversummer survival between 2011 and 2014 in the Mill treatment reach (0.36) and the Mill reference reach (0.64) were higher than average survival in all treatment and reference reaches collectively over the 2011 to 2014 study period (0.27 and 0.51, respectively).

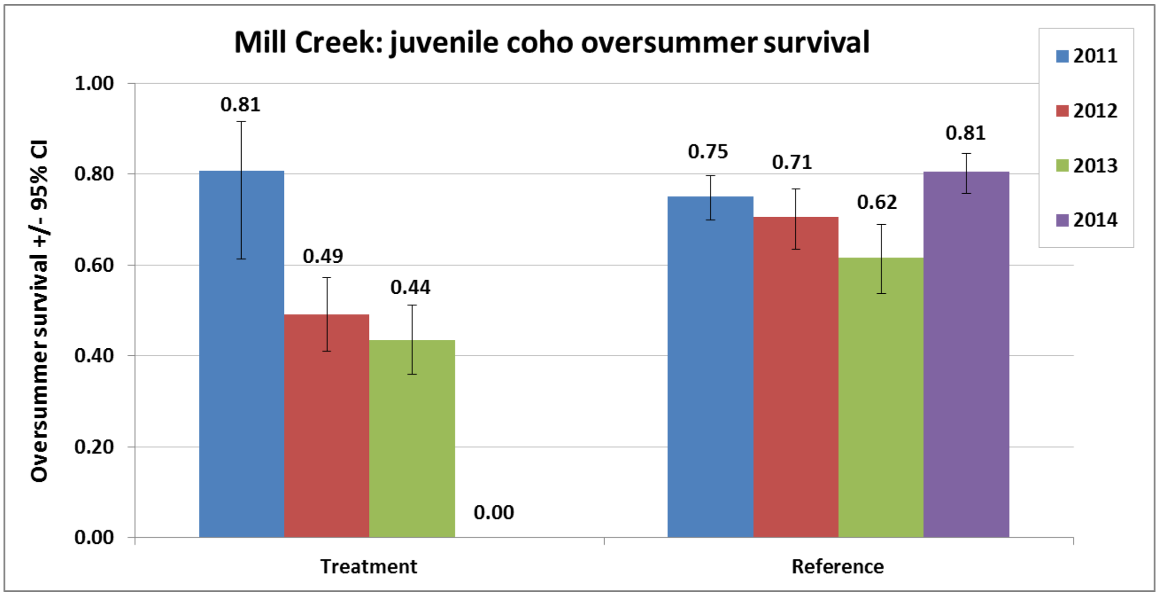

Figure 32.Survival in the Mill Creek treatment and reference reaches from 2011-2014, scaled to the period of June 25-October 15.

Flow patterns from 2011 through 2014 also differed between the two reaches (Figure 33, Figure 34). In general, flows were lower but more consistent in the reference reach compared to the treatment reach (Figure 33, Figure 34). The generally lower stream flows observed in the reference reach can be explained partly by the fact that it is located more than six kilometers upstream of the treatment reach, above the confluence with a substantial tributary, and has a smaller cross-sectional area. While stream discharge in June and July was typically higher each year in the treatment reach, more variation was observed from late July through October in this reach, with levels dropping to 0.00 ft^3/s for extended periods in both 2013 and 2014 (Figure 33). In the reference reach, discharge nearly always remained below 0.5 ft^3/s, with the exception of 2011, but only dropped to 0.00 ft^3/s for one day in 2014 (Figure 34, Figure 35).

Relationships between flow and survival in Mill Creek are complex. Despite generally lower surface flows in the Mill reference reach (Figure 33, Figure 34), survival was almost always higher in this reach (Figure 32). In part, this may be attributed to the fact that flow is not the only factor influencing survival. Differences in shelter (Table 6), temperature (Figure 28, Figure 29) or factors that we did not account for, such as predation or density, may also explain the overall differences in survival between the two reaches. Geophysical differences such as substrate and connection to the aquifer may also influence the relationship between flow and survival in these reaches.

Within the treatment reach, we observed a decrease in survival that corresponded to increasingly lower surface flows between 2011 and 2014, but we did not observe this pattern in the reference reach (Figure 36, Figure 37). The 100% mortality observed in the Mill treatment reach in 2014, after three years of high to average oversummer survival, can be attributed to an extreme drop in surface flow conditions that year. In late July, average daily discharge dropped from 0.18 ft^3/s to 0.0 ft^3/s in just three days and minimum daily discharge over that period fell from 0.10 ft^3/s to 0.00 ft^3/s (Figure 35). Zero surface flow persisted, leaving pools disconnected and/or dry for 65 days (Figure 35).

By contrast, survival was high in the reference reach in 2014 and the hydrograph sustained a natural pattern of minimal and gradual reduction through late September (Figure 35). There was only one day during the study period with an average discharge of 0.0 ft^3/s, so there was no persistent disconnectivity in that reach (Figure 35).

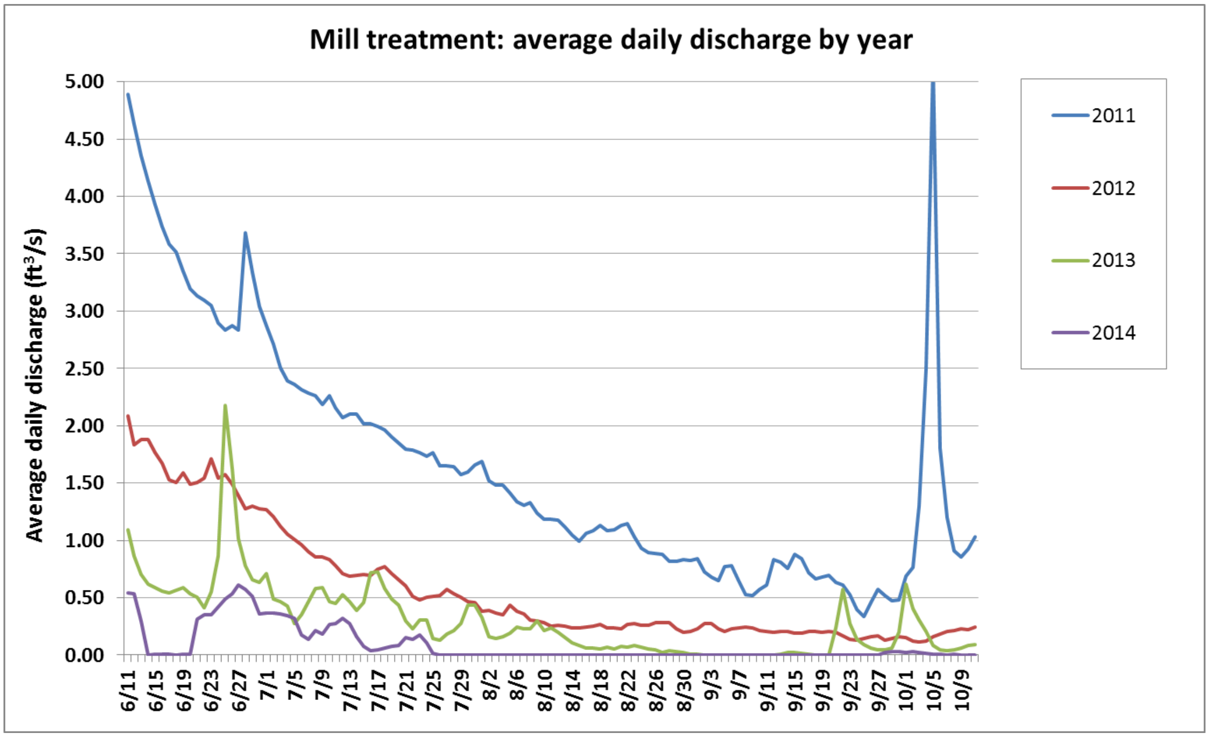

Figure 33. Average daily discharge in the Mill Creek treatment reach over the summers of 2011-2014.

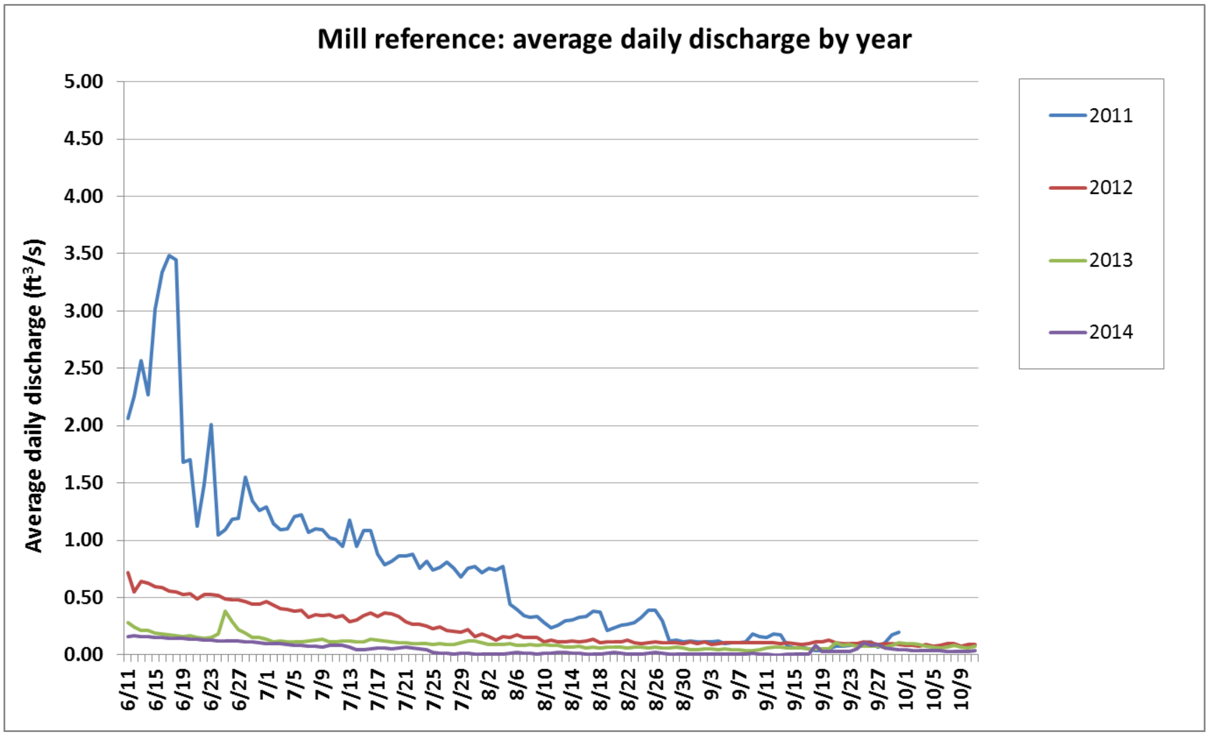

Figure 34. Average daily discharge in the Mill Creek reference reach over the summers of 2011-2014.

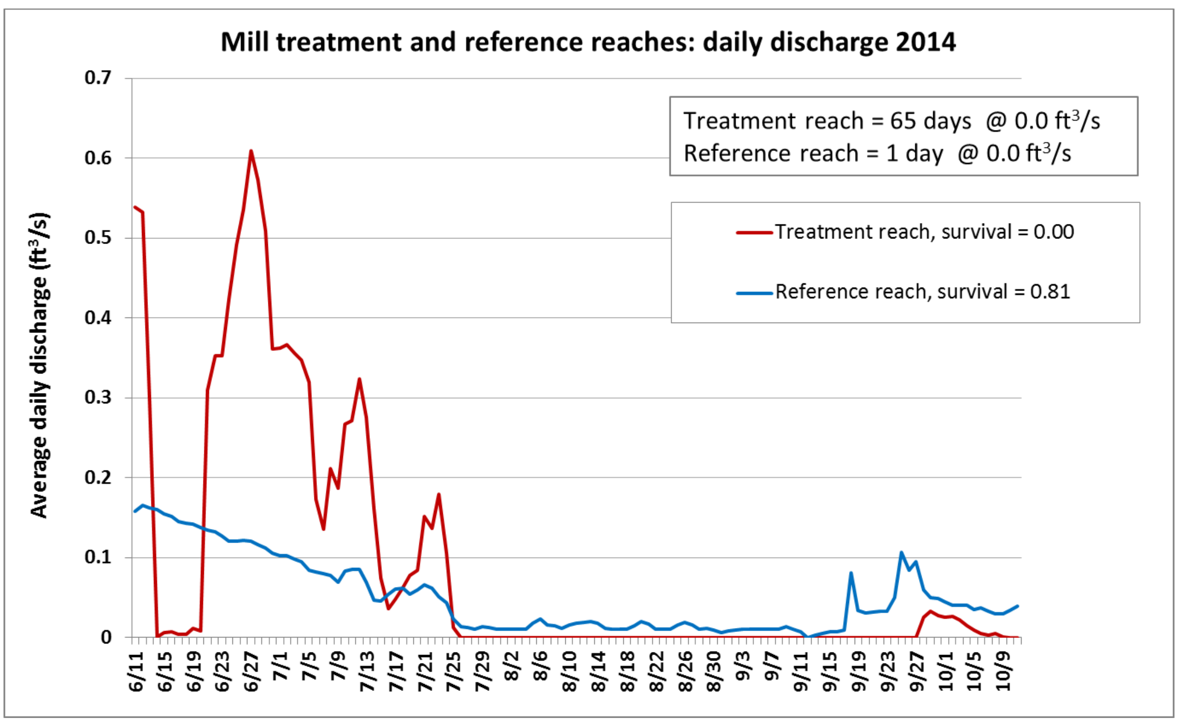

Figure 35. Average daily discharge in the Mill Creek treatment and reference reaches over the summer of 2014. Table shows total number of days over the study period that average discharge was at 0.00 ft3/s—the value at which pools were disconnected.

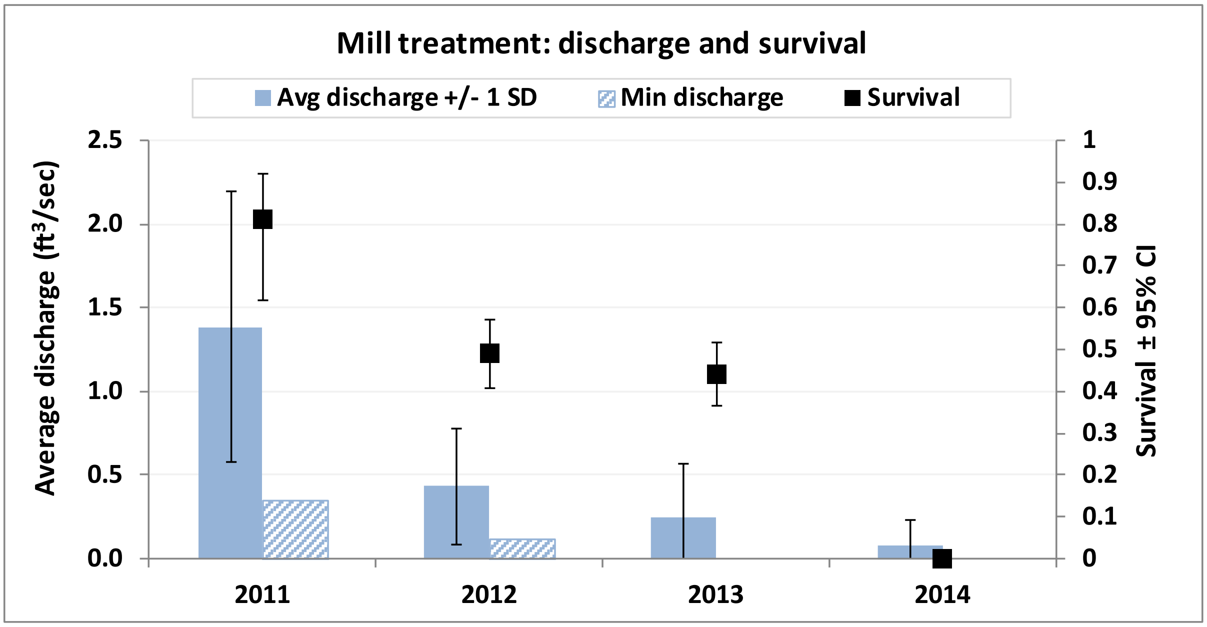

Figure 36. Stream discharge and survival in Mill Creek treatment reach between 2011 and 2014.

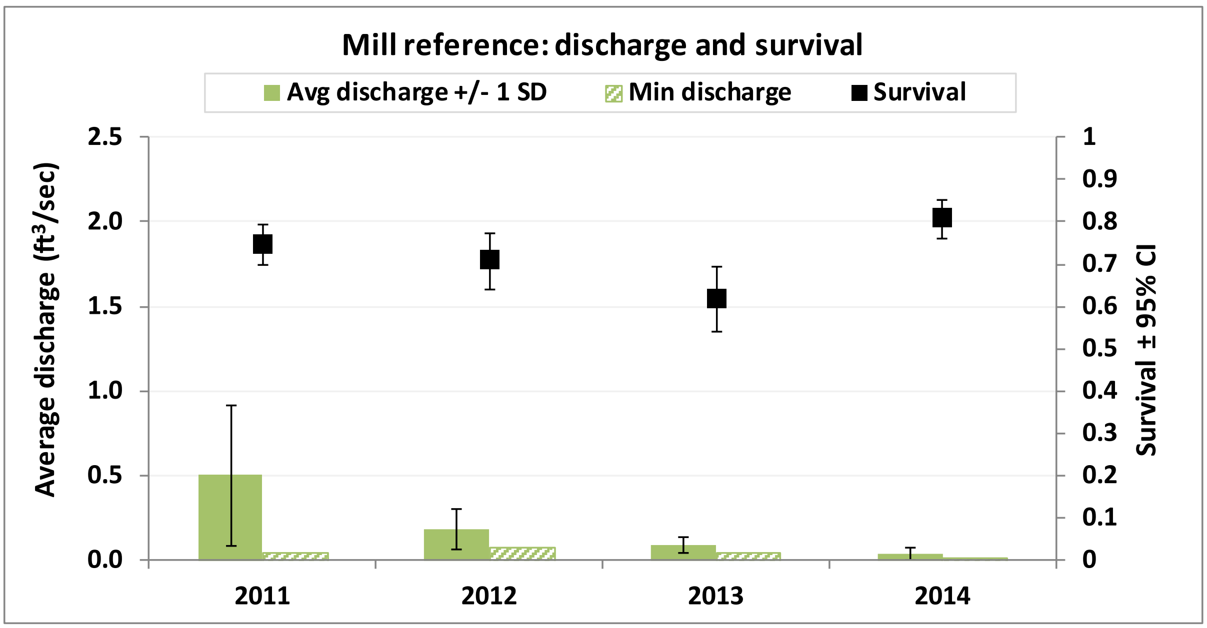

Figure 37. Stream discharge and survival in Mill Creek reference reaches between 2011 and 2014.

4.5.3.5 Survival and other environmental conditions

Comparison of survival with wetted volume, dissolved oxygen levels and stream temperature provides insight into the differing survival patterns observed in the two reaches. In general, while streamflow was lower in the reference reach, wetted volume remained more consistent, dissolved oxygen levels were higher and temperatures were lower.

The change in reach-scale total wetted volume over each summer was evaluated for the Mill treatment reach in relation to survival (Figure 38). The highest wetted volume each year in Figure 38 is the amount of water available in cubic meters during the June sample and the lowest is the amount remaining at the driest point of the season (generally in September). Surface flow in the Mill treatment reach dropped to 0.0 ft^3 in late July, 2014 and the reach was essentially dry during our August habitat survey, with a total wetted volume of only 16.6 m^3. Compared to our June measurement of 355.1 m^3, this equaled a reduction in wetted pool volume of 97% (Figure 38). The reach remained dry through our final sample in late September. Desiccation of nearly all of the pools corresponded to zero survival (Figure 38).

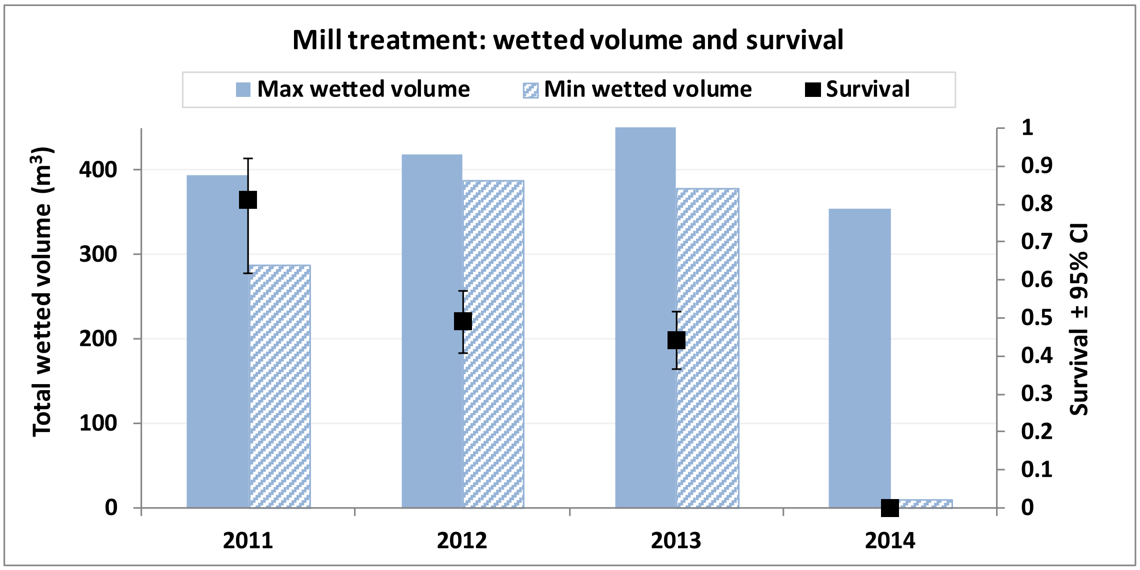

Figure 38. Total wetted volume at the wettest (June) and driest points in the season and oversummer survival in the Mill treatment reach.

During that same year, wetted volume in the Mill reference reach dropped by only 10%, from 203.2 m^3 to 182.5 m^3 (Figure 39). Due to location within the watershed, the reference reach started the 2014 season with less than 60% of the wetted volume of the treatment reach but, remarkably, there was very little decrease in wetted volume over the summer in this reach, despite drought conditions. The stability of streamflow and wetted volume at the Mill Creek reference reach indicates that the springs, groundwater inflow, and other sources of water were capable of sustaining summer base flow through the third consecutive drought year; and upstream human water uses were not large enough to deplete these sources before reaching the reference reach. This likely contributed to the higher survival rates observed.

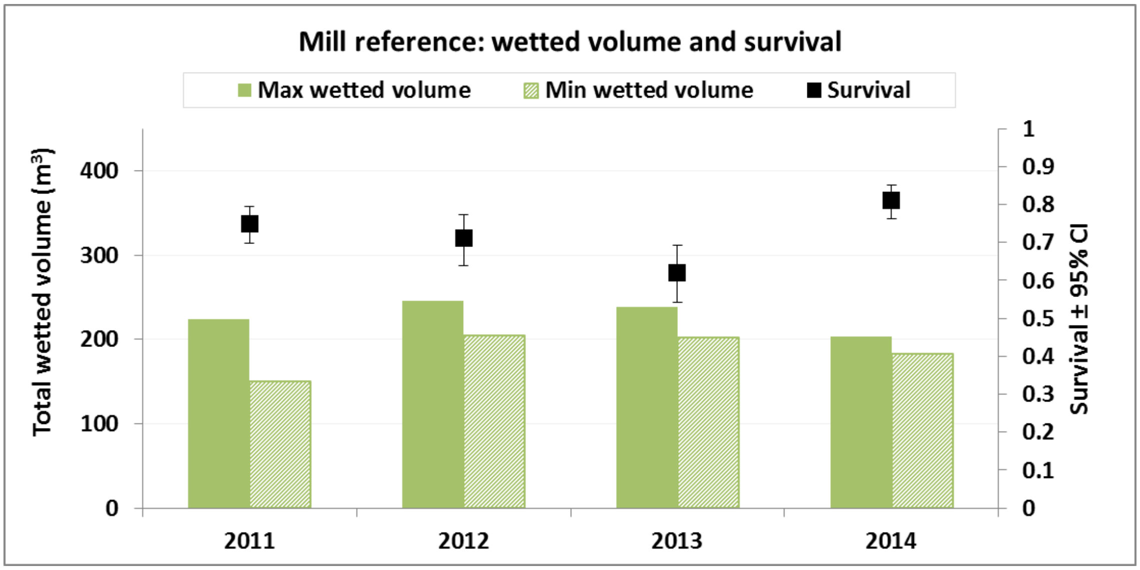

Figure 39. Total wetted volume in the Mill reference reach by year at the wettest (June) and driest points in the season.

Changes in average DO over the study period followed similar patterns as changes in wetted volume (Figure 38 - Figure 41). In the Mill treatment reach, DO concentrations were above impairment levels for salmonids at the lowest points of the 2011 to 2013 seasons. DO dropped to lethal levels in 2014, however, when—or shortly after—flow reached 0.00 ft^3/s and pools became disconnected (Figure 40).

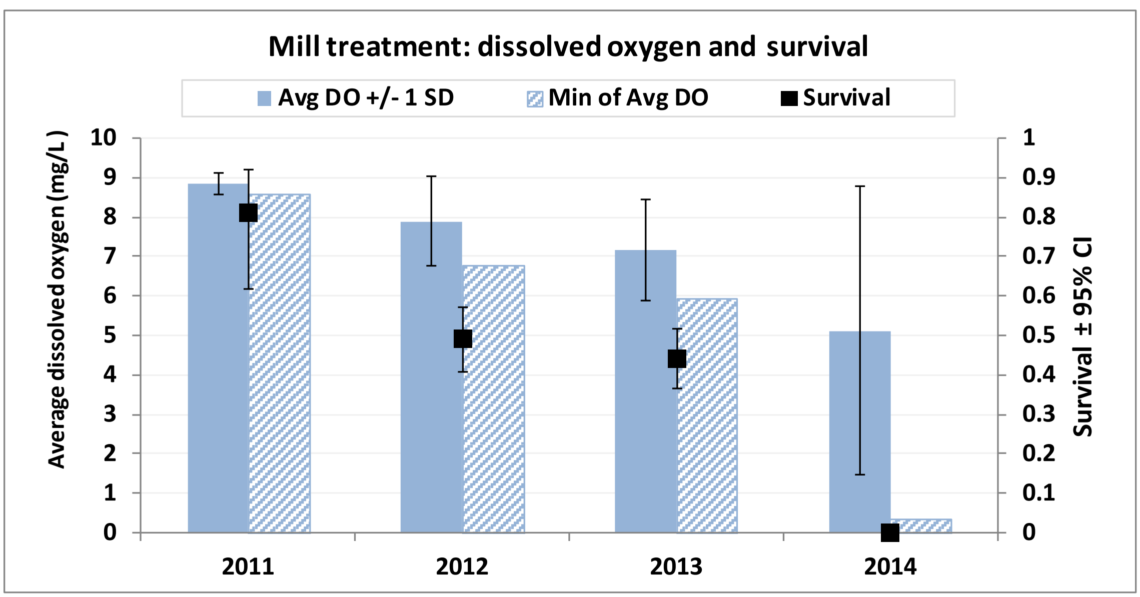

Figure 40. Average dissolved oxygen concentrations in the Mill treatment reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

In the Mill reference reach, average DO concentrations over the summers of 2011 to 2013 remained significantly higher than NCRWQCB's recommended objective of 7.0 mg/L, even at the lowest points (Figure 41). In 2014, the lowest average DO observed, 6.72 mg/L, was below this objective but well above impairment levels to salmonids (Figure 41). The high DO concentrations observed in this reach can likely be explained by the consistent inflow of aerated water into pools due to riffle connectivity.

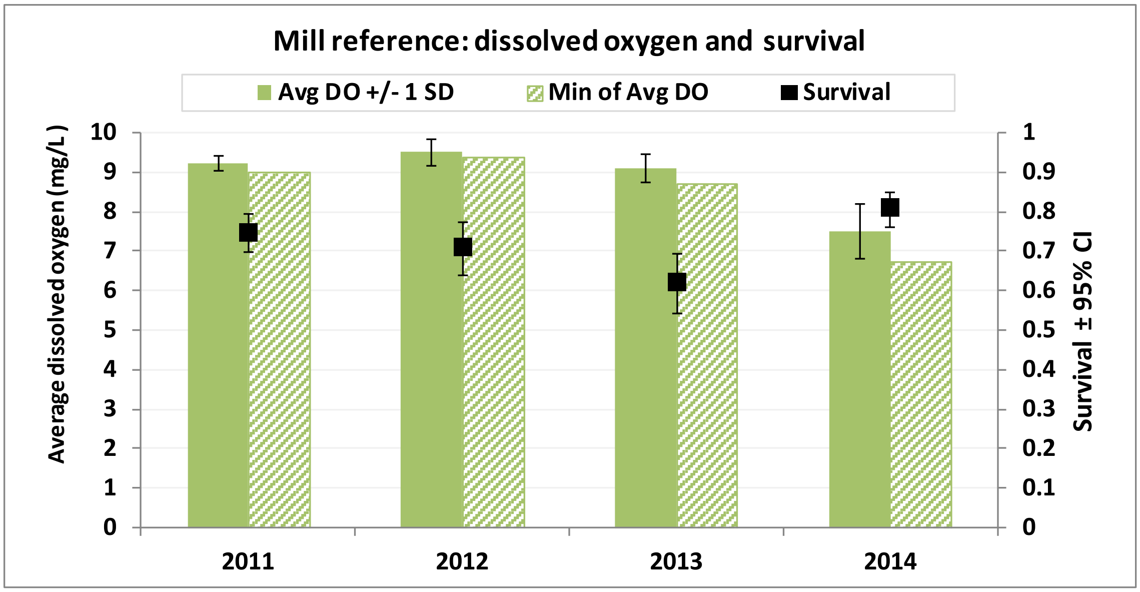

Figure 41. Average dissolved oxygen concentrations in the Mill reference reach by year at the highest (June) and lowest points in the season in relation to oversummer survival.

Although we did not observe a strong correlation between temperature and survival, it may help explain some of the finer scale differences observed between and within reaches (Figure 42, Figure 43). For example, in 2013—the year with the highest water temperatures—survival was slightly lower in both reaches compared with the previous year, despite relatively similar wetted volume and DO values. The lower temperatures observed in the reference reach may also help explain the generally higher survival rates in years when surface flows remained connected in both reaches. Temperatures above the tolerance threshold for salmonids may cause other stressors (e.g., disease, limited food supply) to have a greater detrimental impact than they would under optimal temperature conditions.

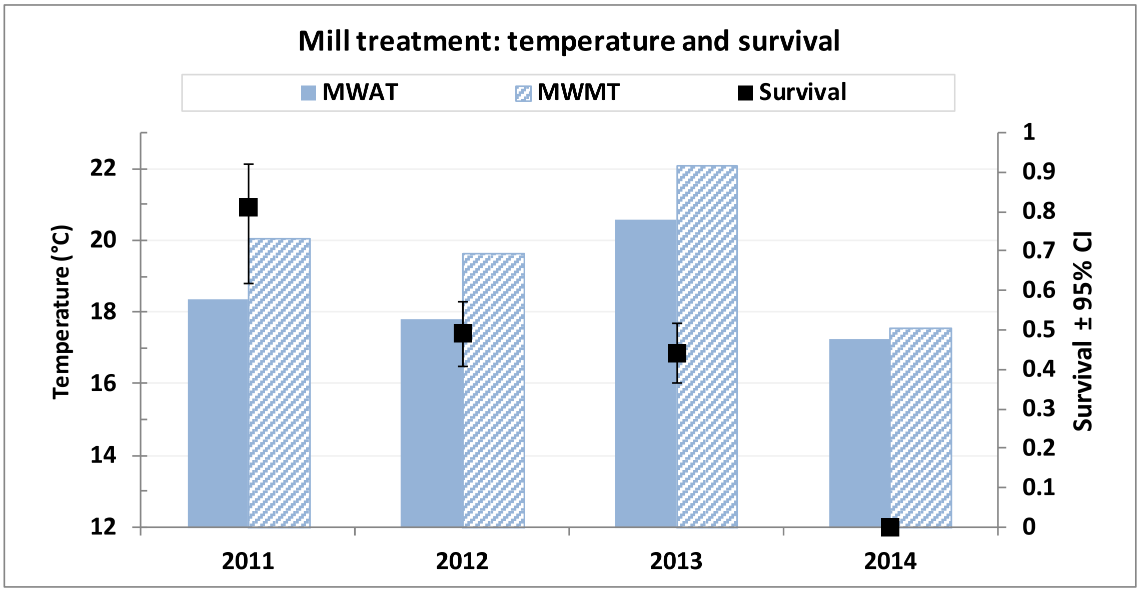

Figure 42. MWAT, MWMT, and oversummer survival of juvenile coho in the Mill treatment reach each year from 2011 through 2014.

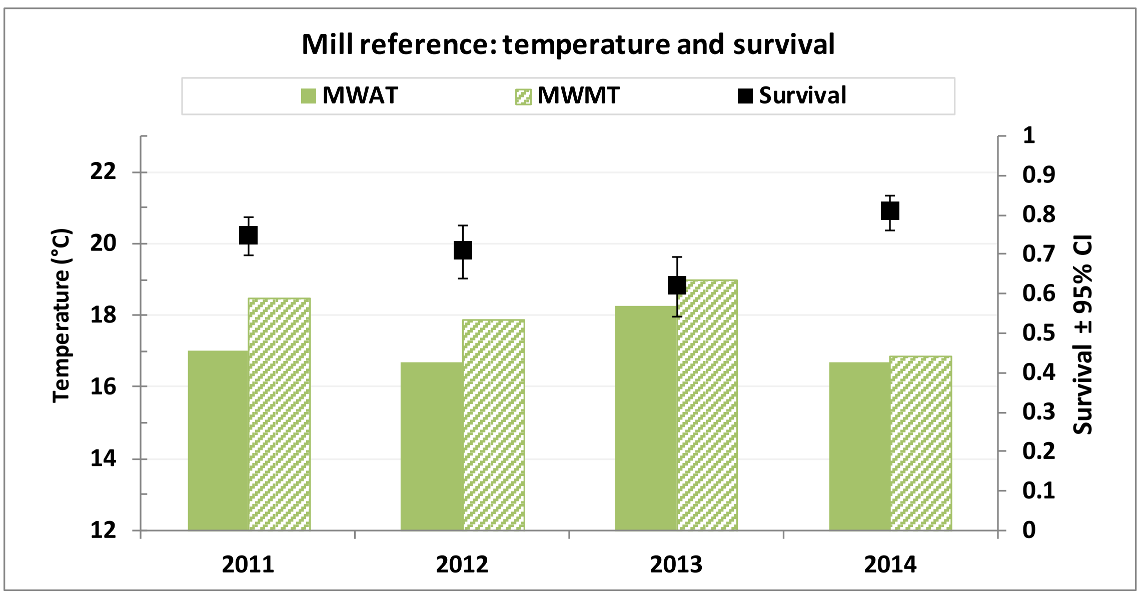

Figure 43. MWAT, MWMT, and oversummer survival of juvenile coho in the Mill reference reach each year from 2011 through 2014.

4.5.3.6 Oversummer growth

Fish length and weight was measured during PIT tagging prior to the June release and, again, at recapture during electrofishing surveys in September and October. Over the summers of 2011 to 2013, juvenile coho in the Mill treatment reach experienced an average daily growth rate, in fork length, of 0.09 mm/day, while fish in the Mill reference reach grew an average of 0.06 mm/day. Growth rates in both of the Mill reaches reflected the precise average growth for treatment and reference reaches in all four study streams for that period; 0.09 and 0.06 mm/day, respectively.

Growth was higher in treatment reaches than in reference reaches (Figure 44), which could be explained by the fact that treatment reaches, which are lower in the stream systems, tend to have higher flow, greater wetted volume, and deeper pools and, in turn, lower fish densities than reference reaches in the upper watershed.

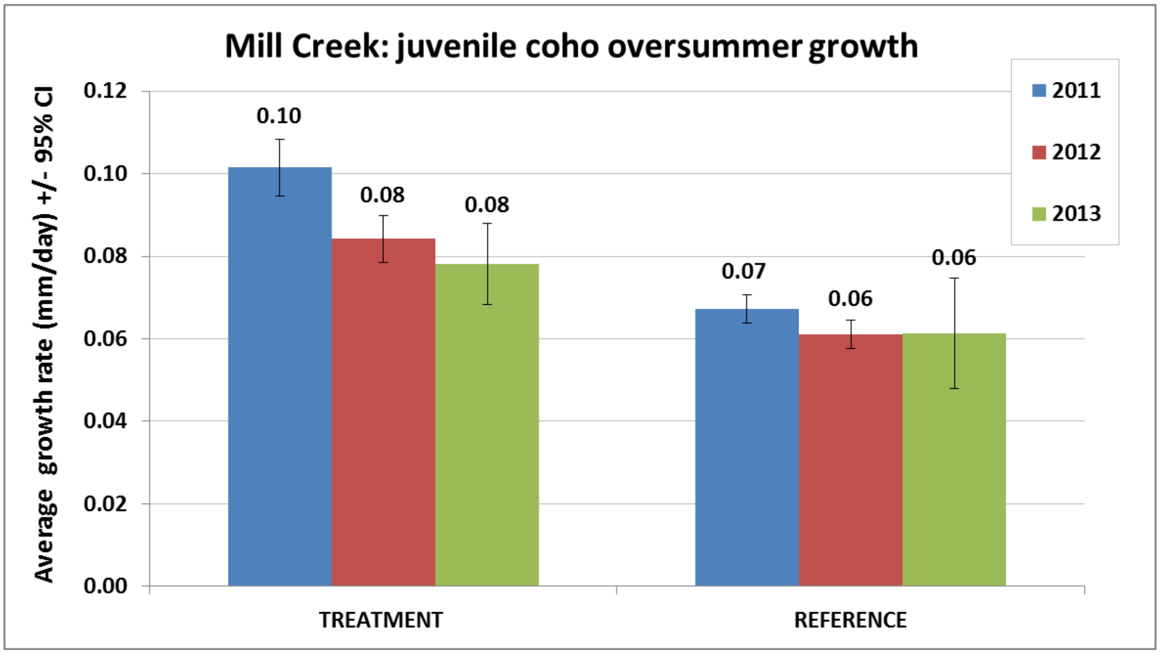

Figure 44. Average daily oversummer growth rate, in fork length, by year in the Mill Creek study reaches.

4.5.4 Evaluation of streamflow improvement projects

To date, all of the monitoring data that has been collected is considered “before” or pre-project data in our BACI design. Following implementation of stream flow improvement projects, continued monitoring in the treatment and reference reaches will allow us to evaluate the effects of projects on flow and survival.

4.6 Discussion

A key finding of this study is that juvenile coho were able to persist at extremely low surface flows in Mill Creek (Figure 32- Figure 37). In almost all years, flow levels dropped below 0.5 ft^3/s for at least a portion of the season and, with the exception of the treatment reach in 2014, survival from June 25 to October 15 ranged from 0.44 to 0.81 (average 0.66) (Figure 32). Between 2011 and 2014, the only extreme acute mortality event occurred in the treatment reach in 2014 when surface flow dropped to zero for an extended period, DO levels declined below impairment levels and pools dried out, causing all of the fish to die. Similar findings in other Russian River tributaries indicate that pool connectivity is a key factor in survival of juvenile coho during the summer season. In Green Valley and Grape Creeks, we have observed that when surface flow drops to zero, pools become disconnected, DO levels and wetted volume decline and survival, in turn, decreases. The rate at which this decline occurs varies by reach. In lower, more alluvial reaches (e.g. lower Green Valley and Grape treatment reaches), pool desiccation can occur within a matter of days following disconnectivity, whereas in other reaches (e.g. upper Green Valley and Grape reference reaches), the decline may occur over several weeks. Although geology of reaches was not characterized in this study, reaches that continue to hold water following disconnectivity appear to contain more clay substrate than the ones that rapidly dry out following pool disconnection. Cold water temperatures in the reaches that tend to hold water for a longer period after disconnection suggest that they are closely connected to an aquifer.

Given these findings, an important goal in stream flow improvement plans designed to benefit salmonid populations is to support efforts that will, at a minimum, keep pools connected. In reaches that appear to be closely connected to an aquifer, such as the upper reference reaches of Mill, Green Valley and Grape Creeks, stream flow improvement projects that increase stream flow by as little as 0.1 ft^3/s could improve survival of juvenile coho throughout the summer season. In more alluvial reaches, where connection to the aquifer is less certain (e.g., lower Mill Creek), surface flow levels that support connectivity will have to be determined in order to set minimum targets.

Achievement of recovery goals for coho populations in the Russian River will require more than minimum connectivity of pools. Growth, fish condition and habitat availability in relation to flow are all important factors to consider when determining what flow levels will support the long-term viability of coho populations. Although fish may be able to persist at extremely low flows in Mill Creek, if they are in poor condition at the end of the summer (small size, disease, parasites, etc.), survival may be compromised at later life stages. Additionally, low flow may reduce the amount of habitat available to fish and, in turn, the number of fish that can be produced—a further limitation to population viability and recovery.

Survival of salmonids to the adult stage is positively correlated with smolt size (Bennett et. al. 2015, Hayes et. al. 2008), therefore, increased growth in the stream environment can increase the chances of fish returning as adults to spawn. Flow has been positively correlated with benthic macroinvertebrate (BMI) production (Gore et al. 2001), which are the primary prey for rearing juvenile salmon. The greatest diversity and abundance of BMI species have been documented in riffles with velocities of 1.5 to 2.5 ft/s, while significantly fewer species are present at velocities of less than 0.5 ft/s (Gore et al. 2001). Through controlled flow manipulations in a small California stream, Harvey et al. (2006) found that with increased stream flow, invertebrate drift and juvenile rainbow trout growth increased while survival remained similar. Similarly, Nislow et al. (2004) found increased growth in juvenile Atlantic salmon rearing in a stream in years with higher stream flow.

Based on these findings, we can expect that increasing summer velocities beyond minimum persistence flows would likely promote higher growth in juvenile salmon and, in turn, more adults returning to spawn. Growth was minimal during the summer season in both reaches of Mill Creek, however, in the treatment reach, which generally had higher flow, we observed higher growth rates than in the reference reach (Figure 44).

The amount of foraging habitat available to fish in a stream is a function of stream flow (Nislow et al. 2004). If more habitat is available, there is an opportunity for production of greater numbers of fish and/or larger fish, further improving chances for recovery.

In this study, we observed juvenile coho surviving at flows that dropped below 0.5 ft^3/s, as long as pools remained connected. These low surface flows that sustain connectivity should be considered minimum persistence flows for the upper Mill Creek watershed, and not levels that support high growth or sufficient production. Identifying such flows is beyond the scope of this study, however other approaches have been used to estimate these values in the Mattole Headwaters Sub-basin, a similar sized watershed as Mill Creek (McBain and Trush, Inc. 2012). In an instream flow needs study, McBain and Trush, Inc. recommended summer low flow juvenile rearing thresholds ranging from 1.5 to 5 ft^3/s (depending on location in the watershed) to avoid poor to negative growth, high risk of disease and predation, shrinking habitat availability and heightened competition for food. A similar study in Russian River tributaries to determine such thresholds would greatly help in setting stream flow targets relative to specific goals (e.g., minimum persistence, population stability, population growth).

UC will continue its monitoring effort in the Mill Creek watershed to evaluate the effects of project implementation and water management changes on oversummer survival and to provide further insight into the complex relationship between flow, survival and environmental factors. We recommend further studies to help generalize results and to identify flow thresholds appropriate to maximize survival, growth, condition and abundance.

5 Diversion Management Recommendations

Drawing on the streamflow, water need, and fish monitoring data provided above, this section recommends actions to maintain pool connectivity and reduce drops in flow within the Mill Creek watershed. It then provides an overview of permitting considerations for projects that may result from those actions.

5.1 Project and Management Recommendations

5.1.1 Residential Water User Tank Program

Because the data suggest that summer flow is adversely affected by the cumulative effect of residential diversions, we recommend pursuing a tank program for residential users, especially along the stream reaches between Puccioni Road and West Side Elementary School.

The program would provide technical and financial assistance to landowners whose residential water use may be impacting streamflow. A typical project would include water storage tanks and an agreement with the landowner to forbear use of their diversion during critical low-flow periods. The tanks would be filled with water from sources most suitable for each parcel (e.g., roofwater, surface water, springs, or wells). This program could be combined with other strategies to reduce water use and reduce the instantaneous draw-down of streamflow, such as encouraging use of water-efficient appliances and irrigation systems, coordinating timing of diversions, reducing diversion rates/pump size, and/or using pumps with variable pumping rates.

Examples of successful residential demonstration projects can be found in other watersheds. Sanctuary Forest has a surface water tank storage and forbearance program in the Mattole River Headwaters. Gold Ridge RCD and OAEC piloted a successful roofwater harvesting storage and forbearance program in Salmon Creek (south of the Russian River watershed). Clusters of projects will likely need to be implemented before streamflow is appreciably improved, but there may be ample opportunity for implementing water storage projects, given the number of houses along Mill Creek that likely obtain water from the stream or adjacent shallow aquifer.

5.1.1.1 Roofwater harvesting Analysis

Several factors make roofwater harvesting a viable and ecologically compatible means of meeting water needs in the Mill Creek watershed. First, impacts to streamflow caused by roofwater harvesting systems are low. This is mainly because the amount of surface area (typically rooftops) comprises a small fraction of the total watershed area. Roofwater harvesting systems effectively eliminate the production of runoff from the collection surface, but the proportion of watershed area comprised by collection surfaces makes this impact negligible. For example, if 40 roofwater harvesting systems are implemented in the Wallace Creek subcatchment of the Mill Creek watershed, and the average collection surface is 2,000 square feet, then a total of 80,000 square feet (1.8 acres) would no longer produce runoff. The total area of the Wallace Creek subcatchment is approximately 5.3 square miles, or 3,400 acres; in this scenario, the amount of area that would no longer generate runoff is 0.05% of the total Wallace Creek subcatchment. Similarly, if 400 roofwater harvesting systems are implemented in the Mill Creek watershed (total watershed area 14,300 acres, or 22.3 square miles) and the average collection area is 2,000 square feet (totaling 800,000 square feet, or 18.4 acres), the 400 projects would reduce the total area producing runoff in the Mill Creek watershed by 0.1%. (If the average collection area is doubled to 4,000 square feet, the total loss of runoff would be 0.2%) Roofwater harvesting also is low-impact compared to other methods of obtaining water because it only collects water when rainfall is occurring, and does not collect water during periods of lower flow between rainfall events.

Roofwater harvesting may not always be adequate to meet all water needs. Most notably, the rooftop area may limit the amount of water that can be captured and stored. For example, a surface area of 1,000 square feet in an area that receives 3.5 feet (42 inches) of rainfall will produce 26,000 gallons of water—not enough to meet needs usually associated with residential uses through a four- or five-month dry season (typically 40,000 to 50,000 gallons). For larger agricultural uses, water needs are typically described in acre-feet: if an area receives 3.5 feet of rain, then the amount of rooftop needed to store an acre-foot of water (approximately 326,000 gallons) is approximately 12,500 square ft. This is feasible for a large operation with a lot of rooftop area, but for smaller developments, this may not be realistic. The amount of water available to harvest also depends on annual variation in rainfall: less water will be stored in a dry year than in a wet year. For example, in 2014, Healdsburg only received 1.9 feet (22.6 inches) of rainfall. Under these conditions, a storage facility designed around the average annual rainfall of 3.5 feet would be little more than one-half full at the end of the rainy season. In order for roofwater harvesting to be resilient to climate variability (and thus resilient to climate variations expected in the coming decades), projects would need to significantly overbuild for normal-year conditions or have additional water sources to meet needs in dry years; or develop a contingency plan for how to prioritize water uses if only a fraction of the desired amount of water is available.

Another common limiting factor to roofwater harvesting is the amount of space that can be dedicated to storage. A 50,000 gallon tank standing 8 feet tall would have a diameter of 35 feet. One option is to place tanks underground. For example, elsewhere in Sonoma County, a 270,000 gallon cistern system was buried under a dairy to allow the surface area to be continuously used for other purposes (Ag Innovations Network 2013). In a watershed as mountainous as Mill Creek, finding space to dedicate to a large water tank may be the most limiting condition to the implementation of a roofwater harvesting system.

5.1.2 Agricultural Water User Program (frost, reducing rates of diversion, releases, roofwater storage)

Agricultural irrigation and frost protection represent a significant portion of the water used in the Mill Creek watershed in both the wet and dry seasons. Before recent frost protection regulations took effect, the quick withdrawal of large amounts of water for frost protection threatened coho and steelhead by stranding them as streamflow dropped. We recommend continued compliance with recent frost regulations, researching the viability of other methods of frost protection such as frost fans, or development and use of alternative water sources like off-stream ponds.

Additionally, we recommend that agricultural water users outside of Lower Mill Creek (Dry Creek to Felta Creek), employ irrigation auditing and efficiency measures, and consider installing off-stream storage to offset dry season diversion and/or allow for a reduction in pump rates. For water users that have excess stored water, we recommend that users work with CDFW during the driest periods to explore reservoir releases to benefit coho and steelhead.

The program would initially target water conservation and water storage projects with a goal of reducing instantaneous demand for frost protection water and reducing the quantity or rate of water used for irrigation.

5.1.2.1 Hydrologic Assessment of Lower Mill Creek

In lower Mill Creek, we recommend completing a ground-surface water assessment prior to developing streamflow improvement projects with agricultural and other water users. In Lower Mill Creek, there are 90.5 acres of vineyards – using approximately 45 acre-feet of water annually - and 1.8 acres of orchards – using approximately 3.9 acre-feet of water annually. There are no reservoirs in the area, and water is diverted directly from the creek or from groundwater wells adjacent the creek to meet most of these agricultural water needs.

As described above, lower Mill Creek has been a main focus for coho spawning; but juvenile monitoring has indicated that much of this reach may become dry under normal conditions. This drying may be a result of nearby water use, but it also may be a result of geological conditions frequently found in alluvial fans similar to lower Mill Creek.

We recommend conducting additional research in lower Mill Creek to evaluate the extent of pools and surface flow in lower Mill Creek, as well as the water level in the aquifer adjacent to Mill Creek through the dry season. The study would help determine whether habitat restoration activities in Mill Creek will be beneficial or would be undermined by the lack of water in the shallow groundwater table. Most spawning in recent years has occurred in the lower portion of the watershed, but habitat is poor and pools may not be persistent. Such a study could include the following:

- Mapping the presence of pools and water table levels along Mill Creek below the Falls during the spring-summer dry season.
- Correlating the level of the stream bed with the level of Dry Creek and the Russian River using LiDAR data sets available through the Sonoma County Vegetation Mapping and LiDAR Program.
- Conducting visual surveys of pools through the lower reaches by walking from West Side Elementary School to the confluence with Dry Creek weekly from June through October, and recording and tracking pool depths and note the extent of surface flow through lower Mill Creek.
- Measuring the depth to groundwater in at least four existing test wells during each visit (access dependent).
- Evaluating whether Mill Creek is gaining or losing to the aquifer at each visit.

- Determining how closely the level of Dry Creek is related to Mill Creek and its adjacent shallow aquifer.
- Installing a minimum of two pressure transducers in lower Mill Creek and set recording intervals to 15 minutes, to determine whether additional, otherwise unobserved, flow dynamics make lower Mill Creek unsuitable for supporting juvenile salmonids (e.g., channel going dry at night, or just for a few days during the summer).

If the results of the study suggest that changes in water management will lead to an increase in streamflow, we recommend exploring options with landowners in this reach.

5.1.3 Community Awareness, Education, and Demonstration

We recommend additional outreach to the Mill Creek watershed community. This could include:

- Larger landowner meetings to solicit public input on short- and long-term opportunities and challenges in the watershed;
- Small-group and individual meetings with landowners or neighborhoods to scope out project opportunities;
- Trainings and other technical assistance in developing and troubleshooting projects and monitoring and changing water use practices;
- Signage to remind water users to conserve during the low flow season and store during the rainy season.

In addition, we recommend using other projects to demonstrate water management alternatives. The Coho Partnership is working currently with West Side Elementary School to implement a roofwater harvesting project that will offset dry season diversion for garden irrigation with rainwater. The project has a significant educational component, and we recommend using the project and the opportunity to showcase roofwater harvesting within the watershed. West Side Elementary School has been a long-standing partner in fisheries restoration in the Mill Creek watershed; its students have participated in coho Broodstock monitoring and the school has partnered with many organizations to integrate the natural environmental into both its facilities and curriculum.[8] A similar project was completed in 2014 in the Mattole River watershed with Whitethorn School and the Southern Humboldt Unified School District and it has been a valuable example for students and their families.

5.1.4 Explore Collective Options

We recommend that the Mill Creek water user community explore collective options such as constructing shared storage (particularly in cases where one landowner may have locations for off-stream storage and others have site constraints), rotations among neighbors to reduce diversion

[8] http://www.westsideusd.org/main/about/history.html

rates (e.g., diverting every other day or at different hours), and releases (e.g., neighbors agree to allow water released from a reservoir to reach the intended reach to benefit fish populations).

5.1.5 Mill Creek Recharge Potential

We recommend exploring opportunities for recharge in Mill Creek in areas with the greatest recharge potential. Over the past century, land use changes in Russian River tributary watersheds have resulted in drastically reduced infiltration of rainfall, leading to lower base flow in the dry season. Mechanisms for this loss of infiltration include reducing the amount of soil to absorb rainfall, increasing the headwater drainage network, and installing subsurface drainage tiles beneath agricultural fields, all leading to more storm runoff. While these processes have often been altered over the entire watershed, it may be possible to implement projects to increase infiltration in key strategic locations where the potential for influencing recharge is greatest. We evaluate locations within the Mill Creek watershed with the greatest potential for recharge below.

In its recent Sonoma Creek Watershed study, SCWA outlined a process for evaluating the potential for groundwater recharge based on four main factors: geology, soil type, vegetation cover, and slope. Spatially explicit data characterizing each of these broad categories is widely available for input into a GIS. The potential for recharge was calculated throughout the watershed based on these four factors, though the weight of each factor was not equivalent. Underlying geology was given the heaviest weight, at 50%; soil was weighted 25%; slope was weighted 15%; and vegetation cover was weighted 10%. We applied this process for evaluating recharge potential to the Mill Creek watershed to identify those locations where projects aimed at augmenting groundwater recharge could have beneficial effects to base flow in Mill Creek.

Most of the underlying geology of the Mill Creek watershed is composed of the Franciscan assemblage, referring to a combination of mélange and pressurized sedimentary rock (Graymer et al. 2007), often resulting in minerals like quartz, feldspar, and other minerals formed within the pressurized sedimentary matrix, formed originally as ocean floor during the Jurassic and Cretaceous Period (to an age of 60 to 200 million years) and pressurized through tectonic uplift. Franciscan bedrock is characteristically poor for storing and transmitting water (Kleinfelder Inc. 2003, Su et al. 2007). However, the uplift that created the coastal ranges in California resulted in many fractures in the bedrock; these fractures allow water to move much more easily through Franciscan formations than it can through the bedrock itself. Local geohydrologists attribute these fractures, which have greater porosity, permeability, and hydraulic conductivity, as the reason why springs are common and wells can provide adequate yield for domestic and some agricultural uses in Franciscan geology (e.g., Phillips 2012). Because these fractured bedrock aquifers are irregular features in the landscape, they are seldom mapped at a watershed scale and their influence to supporting summer base flow is highly variable and poorly known.

A few other locations in the Mill Creek watershed are categorized as having soft sedimentary geology—Huichica or Glen Ellen formation. These formations have high clay content and are often described as poor for aquifers, but not as poor as Franciscan bedrock. We characterized geology as ranked from 1 (poor) to 3.5 (high) potential for recharge, where Franciscan bedrock had a ranking of either 1 or 1.5; the sedimentary bedrock was ranked at 2, and alluvium ranked as 3 or 3.5, depending on when it was believed to be deposited (Pleistocene or Holocene; Figure 45A). We did not attempt to incorporate fractured Franciscan bedrock into this analysis, but it may be useful to consider at a later stage of the project.

Soil types were generally categorized following the same rankings as were outlined by the SCWA study, based on clay content of the soil. Those soils with high clay content were ranked low, whereas those with low clay content were ranked high (Figure 45B). Vegetation was ranked based on its capacity for interception: forest land was ranked low, whereas grassland was ranked high (Figure 45C). Based on these features, the Mill Creek watershed has variable but overall low potential for recharge through most of the watershed (Figure 45D); with the greatest potential for recharge in the lower reaches near the confluence with Dry Creek and the lowest potential for recharge in the mountainous headwaters.

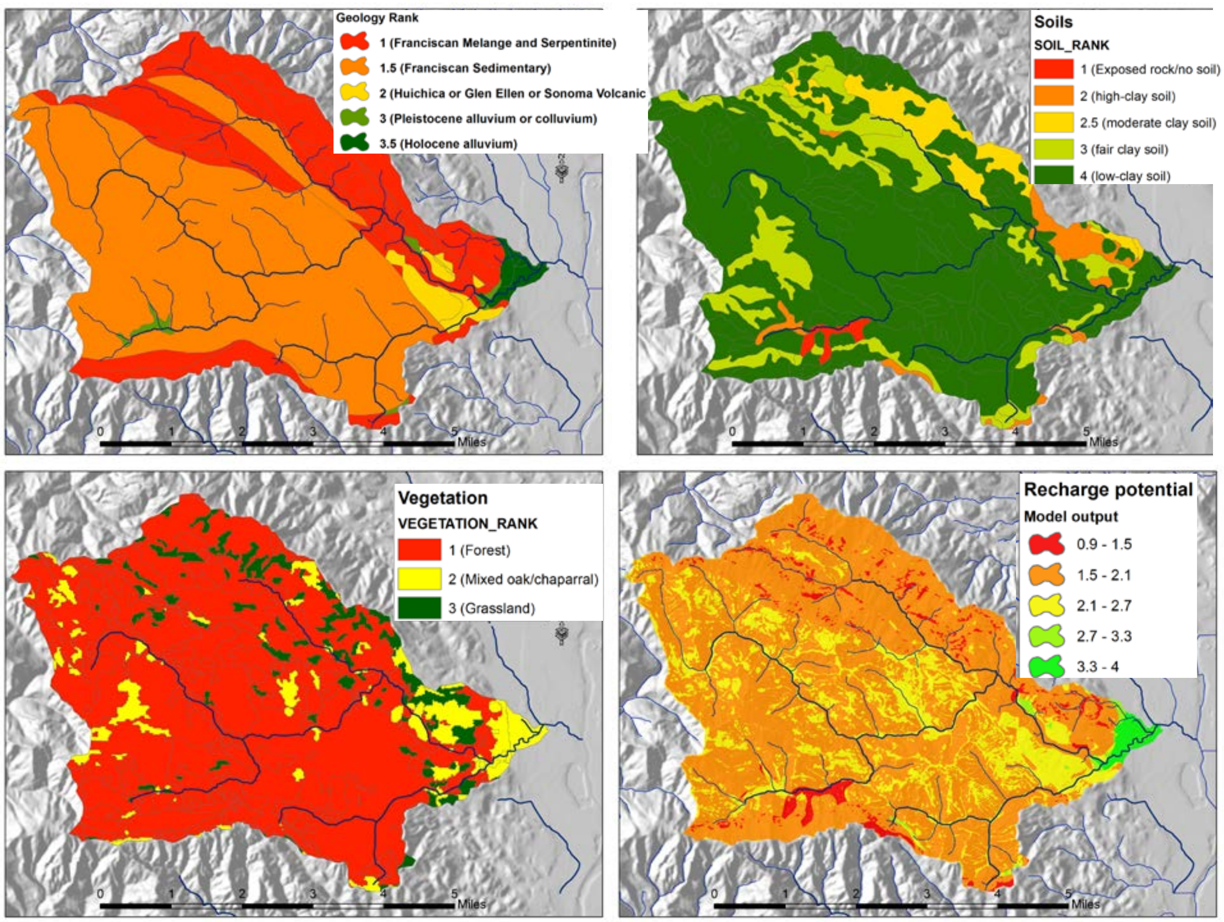

Figure 45A-D. Recharge potential in the Mill Creek watershed.

5.1.6 Fish Passage and Habitat Projects

We recommend continuing to implement habitat and fish passage projects that improve conditions for coho and steelhead, particularly barrier removal projects that allow salmonids to access the wetter reaches of Mill Creek and instream habitat improvements (e.g., large wood) that increase pool depth. We recommend that project proponents consider and integrate flow information and instream flow project locations in their project selection and design.

5.2 Permitting Considerations

Some of the projects recommended above will require water rights permitting or water rights changes. For example, projects that divert and store water may require an appropriative water right from the State Water Board if water is seasonally stored (e.g., diverted in winter for summer use) and if the source is a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 5.2.4). Water users may also be required to notify CDFW of the diversion as part of the Lake and Streambed Alteration program (Fish and Game Code Section 1600). Below we provide an overview of likely water rights permitting pathways, if applicable, for various project types.

5.2.1 Roofwater harvesting

As described above, projects that include rainwater harvesting have the dual benefit of reducing diversions from the creek during the dry season (by offsetting summer need) and reducing runoff from impervious surfaces (roofs) during the winter. The State Water Board has clarified that a water right permit is not required for roofwater capture and storage.[9] For any project that reduces the quantity of water that users need to divert in the dry season, landowners, project partners, and funders should ensure that reductions in water use under any existing water rights are protected instream (e.g., through an instream dedication and/or forbearance agreement) (See Section 6.1).

This approach has been implemented successfully in Salmon Creek (Sonoma County)[10] where Gold Ridge Resource Conservation District, Occidental Arts and Ecology Center, Prunuske Chatham Inc., and NOAA Restoration Center piloted an approach to offset dry season use through winter roofwater harvesting[11] and in Chorro Creek where Morro Bay National Estuary Program and NOAA-RC installed roof rainwater tanks with Cal Poly San Luis Obispo. In both cases, landowners ceased summer use under a forbearance agreement.

5.2.2 Residential tank storage

Where residential users switch the timing of their diversions from the creek from summer to winter and add storage tanks to satisfy year-round use, the projects will likely require a new water right. (A riparian right does not allow for seasonal storage.) It is likely that many diversions will be small

[9] http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml
[10] http://salmoncreekwater.org/cs/Roofwater_Harvesting.pdf
[11] http://salmoncreekwater.org/bodega-pilot-program.html

enough to qualify for a Small Domestic Use Registration (SDU) or Emergency Small Domestic Use Registration (ESDU).

The ESDU streamlines the process for obtaining a SDU registration while the drought is in effect. As CDFW states, the agencies have "essentially 'pre-approved' the installation of storage tanks that meet general criteria. The State Water Board has agreed to incorporate these criteria as conditions of approval, and to expedite the issuance of the registrations."[12]

This residential tank storage approach has been implemented successfully in the Mattole River watershed through Sanctuary Forest's Water Storage and Forbearance Program, and more information is available in Legal Options for Streamflow Protection (Sanctuary Forest 2008). Sanctuary Forest's approach has included installing tank storage to provide sufficient potable water for the dry season, restrictions on diversion during the dry season (while the water user relies on the stored water), and rotation schedules among multiple users when flow falls below certain thresholds. These terms and conditions are implemented through a combination of a forbearance agreement (a covenant that runs with the land restricting riparian water use), a Small Domestic Use registration issued by the State Water Board, and a Streambed Alteration Agreement issued by CDFW.

5.2.3 Agricultural water storage

Projects with agricultural water users that rely on diversion from the stream and store water for seasonal use will require an appropriative water right. For diversions to storage that do not exceed 20 acre-feet per year for irrigation, frost protection, or heat control of currently cultivated lands, water users may be able to file a small irrigation registration, a type of appropriative right.[13] For projects that relay on streamside wells and seek to reduce dry season impacts by pumping through the rainy season and storing water for year-round use, water rights permitting requirements will depend on the method of diversion and the nature of the water source (see Section 5.2.4).

A summary of the registration options is provided in Table 7.

[12] http://cdfgnews.wordpress.com/2014/03/13/state-streamlines-domestic-water-tank-storage-process-in-response-to-drought/

[13] http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/

Table 7. Summary of Water Rights Registrations

	Small Domestic Use Registration (SDU)	Emergency Small Domestic Use Registration (ESDU)	Small Irrigation Use Registration (SIU)
Max Quantity	4,500 gallons per day or diversion to storage of 10 acre-feet per year	4,500 gallons per day or diversion to storage of 10 acre-feet per year	42,000 gallons per day or 20 acre-feet per year
Permitted Uses	Domestic uses* or aesthetic, fire protection, recreational, or fish and wildlife purposes associated with a dwelling or other facility for human occupation	Domestic uses* or aesthetic, fire protection, recreational, or fish and wildlife purposes associated with a dwelling or other facility for human occupation	Irrigation, heat control, or frost protection, including impoundment for incidental aesthetic, fire protection, recreational, or fish and wildlife purposes
Other restrictions	Diversions from stream segments (1) that have established minimum streamflow requirements, (2) are fully appropriated, (3) are on designated Wild and Scenic Rivers	Restrictions on SDUs apply plus: (1) Only eligible during a drought emergency, (2) must have an existing water right for domestic use, (3) rigid tanks only (no bladders), (4) at least 60 days of storage + forbearance	Only for (1) offstream reservoirs existing or proposed on cultivated lands or (2) onstream reservoirs on Class III streams
Geography	No restriction	Coastal streams within CDFW Region 1 or 3	Currently limited to North Coast Instream Flow Policy Area***
Expedited? **	No	Yes - no CDFW site inspection and no individually tailored conditions required	No
Fee	$250	$250	$250
Flow chart	Small Domestic Use Flow Chart		Small Irrigation Use Flow Chart
Lake and Streambed Alteration Agreement req?	Yes	No	Yes
Renewal	Every 5 years	Every 5 years	Every 5 years
Renewal Fee	$100	$100	$100

More information: http://www.waterboards.ca.gov/waterrights/water_issues/programs/registrations/

* Domestic use means the use of water in homes, resorts, motels, organization camps, camp grounds, etc., including the incidental watering of domestic stock for family sustenance or enjoyment and the irrigation of not to exceed one-half acre in lawn, ornamental shrubbery, or gardens at any single establishments (California Code of Regulations §660 - Domestic Uses).

** The Division of Water Rights prioritizes applications that meet certain conditions.

*** Coastal streams from the Mattole River to San Francisco and coastal streams entering northern San Pablo Bay.

5.2.4 Groundwater Use

Where a landowner pumps from a groundwater well in the winter and stores that water for dry season use, an appropriative water right may or may not be required. Permitting requirements depend on the categorical nature of the groundwater pumped. Where the well lies within a subterranean stream and water use is in accordance with riparianism, the water user may assert a riparian right to the water. However, since the objective of most streamflow projects includes storage of water across seasons and because riparian rights do not allow for seasonal water storage, a groundwater user pumping water from a subterranean stream may be required to obtain an appropriative water right for storage and use. For reference, a draft subterranean stream map covering the Mill Creek watershed is included as Figure 46. If the well lies outside of a subterranean stream, the water diverted from the well may be considered percolating groundwater, and not submit to the permitting jurisdiction of the State Water Board.[14]

[14] See also: State Water Board, FAQs, "How do I know if I need a water right permit?" at http://www.waterboards.ca.gov/waterrights/board_info/faqs.shtml

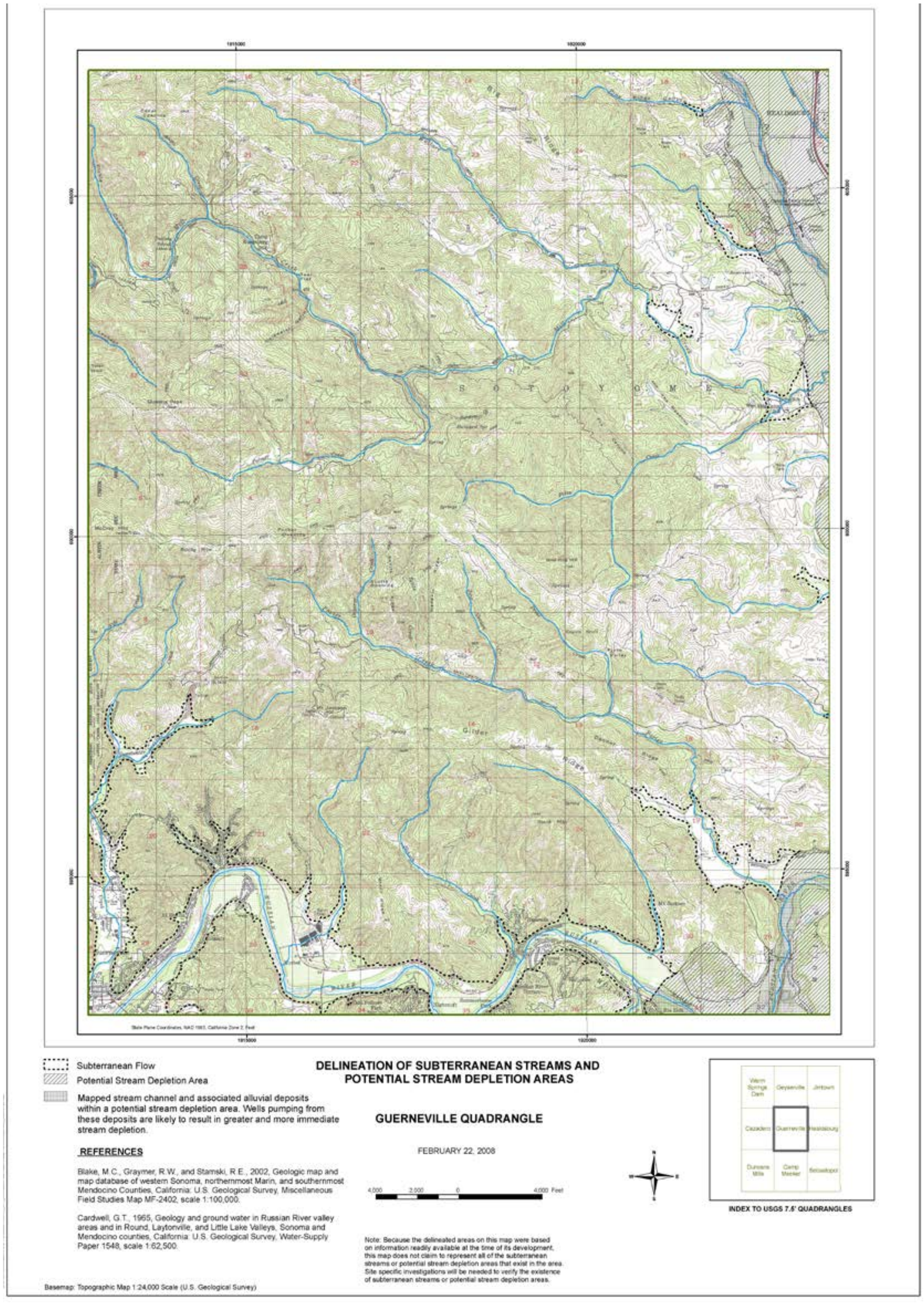

Figure 46. Excerpt from draft subterranean stream map (Stetson Engineers 2008).

5.2.5 Water Availability Analysis

If an appropriative water right is required for a project, the State Water Board will likely require a thorough evaluation of how additional water appropriation will affect new water right holders, as well as how the rate of diversion used to obtain water will affect streamflow and environmental resources (such as habitat for anadromous salmonids). In order to evaluate the feasibility of obtaining a new appropriative water right in the Mill Creek watershed, we performed a preliminary set of calculations required for a Water Availability Analysis.

This calculation represents the first step in evaluating whether additional water can be appropriated: any new diversion needs to be considered in combination with all existing water rights to ensure that downstream water right holders will be minimally affected by a new diversion. The calculation is a comparison of estimated "unimpaired" discharge at a particular location based on historical streamflow data[15] to the amount of water requested by existing documented water rights holders (including appropriative and riparian rights). The resulting statistic of this analysis is a percentage of water that remains, given existing upstream diversions, at the particular location. Generally, if the amount of water accounted for in existing diversions is less than 5 percent of unappropriated discharge, then it is possible that more water could be appropriated.

We calculated Water Supply Tables (Tables 8-10) for the water rights in the Mill Creek watershed (similar to that which would be required for submission to the State Board in an appropriative water right application). All of the water rights in the watershed need to be considered when determining unappropriated water volume. Each table includes the following fields:

- Each water right is given an ID number (POD_ID); this POD_ID provides a label for each water right in the accompanying map.
- For each water right, we begin by calculating the upstream watershed area and average annual precipitation in the upstream watershed (which we have done using the PRISM data set). We use these data to scale historical streamflow measured at the historical Pena Creek USGS streamflow gauge to each water right location: historical streamflow is scaled to all water rights by a ratio of upstream watershed area and mean annual precipitation, as described in the State Water Board's Policy for Maintaining Instream Flows in Northern California Coastal Streams.
- From these data, we calculate the "Seasonal Unimpaired Flow Volume", which is an estimate of unimpaired discharge over the period of interest (for example, the diversion season December 15 through March 31) based on streamflow from the historical USGS streamflow gauge scaled by Ratio1.
- The "Water Right Volume" over the defined period reflects the amount of water that each water right has a right to use during the period of interest.

[15] Using an average of discharge from a USGS streamflow gauge such as the nearby Pena Creek near Geyserville gauge, number 11465150, which was operated from 1978 to 1990.

- The “Senior Upstream Water Right Volume” represents the sum of volume for all water rights upstream of each diversion point.
- The “Remaining Impaired Discharge” quantifies how much of the unimpaired flow remains, given what upstream water right holders have a right to take. This can also be expressed as a percentage, as seen in the final column.
- We calculated the Remaining Impaired Discharge for all Mill Creek watershed water rights over the following periods: the winter season December 15 through March 31 (which the State Water Board identifies as the “diversion season” for north coast streams; Table 3, below), as well as the months of April and May for additional comparison for water availability from a regulatory perspective (Tables 4 and 5). The tables below show the Water Supply Tables for the 49 points of diversion in the watershed.

Table 8. Winter season (December 15 through March 31) Draft Water Supply Table for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	21,054	0.00	173.44	20,881	99.18
A024688A	14,191	47.1	21,079	0.00	173.44	20,905	99.18
S023680	14,168	47.3	21,149	0.00	173.44	20,976	99.18
S019972	14,162	47.4	21,196	2.35	173.44	21,022	99.18
S023682	14,140	47.5	21,219	0.00	171.09	21,048	99.19
S013760	14,123	47.7	21,246	0.00	171.09	21,075	99.19
S016032	11,784	49.1	18,273	0.29	125.09	18,148	99.32
S022582	11,740	49.3	18,275	0.00	124.79	18,150	99.32
A011327	11,497	49.5	17,963	3.78	124.79	17,839	99.31
S009039	11,094	50.2	17,565	0.00	110.01	17,455	99.37
S009045	11,094	50.2	17,565	0.00	110.01	17,455	99.37
S009040	11,094	50.2	17,565	0.00	110.01	17,455	99.37
A004612	11,094	50.2	17,565	0.00	110.01	17,455	99.37
A023077	3,243	49.4	5,061	0.00	61.81	4,999	98.78
A023077	3,200	49.6	5,011	0.00	61.81	4,949	98.77
A031521	2,282	50.3	3,623	15.14	37.08	3,586	98.98
S013709	2,248	44.7	3,173	2.78	46.01	3,127	98.55
D029507R	2,232	44.9	3,166	0.18	43.22	3,123	98.63
A018127	2,230	45.2	3,184	0.00	43.05	3,141	98.65
A025125	2,221	58.3	4,087	0.00	8.37	4,079	99.80
A017833	2,193	45.5	3,149	1.63	43.05	3,106	98.63
A020005	2,123	45.7	3,060	1.55	41.42	3,018	98.65
S015862	2,121	45.9	3,073	0.00	39.87	3,033	98.70
S009168	2,064	46.1	3,006	18.41	39.87	2,966	98.67
S013563	2,034	46.2	2,966	0.00	21.46	2,944	99.28
S015916	565	59.3	1,057	0.00	8.37	1,049	99.21
S022703	452	53.8	768	6.80	6.80	761	99.11
A021052	433	59.8	817	8.37	8.37	808	98.98
A015299	356	50.5	568	0.00	1.49	566	99.74
A019554	332	50.6	530	0.00	1.49	529	99.72
A021191	177	49.2	275	2.21	2.21	273	99.20
A031521	126	49.2	195	15.14	15.14	180	92.25
A020951	116	48.1	177	9.54	9.54	167	94.60
A019554	76	48.9	117	13.69	13.69	103	88.28
C003981	72	47.1	107	5.17	5.17	102	95.17
D030758R	42	45.6	61	2.34	22.34	39	63.39
A017479	39	53.8	67	9.86	9.86	57	85.31
A030933	38	45.6	55	20.00	20.00	35	63.59
A019554	32	50.4	51	0.95	0.95	50	98.11
A031256	26	43.0	36	24.00	24.00	12	32.40
S019409	26	43.0	36	24.00	24.00	12	32.40
A029986	18	46.6	26	12.41	21.46	4	17.17
A020728	17	46.6	24	9.04	9.04	15	62.96
A019554	13	51.6	21	0.54	0.54	21	97.47
S013814	8.8	46.0	13	0.00	0.00	13	100.00
S013813	3.2	46.0	5	0.00	0.00	5	100.00
D031569R	0.74	54.3	1	0.26	0.26	1	79.70
A031256	0.22	43.0	0	24.00	24.00	0	0

Table 9. Draft Water Supply Table, month of April, for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	2,028.5	0.73	62.70	1,965.8	96.91
A024688A	14,191	47.1	2,030.9	0.00	61.98	1,968.9	96.95
S023680	14,168	47.3	2,037.7	0.00	61.98	1,975.7	96.96
S019972	14,162	47.4	2,042.1	0.66	61.98	1,980.2	96.97
S023682	14,140	47.5	2,044.4	0.00	61.32	1,983.1	97.00
S013760	14,123	47.7	2,047.0	0.00	61.32	1,985.7	97.00
S016032	11,784	49.1	1,760.6	0.08	35.39	1,725.2	97.99
S022582	11,740	49.3	1,760.7	0.00	35.30	1,725.4	97.99
A011327	11,497	49.5	1,730.7	1.06	35.30	1,695.4	97.96
S009039	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
S009045	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
S009040	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
A004612	11,094	50.2	1,692.3	0.00	34.14	1,658.2	97.98
A023077	3,243	49.4	487.6	4.51	26.35	461.3	94.60
A023077	3,200	49.6	482.8	4.51	21.84	461.0	95.48
A031521	2,282	50.3	349.1	4.25	10.40	338.7	97.02
S013709	2,248	44.7	305.7	0.78	25.93	279.7	91.52
D029507R	2,232	44.9	305.1	0.05	25.15	279.9	91.76
A018127	2,230	45.2	306.8	0.00	25.10	281.7	91.82
A025125	2,221	58.3	393.8	0.00	2.35	391.4	99.40
A017833	2,193	45.5	303.4	0.24	25.10	278.3	91.73
A020005	2,123	45.7	294.8	0.44	24.86	270.0	91.57
S015862	2,121	45.9	296.0	0.00	24.42	271.6	91.75
S009168	2,064	46.1	289.6	18.41	24.42	265.2	91.57
S013563	2,034	46.2	285.8	0.00	6.02	279.7	97.89
S015916	565	59.3	101.8	0.00	2.35	99.5	97.70
S022703	452	53.8	73.9	1.91	1.91	72.0	97.42
A021052	433	59.8	78.7	2.35	2.35	76.3	97.02
A015299	356	50.5	54.7	0.00	0.42	54.3	99.23
A019554	332	50.6	51.1	0.00	0.42	50.7	99.18
A021191	177	49.2	26.5	0.62	0.62	25.8	97.66
A031521	126	49.2	18.8	4.25	4.25	14.6	77.44
A020951	116	48.1	17.0	2.68	2.68	14.3	84.27
A019554	76	48.9	11.3	3.84	3.84	7.4	65.89
C003981	72	47.1	10.3	1.45	1.45	8.9	85.95
D030758R	42	45.6	5.9	0.35	0.54	5.3	90.87
A017479	39	53.8	6.5	2.76	2.76	3.7	57.25
A030933	38	45.6	5.3	0.19	0.19	5.1	96.47
A019554	32	50.4	4.9	0.27	0.27	4.6	94.51
A031256	26	43.0	3.4	0.22	0.22	3.2	93.44
S019409	26	43.0	3.4	0.22	0.22	3.2	93.44
A029986	18	46.6	2.5	3.48	6.02	0	0
A020728	17	46.6	2.4	2.54	2.54	0	0
A019554	13	51.6	2.1	0.15	0.15	1.9	92.65
S013814	8.8	46.0	1.2	0.00	0.00	1.2	100.00
S013813	3.2	46.0	0.4	0.00	0.00	0.4	100.00
D031569R	0.74	54.3	0.1	0.07	0.07	0.1	40.92
A031256	0.22	43.0	0.0	0.22	0.22	0	0

Table 10. Draft Water Supply Table, month of May for the 49 water rights points in the Mill Creek watershed (sorted from largest upstream catchment area to smallest).

Application ID	Watershed Area, Acres	Annual Precip Upstream, Inches	Seasonal Unimpaired flow volume, acre feet (AF)	Water Right volume, AF, over defined period	Senior Upstream water right volume, AF, during season	Remaining impaired discharge, AF	Remaining Unap-propriated water (%)
A024688B	14,191	47.0	517.54	0.78	49.41	468.14	90.45
A024688A	14,191	47.1	518.15	1.27	48.63	469.51	90.61
S023680	14,168	47.3	519.87	0.00	47.36	472.51	90.89
S019972	14,162	47.4	521.02	0.68	47.36	473.65	90.91
S023682	14,140	47.5	521.60	0.00	46.68	474.92	91.05
S013760	14,123	47.7	522.26	0.00	46.68	475.57	91.06
S016032	11,784	49.1	449.18	0.08	26.07	423.11	94.20
S022582	11,740	49.3	449.22	0.00	25.98	423.24	94.22
A011327	11,497	49.5	441.57	0.04	25.98	415.58	94.12
S009039	11,094	50.2	431.77	6.09	25.95	405.82	93.99
S009045	11,094	50.2	431.77	6.09	25.95	405.82	93.99
S009040	11,094	50.2	431.77	6.09	25.95	405.82	93.99
A004612	11,094	50.2	431.77	6.09	25.95	405.82	93.99
A023077	3,243	49.4	124.40	4.82	16.47	107.93	86.76
A023077	3,200	49.6	123.18	4.82	11.65	111.52	90.54
A031521	2,282	50.3	89.06	0.14	2.25	86.81	97.47
S013709	2,248	44.7	77.99	0.81	20.61	57.37	73.57
D029507R	2,232	44.9	77.83	0.05	19.81	58.02	74.55
A018127	2,230	45.2	78.27	0.00	19.76	58.51	74.76
A025125	2,221	58.3	100.47	0.00	2.42	98.04	97.59
A017833	2,193	45.5	77.40	0.00	19.76	57.64	74.47
A020005	2,123	45.7	75.22	0.45	19.76	55.46	73.73
S015862	2,121	45.9	75.53	0.00	19.31	56.22	74.44
S009168	2,064	46.1	73.89	19.02	19.31	54.58	73.87
S013563	2,034	46.2	72.91	0.00	0.29	72.62	99.61
S015916	565	59.3	25.98	0.00	2.42	23.56	90.67
S022703	452	53.8	18.87	1.97	1.97	16.90	89.56
A021052	433	59.8	20.07	2.42	2.42	17.65	87.92
A015299	356	50.5	13.95	0.00	0.43	13.52	96.90
A019554	332	50.6	13.03	0.00	0.43	12.60	96.68
A021191	177	49.2	6.75	0.64	0.64	6.11	90.52
A031521	126	49.2	4.80	0.14	0.14	4.66	97.05
A020951	116	48.1	4.34	0.18	0.18	4.16	95.89
A019554	76	48.9	2.87	3.97	3.97	0	0
C003981	72	47.1	2.63	0.10	0.10	2.54	96.33
D030758R	42	45.6	1.50	0.00	0.00	1.50	100.00
A017479	39	53.8	1.65	0.18	0.18	1.47	88.83
A030933	38	45.6	1.35	0.00	0.00	1.35	100.00
A019554	32	50.4	1.24	0.28	0.28	0.97	77.78
A031256	26	43.0	0.87	0.00	0.00	0.87	100.00
S019409	26	43.0	0.87	0.00	0.00	0.87	100.00
A029986	18	46.6	0.64	0.12	0.29	0.35	55.24
A020728	17	46.6	0.60	0.17	0.17	0.43	71.84
A019554	13	51.6	0.52	0.16	0.16	0.37	70.22
S013814	8.8	46.0	0.32	0.00	0.00	0.32	100.00
S013813	3.2	46.0	0.11	0.00	0.00	0.11	100.00
D031569R	0.74	54.3	0.03	0.04	0.04	0	0
A031256	0.22	43.0	0.01	0.00	0.00	0.01	0

Our analysis indicates that there is additional water for appropriation in the winter diversion season December 15 through March 31, and possibly in April as well: the percentage of remaining unappropriated water remains above 95 percent at all existing diversion points along Mill Creek and its major tributaries. The data presented in the first table indicate that additional appropriations from Mill Creek may be possible during this winter diversion season. However, in May, this value is below 95 percent for all of these diversion points, suggesting that water may not be available for appropriation during this period.

Along with the analysis of human water needs described in Section 3.3, these data indicate that there is substantial opportunity to store water in winter for use in summer in the Mill Creek watershed while maintaining water needed for environmental processes. Such projects are likely to have benefits to summer streamflow as well.

6 Ensuring Durable Results

As noted above, water users, project managers, and funders should ensure that any summer water use offset through winter storage remains in and is protected instream. Such tools can also benefit landowners and water users.

6.1 Mechanisms for Protecting Saved Water

6.1.1 Forbearance Agreements

Forbearance agreements are one of the tools for protecting instream flow gains achieved through storage and other water conservation projects. It is a covenant that runs with the land and is recorded with the county property records. Forbearance agreements have been used in the Mattole River Headwaters, Salmon Creek (Sonoma County), Grape Creek (Sonoma County), and Green Valley Creek (Sonoma County). In general, a forbearance agreement sets forth the responsibilities as between the project proponent and the landowner and/or water user. It specifies the terms under which diversions and other water management practices can be initiated and must be ceased.

6.1.2 Instream Dedications (Water Code Section 1707)

In addition to entering into forbearance agreements, water users may file a change petition to dedicate their water right – or a portion of a water right – to instream uses during the dry season under California Water Code Section 1707.

The main benefits of an instream water right dedication are that it offers a layer of protection and durability for the instream water restored through projects that is unachievable with a forbearance agreement alone. Specifically, it offers protection as to other water diversions and provides legal recognition of the instream water in the eyes of the state, and it allows funders, project proponents, and the landowner to ensure that water rights no longer used are not lost to the next junior appropriator or to new appropriators. Water users can also elect to add instream uses as a purpose of use without eliminating existing uses, like irrigation.

If a water user is operating under an appropriative water right and ceases diversion during the dry season, the right could be lost through non-use. In this case, ensuring that the water is protected instream – through a water rights change petition – is important. If the landowner is operating under a riparian right, the landowner would not normally lose the water right as a result of non-use (through abandonment or forfeiture[16]), so some type of forbearance agreement should be sufficient to ensure that the water right is not lost through non-use. The main drawback to pursuing a forbearance agreement alone – without a dedication – is that the water is not protected for instream uses from other diverters. A forbearance agreement would be recorded with the county and run with the land (so it binds future landowners) but it would not be known to other water diverters or prevent them from simply taking the water left instream.

[16] Note however that dormant (unexercised) riparian rights can sometimes be subordinated in priority in an adjudication.

A water rights dedication for the water no longer consumptively used can be an important part of the strategy for ensuring durable results. This could be all or a portion of a water right (e.g., in Pine Gulch Creek, the landowners dedicated the portion of their riparian water right used for irrigation during a portion of the year and maintained the non-irrigation portion of that riparian water right). This is especially important where projects involve the initiation of a new water right (e.g., winter diversion and storage) and involve an existing appropriative right, as the right can be lost to non-use. There may be cases where an instream water rights dedication is not appropriate. For example, where the landowner has a documented riparian water right (i.e., not lost through non-use), does not seek to initiate a new water right, and where the water no longer diverted is geographically protected from diversion by others (now and in the future). In addition, cost may be a factor for small projects (where the transactions costs of the dedication could be high relative to the overall project cost – e.g., projects like small roofwater harvesting).

6.2 Monitoring and Evaluation

In this SIP, we recommend actions that will produce additional streamflow in summer and fall while also maintaining sufficient water levels in winter and spring, and we predict that these actions will benefit salmonids. These predictions are based on our best models to evaluate improvement, but they are not actual depictions of the benefits from the projects that will be implemented. We recommend continued streamflow and habitat monitoring to evaluate the actual benefit of these projects on streamflow in the drainage network and to determine whether the projects have the benefits we expect (or the conditions under which the benefits are reached, such as in normal-type years or dry years). Such monitoring protocols will help us and others seeking to restore streamflow in coastal California watersheds to understand the benefits of these types of practices, as well as to understand the limitations of these practices given the range of variability across many years. Continued monitoring will also provide resources necessary for landowners to operate diversions appropriately and to ensure compliance with the terms and conditions stipulated in new diversion operations.

Additionally, continued monitoring of streamflow and expanded examination of habitat conditions will help us to gauge the benefit of these projects on fisheries. If data indicate that streamflow is greater and more stable through summer, and rearing habitat quality and juvenile summer survival do not increase, other factors may need to be considered to achieve the goal of creating a healthy fishery in Mill Creek. We note that streamflow is not the only factor limiting the persistence of a healthy fishery in Mill Creek, and work to increase streamflow in summer and continued fisheries resource monitoring will help us to understand the most significant additional challenges facing anadromous salmonids in the watershed.

6.3 Potential Threats

A significant amount of work has been completed to improve instream flow for fish populations in Mill Creek. We are evaluating the risk that future events will compromise the gains made today and are preparing a series of actions to guard against that possibility. Potential threats include:

- Land use changes. Land use change is a threat to streamflow gains in the Mill Creek watershed. The human footprint remains limited and development pressures are less here than in most places, but we must ensure that any streamflow improvements can withstand land use and ownership changes in the long-term.

- Non-participants. The success of the program depends on our ability to continue to recruit new landowners. This is necessary not only to reach the objectives, but also because having a high concentration of participants also helps ensure that water savings by landowners are not captured by other landowners rather than the stream. In addition, high participation creates a cultural climate conducive to water conservation and discourages water waste. Success breeds success.

- Lack of funding for water storage. All progress is subject to funding. Moreover, no one expects public funds to pay for all restoration, even though the public benefits from the projects. Though the funding available through Proposition 1 is promising, we anticipate that funding will be one of the limiting factors for how quickly streamflow improvement projects can progress.

- Lack of funding for monitoring. As mentioned above, long-term monitoring is important for ensuring compliance with water management conditions, for identifying changes in streamflow associated with water management practices, and for evaluating whether our proposed projects when implemented have the benefit we predict. Without additional resources for monitoring, we will not learn whether the projects implemented in Mill Creek are sufficient to restore streamflow beyond our identified thresholds and whether the results are long-lasting. Funding for any type of monitoring is generally major challenge of these types of projects, and we anticipate that monitoring after projects are implemented (while critical to understanding their success) will be even less attractive.

- Climate change. Although future effects of climate change cannot be quantified or predicted precisely, we consider it a significant risk factor for the future.

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http://oaec.org/our-work/projects-and-partnerships/water-institute/

Russian River Coho Water Resources Partnership:
http://www.cohopartnership.org/

Sonoma Resource Conservation District:
http://www.sonomarcd.org/

State Water Resources Control Board, Electronic Water Right Information Management System:
http://www.waterboards.ca.gov/ewrims/

Trout Unlimited:
www.tu.org

UC Cooperative Extension and California Sea Grant:
http://ca-sgep.ucsd.edu/russianrivercoho

USGS, Water Science for Schools:
http://ga2.er.usgs.gov/edu/sq3action.cfm (school water-use estimates)

Appendix A. Recovery Plan Actions Implemented by the Coho Partnership

The Coho Partnership is addressing and implementing recommendations and actions identified in the following public planning documents:

Central California Coast Coho Recovery Plan

The Central California Coast Coho Recovery Plan identified Mill Creek as Core Priority Area for CCC coho, and deemed the threat to summer rearing juvenile fish from water diversion and impoundments in the Russian River watershed to be "very high" (i.e., the highest threat level) (NMFS 2012). The Coho Partnership's efforts are consistent with and represent progress toward the following recovery plan objectives and recovery actions listed for the Russian River:

RR-CCC-4.1.1.2	Promote, via technical assistance and/or regulatory action, the reduction of water use affecting the natural hydrograph, development of alternative water sources, and implementation of diversion regimes protective of the natural hydrograph.
RR-CCC-4.1.1.3	Avoid and/or minimize the adverse effects of water diversion on coho salmon by establishing: a more natural hydrograph, by-pass flows, season of diversion and off-stream storage.
RR-CCC-4.1.2.1	Reduce the rate of frost protection and domestic drawdown in the spring.
RR-CCC-4.1.2.2	Assess and map water diversions.
RR-CCC-4.2.1.1	Develop cooperative projects with private landowners to conserve summer flows based on the results of the NFWF efforts.
RR-CCC-4.2.2.1	Work with SWRCB and landowners to improve over-summer survival of juveniles by re-establishing summer baseflows (from July 1 to October 1) in rearing reaches that are currently impacted by water use.
RR-CCC-4.2.2.2	Work with SWRCB and landowners to improve flow regimes for adult migration to spawning habitats and smolt outmigration.
RR-CCC-4.2.2.3	Promote alternative frost protection strategies.
RR-CCC-25.1.1	Prevent impairment to stream hydrology (impaired water flow).
RR-CCC-25.1.1.2	Promote water conservation by the public, water agencies, agriculture, private industry, and the citizenry.
RR-CCC-25.1.1.3	Promote off-channel storage to reduce the impacts of water diversion (e.g., storage tanks for rural residential users).

RR-CCC-25.1.1.4	Provide incentives to water rights holders willing to convert some or all of their water right to instream use via petition [for] change of use and [Section] 1707.
RR-CCC-25.1.1.5	Improve coordination between agencies and others to address season of diversion, off-stream reservoirs, bypass flows protective of coho salmon and their habitats, and avoidance of adverse impacts caused by water diversion.
RRR-CCC-25.1.1.8	Promote water conservation best practices such as drip irrigation for vineyards.

Recovery Strategy for California Coho Salmon

The Coho Partnership's efforts are consistent with DFG's Coho Recovery Strategy (CDFW 2004). They address the following recommendations for the Russian River Hydrologic Unit: the identification of water diverters, State Water Board review and/or modification of water use based on the needs of coho salmon and authorized diverters (RR-HU-03) (p. 8.39), and development of "county, city, and other local programs to protect and increase instream flow for coho salmon." The Partnership also implements the following range-wide recommendations:

RW-I-D-01:	Encourage elimination of unnecessary and wasteful use of water from coho salmon habitat…Encourage water conservation for existing uses.
RW-I-D-02:	Where feasible, use programmatic, cost-efficient approaches and incentives to working with landowners to permit off-channel storage ponds.
RW-I-D-08:	Support a comprehensive streamflow evaluation program to determine instream flow needs for coho salmon in priority watersheds.
RW-II-B-01:	Pursue opportunities to acquire or lease water, or acquire water rights from willing sellers for coho salmon recovery purposes. Develop incentives for water right holders to dedicate instream flows for the protection of coho salmon (California Water Code § 1707).

California Wildlife Action Plan

The Partnership addresses recommended actions in the California Wildlife Action Plan for the North Coast (CDFW 2007, p.261):

> "For regional river systems where insufficient or altered flow regimes limit populations of salmon, steelhead, and other sensitive aquatic species, federal and state agencies and other stakeholders should work to increase instream flows and to replicate natural seasonal flow regimes. Priorities specific to this region include:
>
> - Agencies and partners should develop water-use and supply plans that meet minimum flow and seasonal flow-regime requirements for sensitive aquatic species [CDFW 2004].

In determining flow regimes, the suitable range of variability in flow, rate of change, and peak- and low-flow events should be considered (Richter et al. 1997).

- Water trusts or other forums that provide a structured process for willing participants to donate, sell, or lease water dedicated to instream use should be pursued [CDFW 2004].
- Innovative ways to manage small-scale water diversions should be developed, such as agreements to alternate diversion schedules (so that all water users do not withdraw water at once) and the use of off-stream reservoirs to store winter water and limit diversion during the dry season. Incentives should be established for water users to participate in these efforts [CDFW 2004].
- Agencies and partners should encourage water conservation practices and use of technologies that reduce water consumption by residential and agricultural water users through incentives and education [CDFW 2004]."

State Water Resources Control Board

The Partnership furthers the California Water Boards' Strategic Plan Update (California Water Boards 2008). The Plan states:

> "The State Water Board strives to use a collaborative watershed management approach to satisfy competing environmental, land use, and water use interests by taking advantage of opportunities within a watershed, such as joint development of local solutions to watershed-specific problems, cost sharing, and coordination of diversions. For example, instead of the State Water Board and other regulatory agencies establishing and enforcing stream flow objectives through regulation of individual diversions, water users could agree to collectively manage their diversion schedules so that needed stream flows are maintained at particular points in a stream. They could also share costs associated with developing data and monitoring programs, and work together on projects to improve habitat at the most significant locations in the watershed. Extensive use of such approaches using coordination and collaboration, however, is currently beyond the Water Boards' resources."

Furthermore, the State Water Board identified the Russian River as one of its first priority rivers and streams in its prioritized schedule of instream flow studies for the protection of public trust resources (California Water Boards 2010).