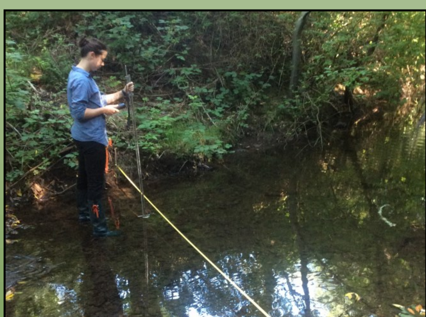
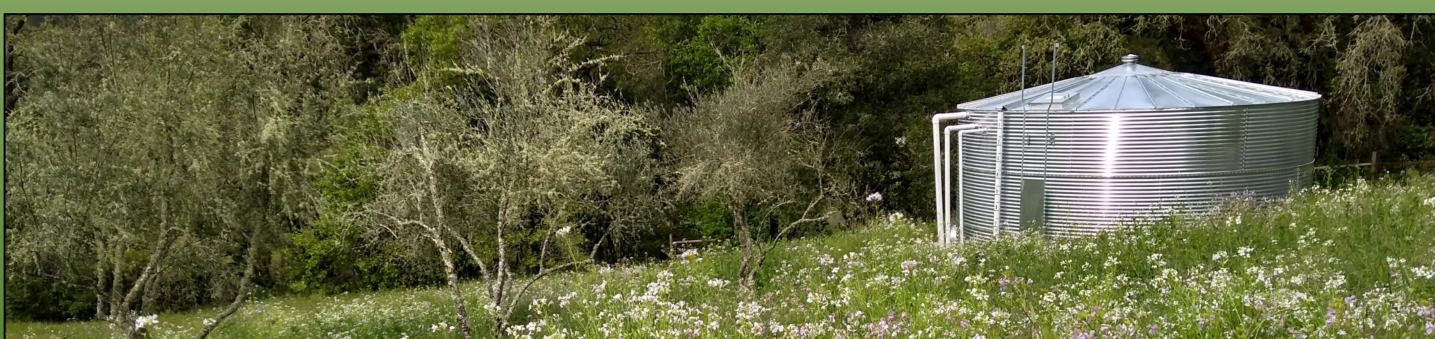
Upper Green Valley Creek Streamflow Improvement Plan





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Acronyms

AF	Acre-Feet or Acre-Foot
ACOE	Army Corps of Engineers
BACI	Before-After Control-Impact
BMI	Benthic Macroinvertebrate
CCC	Central California Coast
CEMAR	Center for Ecosystem Management and Restoration
CDFW	California Department of Fish and Wildlife (formerly CDFG)
CMP	California Coastal Monitoring Program
CSG	California Sea Grant
DO	Dissolved Oxygen
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GRRCD	Gold Ridge Resource Conservation District
KIBP	Keystone Initiative Business Plan
NCRWQCB	North Coast Regional Water Quality Control Board
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
PIT	Passive Integrated Transponder
PPT	Precipitation
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RM	River Mile
SDU	Small Domestic Use (Registration)
SIP	Streamflow Improvement Plan
SIU	Small Irrigation Use (Registration)
SRCD	Sonoma Resource Conservation District
SWRCB	State Water Resource Control Board
TU	Trout Unlimited
USGS	United States Geological Survey
VDI	Voluntary Drought Initiative
WY	Water Year
YOY	Young-of-the-Year (age 0+ fish)

Streamflow Improvement Plan overview

The Russian River Coho Water Resources Partnership (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 and Sonoma Water. 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 right and permitting expertise to modify water use and management to improve instream flow.

This SIP is a roadmap for prioritizing and implementing streamflow improvement projects with multiple public benefits and a diversity of approaches in the Upper Green Valley Creek watershed. Upper Green Valley Creek is the fourth of five watersheds for which we are developing SIPs. The Grape Creek SIP, Mill Creek SIP, and Dutch Bill Creek SIP are complete, and the Mark West Creek SIP will be completed if funding is available.

Executive summary

The purpose of the Upper Green Valley Creek SIP is to identify specific measures to moderate the impact of dry season water demand and improve instream flow for coho salmon and ecosystem function in the Upper Green Valley Creek watershed. Our goal is to work with water users to maintain a flow regime that is protective of the various life history stages of salmon by managing water demand through water conservation, seasonal storage, and other modifications to diversion practices and by augmenting flow through recharge, spring reconnection, and other strategies.

Section 1 introduces the Russian River Coho Water Resources Partnership, reviews our rationale for selecting Upper Green Valley Creek as a focal watershed for the SIP, and describes the purpose of the SIP.

Section 2 describes watershed conditions in the Upper Green Valley Creek watershed, including geology, climate, land use, and hydrology. It provides an overview of the impacts of both human demand and drought on summer streamflow conditions.

Section 3 includes a hydrologic evaluation that compares rainfall, discharge and human water use on annual, seasonal and monthly scales. The evaluation concludes that there is enough water available in the watershed to meet human water need and informs potential changes to water management practices to benefit salmonids.

Section 4 provides a brief overview of the history of salmonids in the Russian River basin and historical presence within the Green Valley Creek watershed, describes recent population monitoring efforts for salmonids, and discusses the impacts of streamflow on habitat.

Section 5 recommends strategies to achieve the Partnership's primary goal of maintaining pool connectivity within Upper Green Valley Creek. It describes the Partnership's priority reaches, provides a suite of recommendations and case studies, and evaluates whether those recommendations -- if and when implemented -- are sufficient to improve pool connectivity.

Section 6 provides an overview of permitting considerations for streamflow enhancement projects and tools to ensure that water remains instream.

Section 7 summarizes the key points of the SIP:

- Upper Green Valley Creek is a critical stream for endangered coho in the Russian River basin.
- Insufficient dry-season streamflow in Green Valley Creek has had a considerable negative impact on rearing juvenile salmonids in most recent years and is a significant limiting factor to local coho salmon recovery. Current oversummer streamflow in Green Valley Creek, while able to

support high survival of rearing juveniles in the wettest years, is generally insufficient to support the biological needs of rearing juvenile salmonids to full productivity.

- A strong environmental predictor of summer survival of juvenile coho salmon in Green Valley Creek is the number of days of pool disconnection.
- Efforts to maintain flow as low as 0.20 ft^3/s will decrease the number of days that pools would be disconnected in any given dry season and thereby increase the probability of fish survival.
- Human water use and diversion during the dry season have a demonstrable impact on streamflow in the Upper Green Valley Creek watershed.
- There is sufficient water in the Upper Green Valley Creek watershed to meet human needs on an annual basis if water use is managed according to seasonal availability.
- The Partnership's suite of current and anticipated future streamflow enhancement projects could cumulatively add sufficient flow for the priority stream reaches to meet estimated pool connectivity thresholds.
- Flows greater than those required to maintain minimum connectivity will ultimately be necessary to increase juvenile production and achieve full population recovery.
- Regulatory, permitting and other changes are necessary to increase the scope and scale of the work.

1 Introduction

1.1 The Russian River Coho Water Resources Partnership

The Russian River Coho Water Resources Partnership (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 California Sea Grant (CSG), Gold Ridge Resource Conservation District (GRRCD), Sonoma Resource Conservation District (SRCD), Occidental Arts and Ecology Center's WATER Institute (OAEC), and Trout Unlimited (TU) in partnership with Sonoma Water. 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 dramatically since 2000, with estimated returns ranging from 192 to 763 over the last nine years. 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 subwatersheds in the Russian River basin where near-term changes in water management are critical to restoring coho salmon: Green Valley, Dutch Bill, Grape, Mark West, and Mill 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; (3) increase water supply reliability for water users in each focal watershed; and (4) increase knowledge and public awareness about watershed processes and their impacts on streamflow and fish. 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 conservation hatchery releases, and conduct coho life-cycle monitoring is unique, and the 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 (NMFS 2012) (see Appendix A). Since NFWF established the Keystone Initiative in 2009, the Russian River has become a focus area for many 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.
- NOAA named the CCC coho salmon population as a "Species in the Spotlight."
- The National Fish Habitat Partnership identified Upper Green Valley Creek as one of its 2019 national "Waters to Watch."
- The California Water Action Plan identified Mark West Creek as one of five stream systems in the state where the California Department of Fish and Wildlife (CDFW) and the State Water Resources Control Board (State Water Board) will "implement a suite of individual and coordinated administrative efforts to enhance flows."
- CDFW and NOAA selected four Russian River tributaries for their Voluntary Drought Initiative (VDI) program.
- The State Water Board adopted a "Drought-related Emergency Regulation Requiring Enhanced Water Conservation and Additional Water User Information for the Protection of Specific Fisheries in tributaries to the Russian River" in 2015 (SWRCB 2015).

1.2 Partnership Focus Area

The Partnership has focused on the Upper Green Valley Creek watershed (Figure 1) as the focus area for its efforts and for this SIP because of its importance for coho within the larger Green Valley and Atascadero Creek watershed. Upper Green Valley Creek and Purrington Creek (in addition to lower Green Valley Creek) were identified by CDFW as optimal coho spawning and rearing habitat within the larger watershed (GRRCD 2014). NMFS's Central California Coast Coho Recovery Plan identifies the Upper Green Valley Creek subwatershed, the Purrington Creek subwatershed, and the Lower Green Valley Creek subwatershed as a Core Priority Area (NMFS 2012). In addition, in 2015, the State Water Board and CDFW identified the Upper Green Valley Creek and Purrington Creek subwatersheds as the "critical rearing portion" of the watershed (SWRCB 2015).

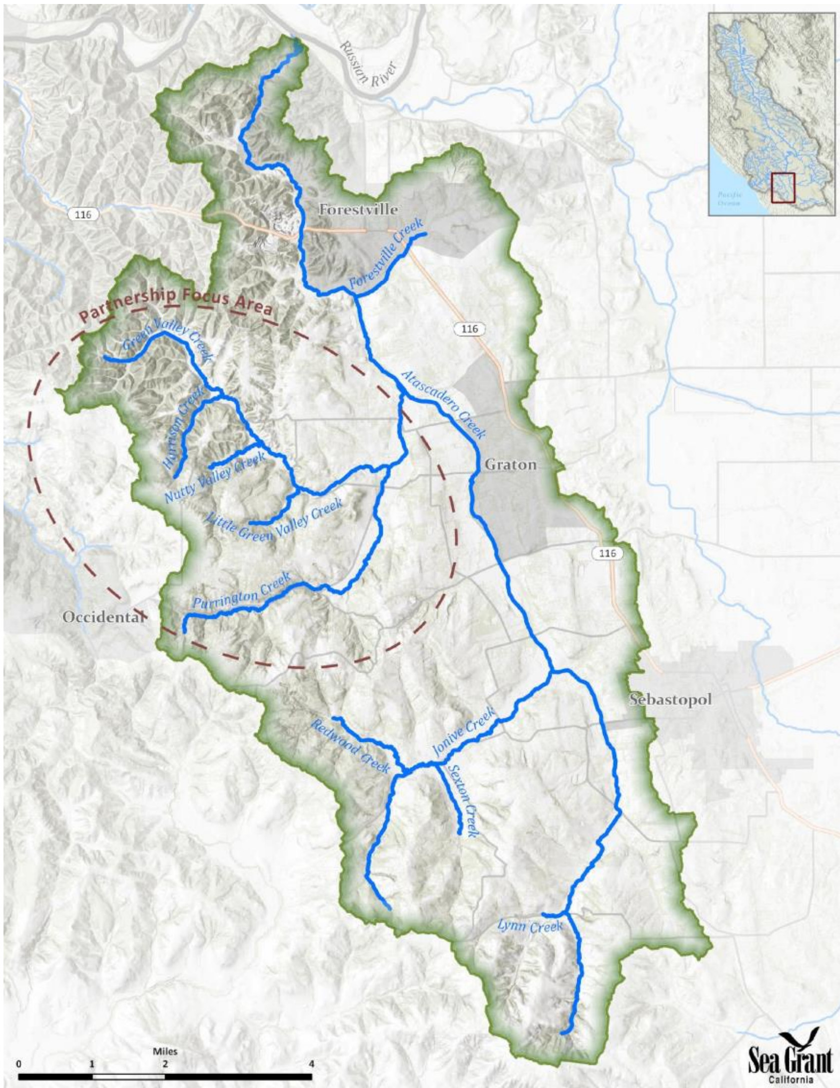

Figure 1. Coho Partnership and SIP focus area within the Green Valley Creek watershed.

1.3 Purpose of the Upper Green Valley 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. It is intended to build on the foundational and ongoing work of so many in the Green Valley Creek watershed and it is intended to be a living document.

2 Watershed conditions

This section describes the watershed conditions in the Upper Green Valley Creek watershed, including land use, climate and hydrology. It provides an overview of the impacts of both human demand and drought on summer streamflow conditions.

2.1 Land use

Upper Green Valley Creek is a tributary to Green Valley Creek, a tributary to the Russian River, located in Sonoma County, west of the city of Sebastopol. The Upper Green Valley watershed drains an approximately 10 mi^2 basin. The Upper Green Valley Creek headwaters start west of the town of Graton. From there, the creek flows north until it reaches its confluence with Green Valley Creek, near the town of Graton. Land use in the Upper Green Valley Creek watershed consists mainly of undeveloped forested lands, agricultural land, and rural residences (Figure 2). The majority of the undeveloped land lies in the north western portion of the watershed, with agriculture and residences dominating the southern half of the watershed.

Vineyards and apple orchards are the primary agricultural land use types in the watershed. Combined, these two uses make up almost 15 percent of the total land area. Within the Upper Green Valley Creek watershed row crops, pastures, small marijuana grows, and fallow fields comprise a small fraction (less than one percent) of other agricultural land use.

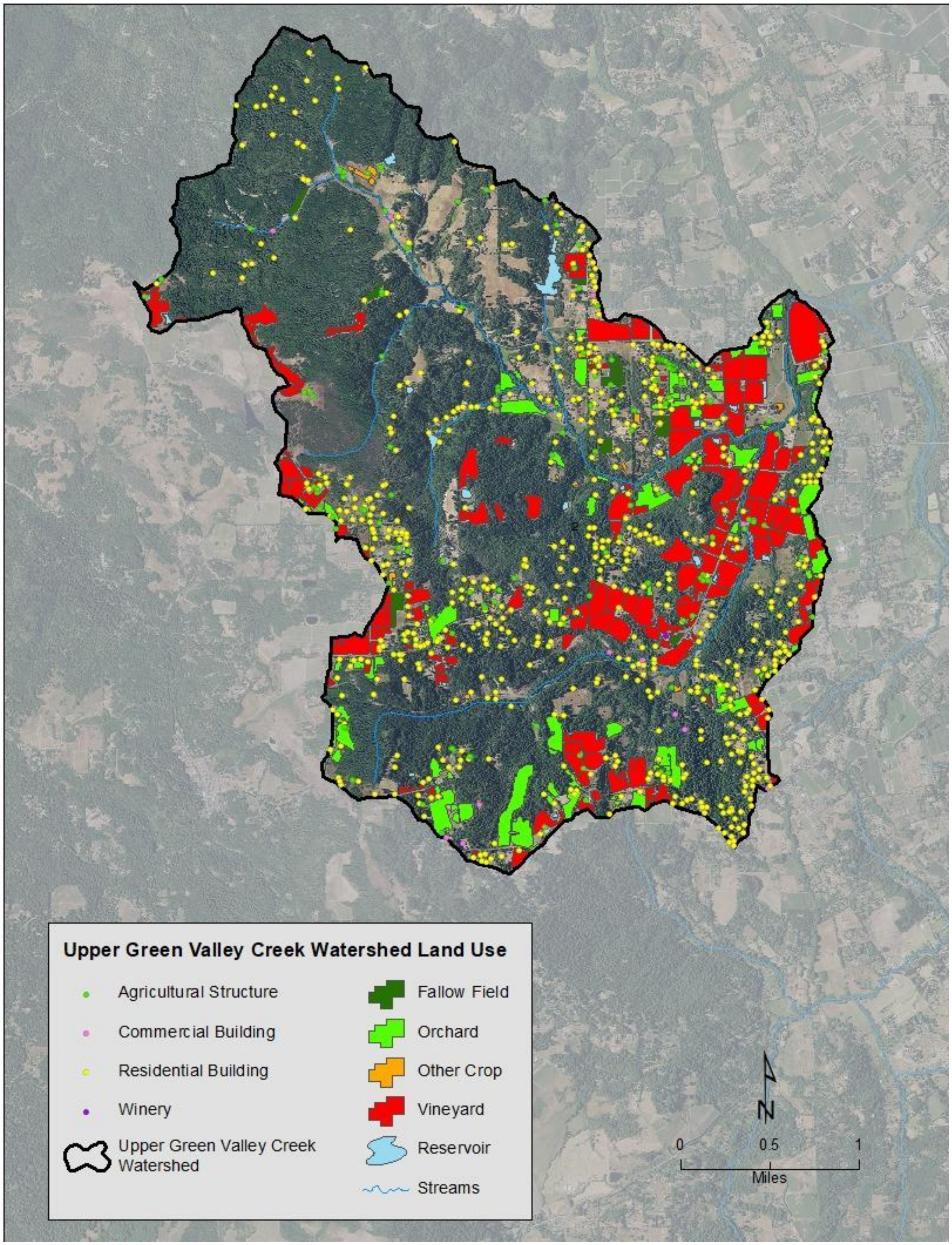

Figure 2. Upper Green Valley Creek watershed land use.

2.2 Climate

The Upper Green Valley Creek watershed has a climate like many watersheds in coastal California and is considered characteristically Mediterranean — the summers are warm and dry while the winters are cool and wet. Average high temperatures recorded in Graton do not exceed 90 degrees Fahrenheit, and the average lows do not fall below 35 degrees (Figure 3). Precipitation occurs almost exclusively as rainfall, mostly during the wet winter months. Rainfall data recorded at the reference gage for this SIP (NCDC Station #3875 in Healdsburg, CA) over a 77-year period show that 90% of the average annual rainfall occurs between November and April, and less than 2% occurs from June through September (Figure 4). These records show that rainfall can be highly variable from one year to the next. Over the 77-year period, annual rainfall varied from a little as 17 inches (1977) to as much as 83 inches (1983), with extended periods of drought and periods of high precipitation (Figure 5).

The study period for this SIP began with two years of above-average rainfall (2010 and 2011), during which 46.93 and 43.19 inches were recorded, respectively. This was followed by five years of below average rainfall during the drought (2012 to 2016). The lowest precipitation year was 2014, in which 19.7 inches of rainfall was recorded. 2017 saw above-average rainfall with the highest amount of annual precipitation recorded for the study period (48.2 inches). The final year of the study period, 2018, was another below-average year with 22.33 inches of rainfall (Figure 6).

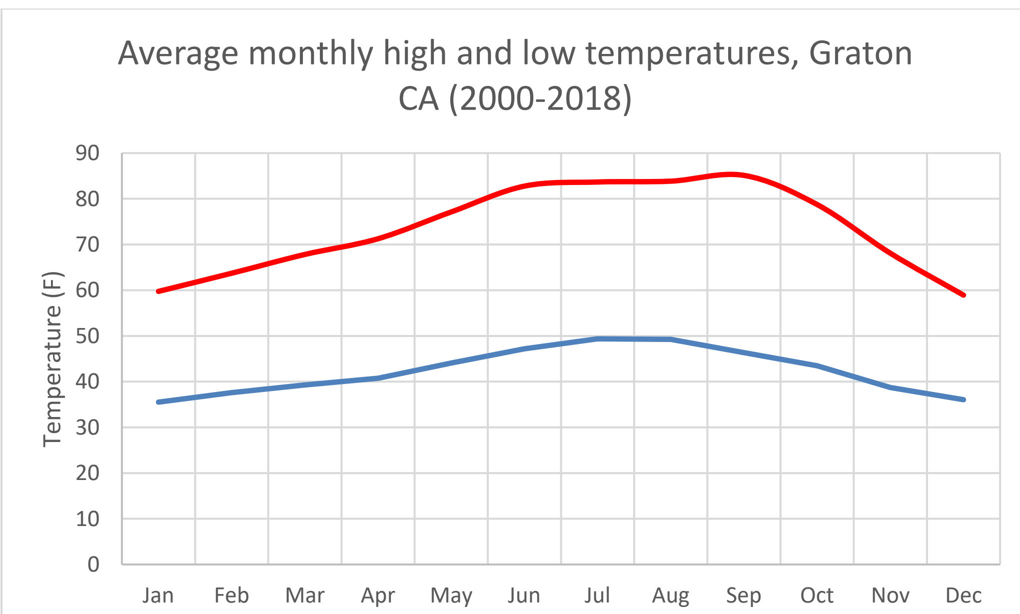

Figure 3. Average monthly high and low temperatures (2000 – 2018) recorded in Graton, CA (NCDC Station USC00043578).

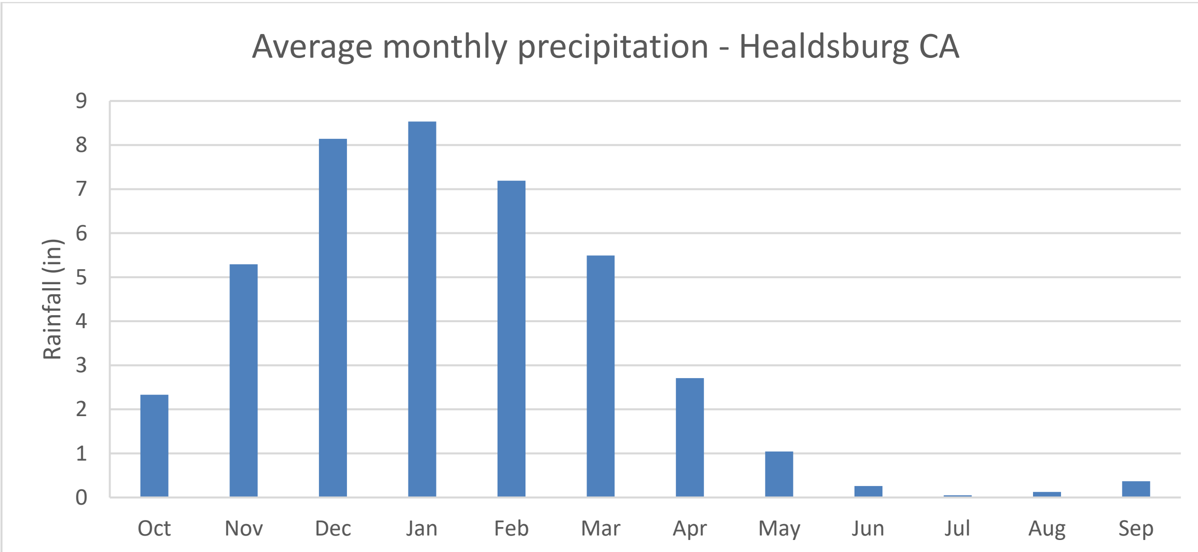

Figure 4. Average monthly rainfall recorded at Healdsburg, CA (NCDC Station #3875).

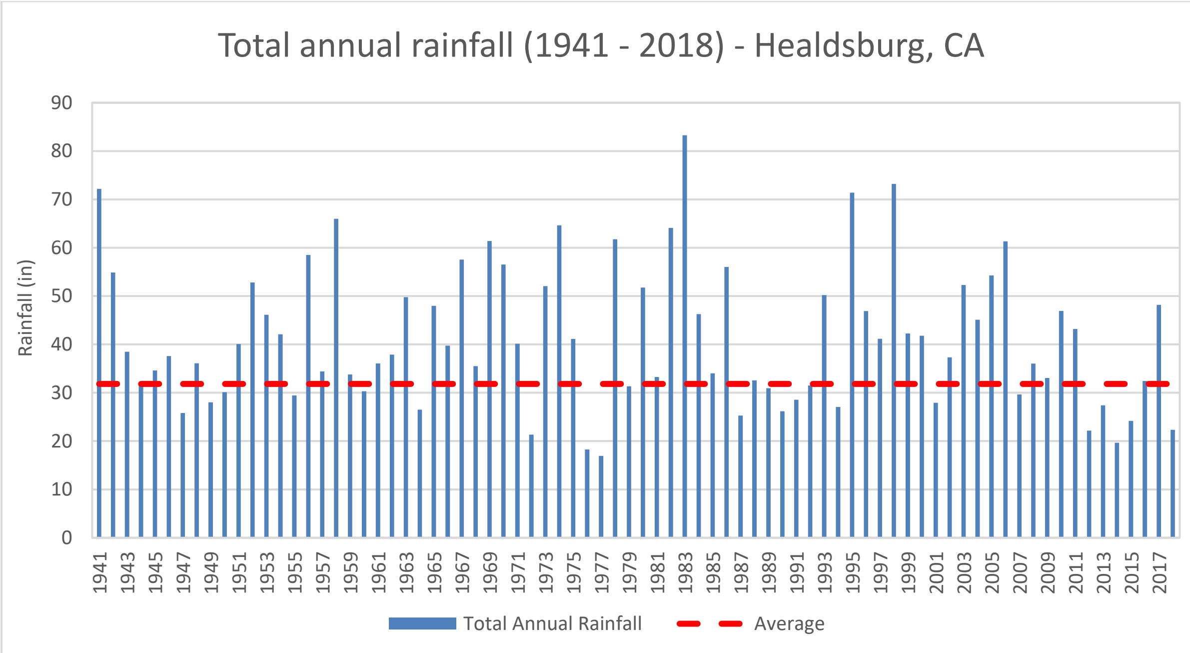

Figure 5. Annual rainfall recorded at Healdsburg, CA, 1941-2018 (NCDC Station #3875).

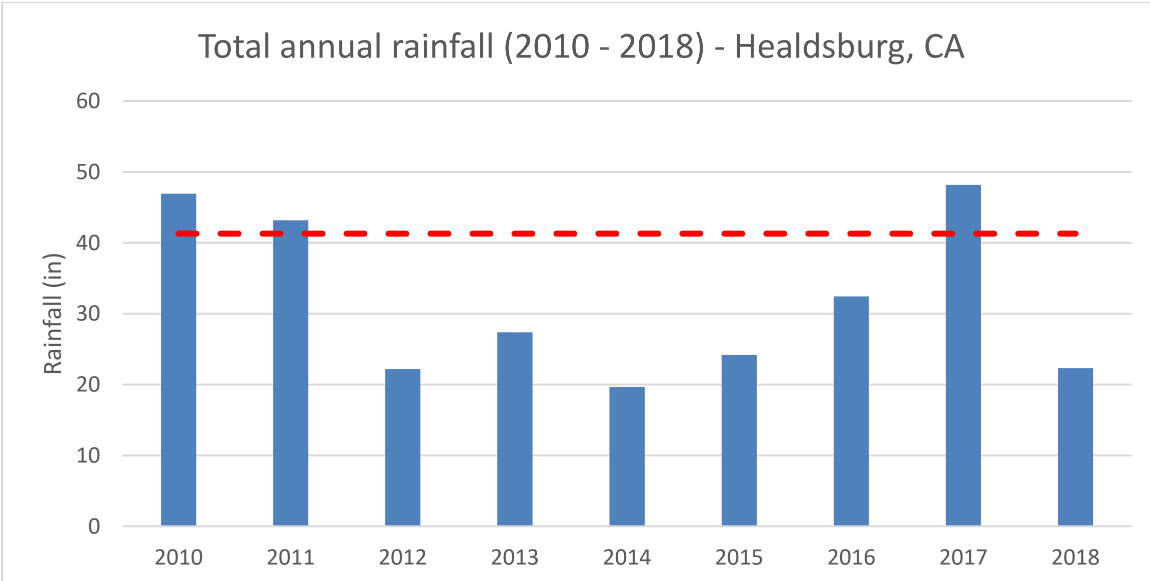

Figure 6. Annual rainfall recorded at Healdsburg, CA, during the study period 2010-2018 (NCDC Station #3875).

2.3 Hydrology

This sub-section describes surface and groundwater conditions in the watershed and focuses on the results of the Partnership's nine years of streamflow monitoring. The majority of the Partnership's work has been focused on surface water monitoring, though the Partnership recently received funding to monitor groundwater conditions in Upper Green Valley Creek. The data described in this section provide important information regarding how the watershed's streamflow conditions vary in different types of water years.

Streamflow

Streamflow data are essential for understanding the health of the Upper Green Valley Creek watershed and the impacts of human water management activities on the surrounding ecosystem. California's dramatic variability in precipitation makes streamflow conditions highly variable between years and monitoring an essential component of streamflow enhancement work in the watershed. Long-term streamflow datasets allow resource managers to quantify the impairment caused by water diversions, to identify priority reaches for restoration and enhancement projects, to estimate the benefit of flow enhancement projects and understand salmonid survival and recovery.

No long-term gage data exist in the Upper Green Valley watershed, so the SIP's coverage of streamflow conditions in Upper Green Valley is limited to the nine years of the Partnership's gage records. Over the course of the Partnership's work, the gage network has evolved to best meet the needs of the program. TU's Conservation Hydrology program (formerly CEMAR) is currently operating five gages in the Upper Green Valley Creek watershed. GV04 is the furthest upstream site on Green Valley Creek, followed by GV01, GV07, and GV08; GV02 is located on Purrington Creek (Figure 7).

Each streamflow gage is operated following United States Geological Survey (USGS) standard procedures, as described in Rantz (1982). Field crews measured streamflow at approximately monthly intervals beginning in Water Year (WY) 2010 following protocols adapted from the CDFW Standard Operating Procedures for Discharge Measurements in Wadeable Streams (CDFW 2013).[1] Using measured streamflow values, we developed rating curves to correlate streamflow with discharge at each site. In addition, we installed staff plates to detect 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.

During the first three years of the Partnership, we collected streamflow data year-round. Due to reductions in funding, we reduced our streamflow data collection to the summer dry season. Data from WY2011 collected at (GV01) Upper Green Valley Creek at Bones Rd. show seasonal trends that are characteristic of Mediterranean-climate streams. Streamflow typically occurs in a series of high-flow events, during and immediately following rain events, and periods of declining baseflow, with a prolonged period of declining baseflow in the summer season (Figure 8).

Total monthly discharge data from WY2011 and WY2012 exemplify how drastically discharge changes between seasons and in different water years. Streamflow is consistently highest during the winter months and lowest during the summer. At the Partnership's gage sites, as much as 90% of discharge occurred between November and April (Figure 9). However, the amount of monthly discharge during the winter season can vary drastically from year to year. Figure 9 shows that in WY2011 December discharge was greater than 25% of annual discharge, and in WY2012 December discharge was less than 5% of annual discharge.

Likewise, spring discharge can vary greatly from year to year. Our data indicate that late spring and early summer rain events may have a significant impact on summer streamflow conditions. Late spring rain events can result in higher streamflow conditions persisting longer into the summer season. Figure 10 shows streamflow in Upper Green Valley in WY2013 and WY2014; streamflow in WY2013 was lower at the beginning of the summer season than conditions in WY2014. A light rain event in late June 2013 increased summer base flow and caused the streamflow to persist longer into the dry season.

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[1] 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.

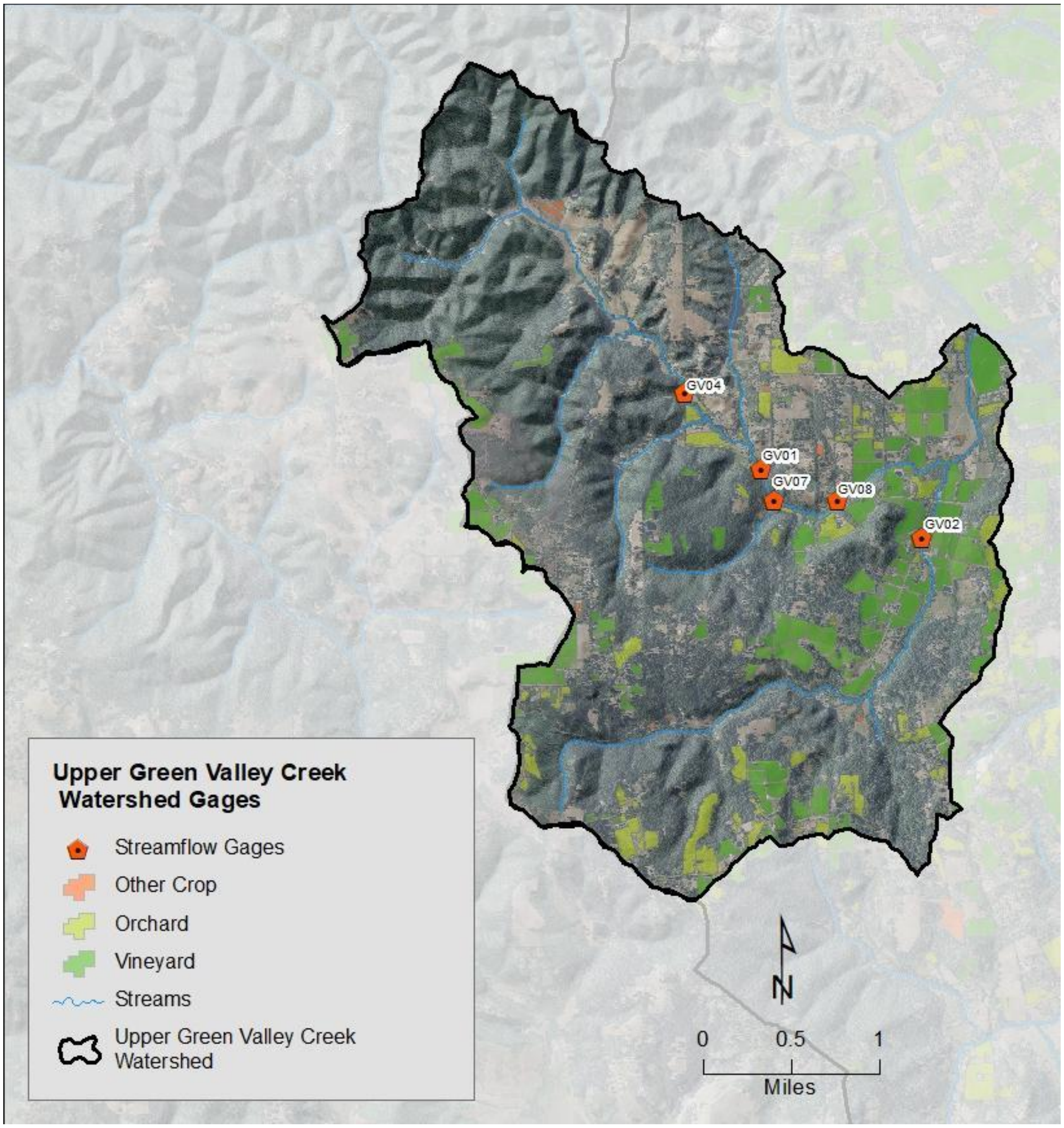

Figure 7. Streamflow gage locations in the Upper Green Valley Creek watershed.

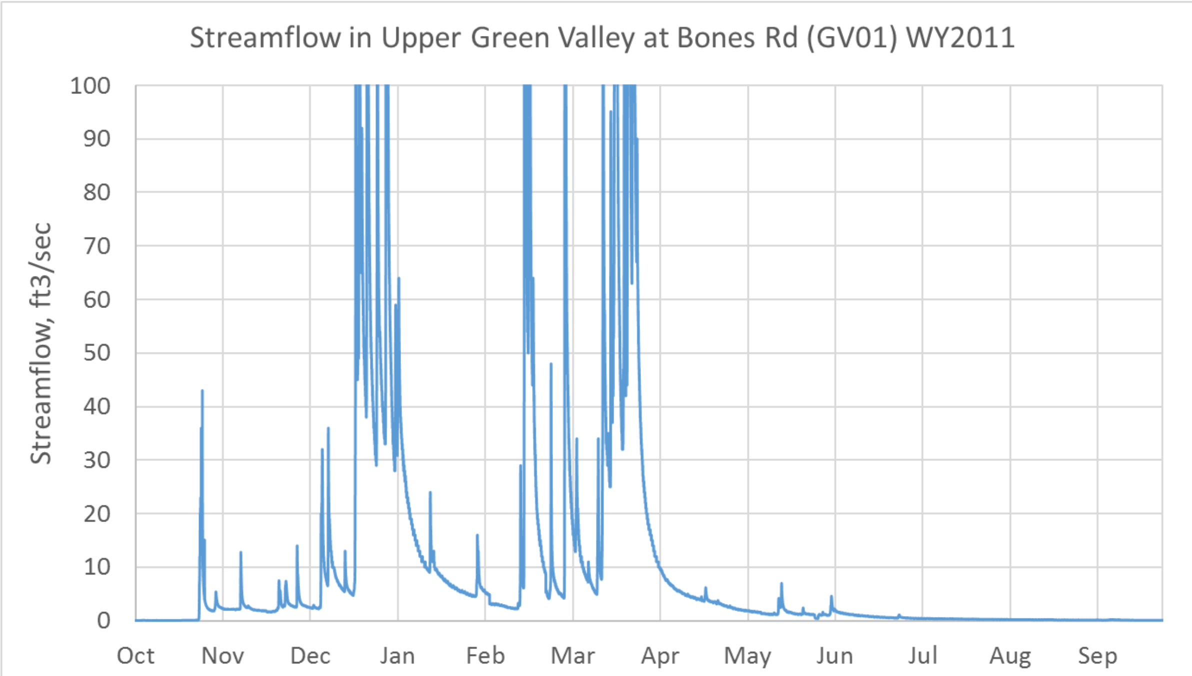

Figure 8. Streamflow recorded in Upper Green Valley Creek at Bones Rd (GV01), WY2011.

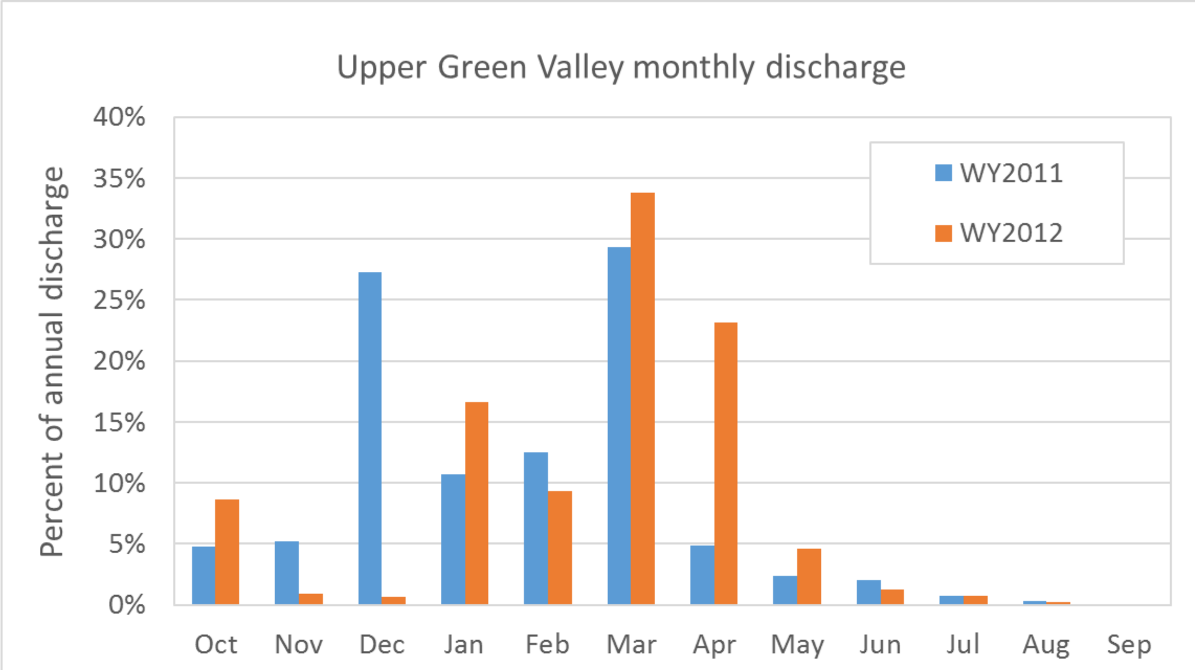

Figure 9. Monthly discharge as a percentage of annual discharge in Upper Green Valley Creek, 2011 and 2012 (WY2011 data from GV01, WY2012 data from GV02 [GV01 malfunctioned for part of WY2012]).

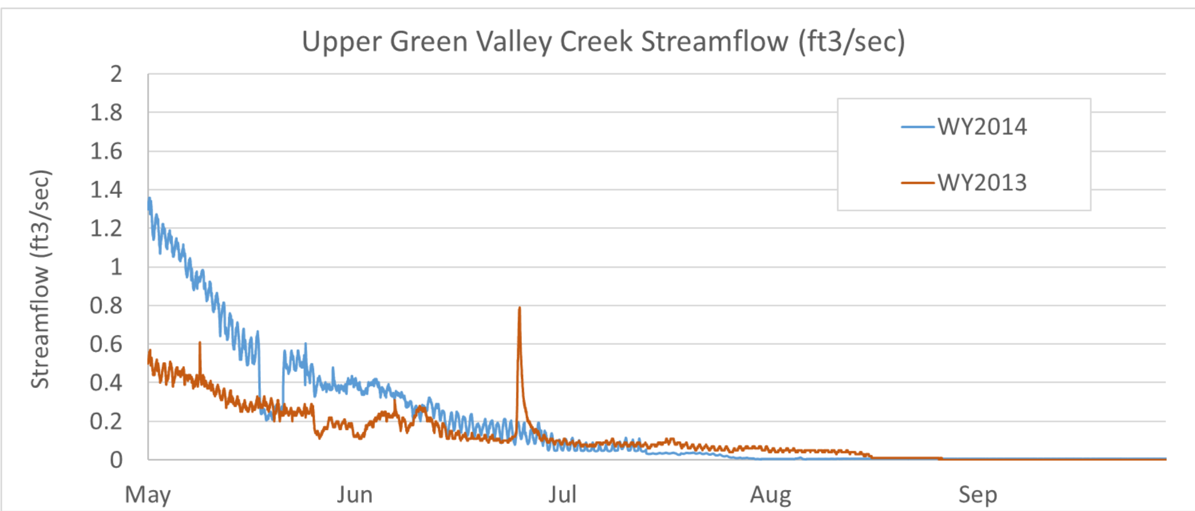

Figure 10. Upper Green Valley summer streamflow from WY2013 and WY2014, showing how summer rainfall events impact streamflow conditions.

2.3.1 Summer baseflow

Summer baseflow is a critical limiting factor for coho salmon and steelhead trout survival and recovery in the Upper Green Valley Creek watershed and is the focus of TU's streamflow monitoring program. Figure 11 shows a summer hydrograph at (GV01) Green Valley Creek at Bones Rd in WY2010 and illustrates the summer recessional flow regime typical to the Upper Green Valley Creek watershed in an average to wet water year. In late spring/early summer 2010 the watershed received a few small rain events, which caused water levels and streamflow to rise. As the summer continued, the stream receded to baseflow, derived from groundwater inputs and local springs. In late September 2010 streamflow reached its lowest levels for the year at 0.03 ft^3/s. In late September/early October riparian trees lost their leaves and decreased their transpiration rates, resulting in a slight increase in water levels and streamflow during the driest time of the year. In 2010 this change in transpiration caused streamflow to rise from approximately 0.03 ft^3/s to 0.05 ft^3/s. Summer baseflow was maintained for the remainder of the summer until the first rain event of the year in late October 2010.

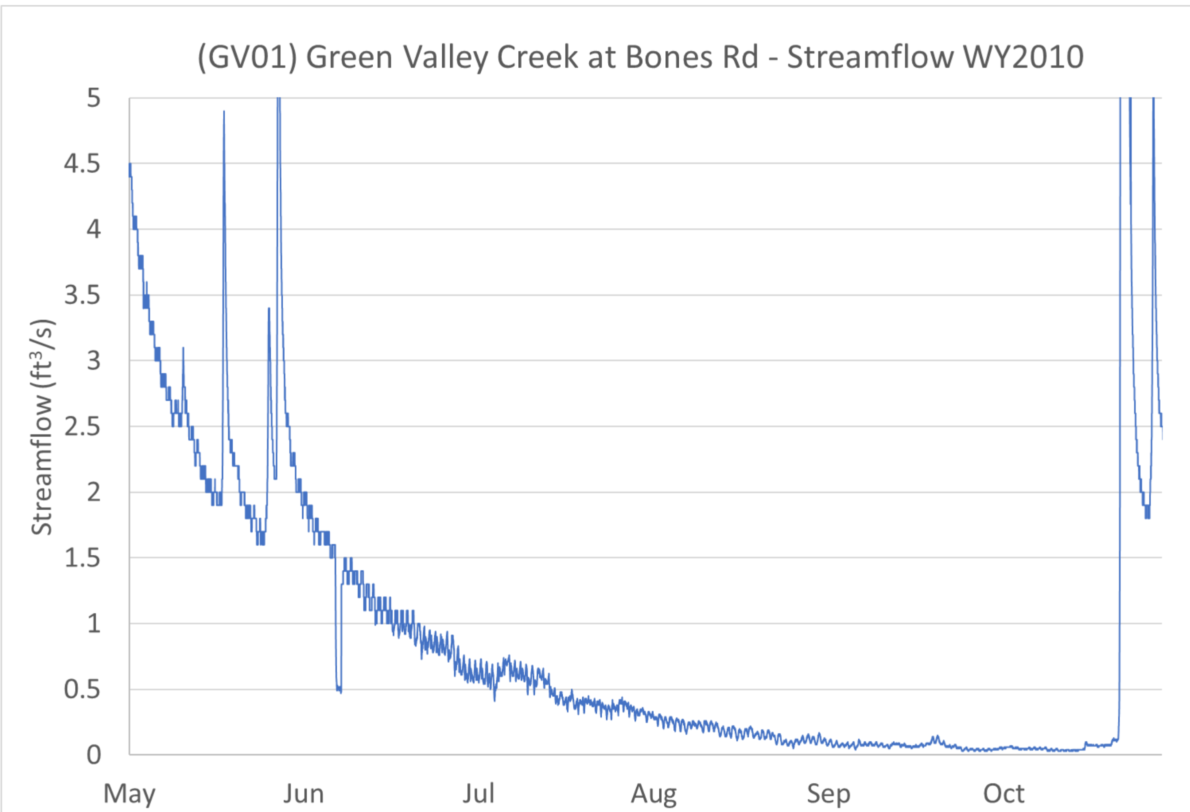

Figure 11. Streamflow in Green Valley Creek, water year 2010, showing summer baseflow to illustrate the magnitude of the dry season flow recession.

2.3.2 Impacts of human water management

Streamflow conditions in Upper Green Valley Creek and Purrington Creek are impacted by human water management practices. Gage data from these watersheds show both a reduction and increase in dry season streamflow conditions at different times as a result of human activities. For example, Figure 12 shows how a reduction in streamflow recorded at our upper gage (GV04) propagates downstream and is detected in all three lower gages. Additionally, a water release in late September/early October recorded at our upper gage (GV04) also propagates downstream (more detailed information on flow releases in Upper Green Valley Creek is described in Section 5.4.3). Figure 13 shows a reduction in streamflow conditions recorded in Purrington Creek at our GV02 gage site, likely caused by one or multiple instream diversions. In 2010, these diversions cause a decrease in streamflow condition ranging from approximately 0.2 – 0.4 ft^3/s.

Groundwater pumping from shallow wells adjacent to the creek also impact summer baseflow conditions in the watershed, however these management activities are difficult to detect in surface water gages. Analysis of the gage networks data from our upper and lower gages shows that the reach between the upper two gages (GV04 and GV01) is a gaining reach for the majority of the time but experiences periods where the stream is losing water to the groundwater table (Figure 14). The timing of when the stream is a gaining or losing reach is influenced by climatic conditions, such as the drought, but it is possible that groundwater pumping at these times may be impacting the amount of surface water that is being lost to the groundwater table. Additional studies and groundwater modeling are needed to confirm this hypothesis.

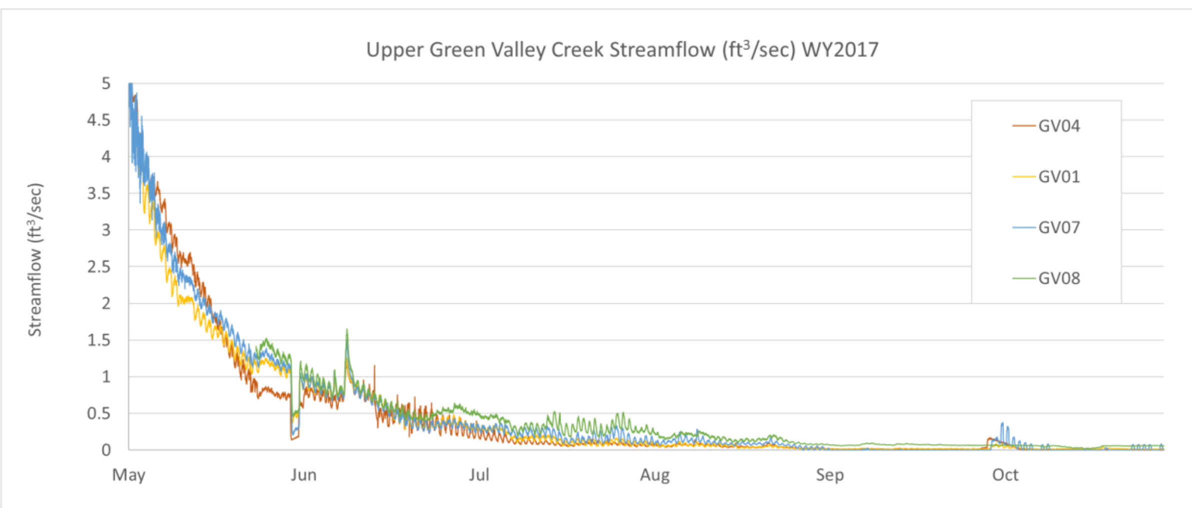

Figure 12. Summer streamflow conditions in Upper Green Valley Creek, water year 2017, at all gage sites.

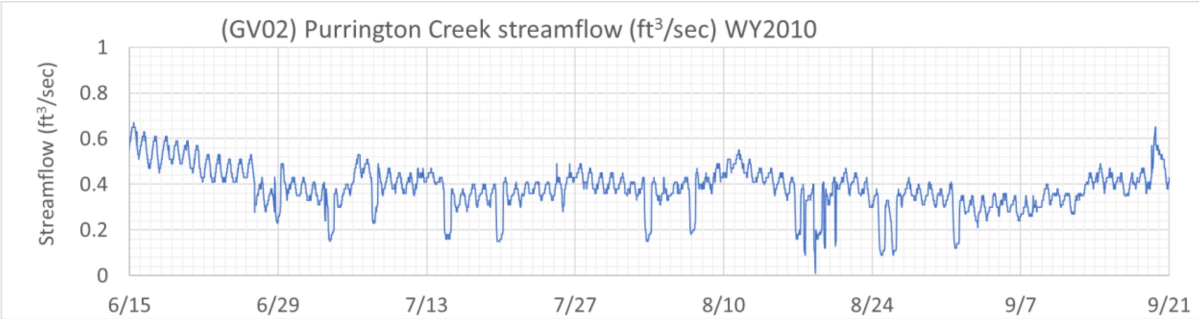

Figure 13. Summer streamflow conditions in Purrington Creek recorded at GV02, water year 2010, showing the impact of direct diversions on streamflow.

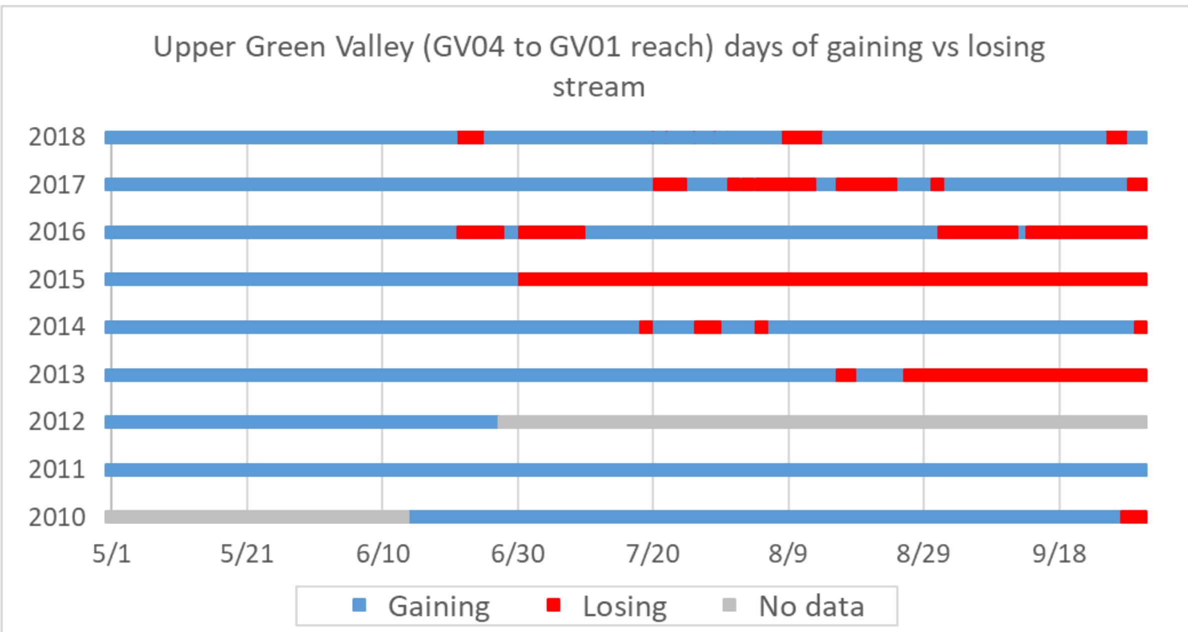

Figure 14. Days when Green Valley Creek between project gages GV04 and GV01 was a gaining vs losing reach. Losing reach days were assumed when the difference in mean daily flow value between reaches was below 0.00 ft^3/s.

2.3.3 Impact of recent drought on streamflow

The recent 2012-2016 drought had a measurable and profound impact on summer baseflow conditions in the Upper Green Valley Creek watershed at all five gage sites. Prior to the drought, water years 2010 and 2011 were average to wet years and the system maintained connected pools throughout the dry season. During all five years of the drought streamflow in Upper Green Valley, at gage site GV01, streamflow dropped to zero in August (if not sooner), and pools remained disconnected until October (and in some years through October) (Figure 16). Following the drought (in water years 2017 and 2018) summer streamflow conditions increased but did not return to levels recorded prior to the drought (Figure 17), despite the watershed receiving more rainfall in water year 2017 than water year 2010 or 2011 (Figure 6). The decrease in streamflow recorded in WY2017 shows the drought had a cumulative and lingering impact on streamflow conditions. It is likely that the drought caused a reduction in groundwater conditions, which caused a reduction in streamflow in water years 2017 and 2018.

Total summer discharge data from our gage sites further illustrate the impact of the drought on streamflow conditions. For example, total summer discharge at GV01 prior to the drought was over twice as much as total summer discharge during the drought (Figure 18). Using water year 2010 as a reference year, summer discharge in 2012 was 30 percent of 2010 discharge, 2013 thru 2016 were 13, 21, 13 and 21 percent, respectively, of 2010 discharge, and 2017 and 2018 were 58 and 40 percent of 2010 discharge. Total monthly discharge data from our gages show the significance of the drought during the driest month of the summer season, September (Figure 19).

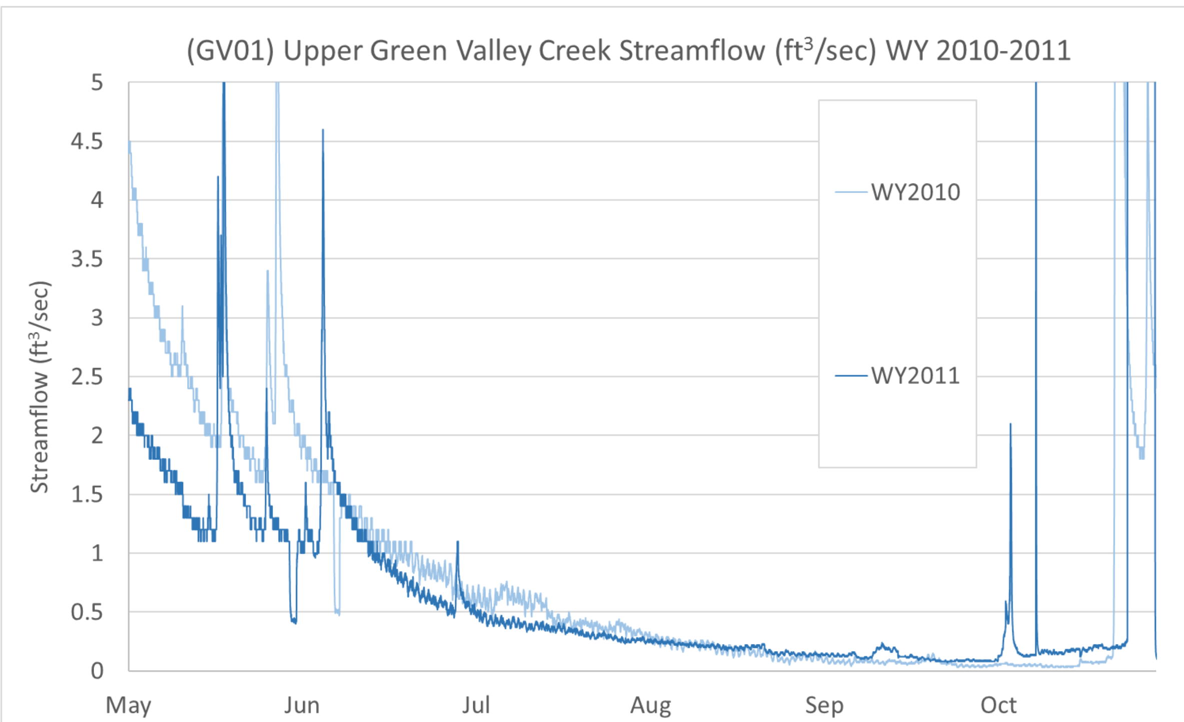

Figure 15. Summer streamflow conditions in Upper Green Valley at gage site GV01, water years 2010 and 2011, showing streamflow conditions before the 2012-2016 drought.

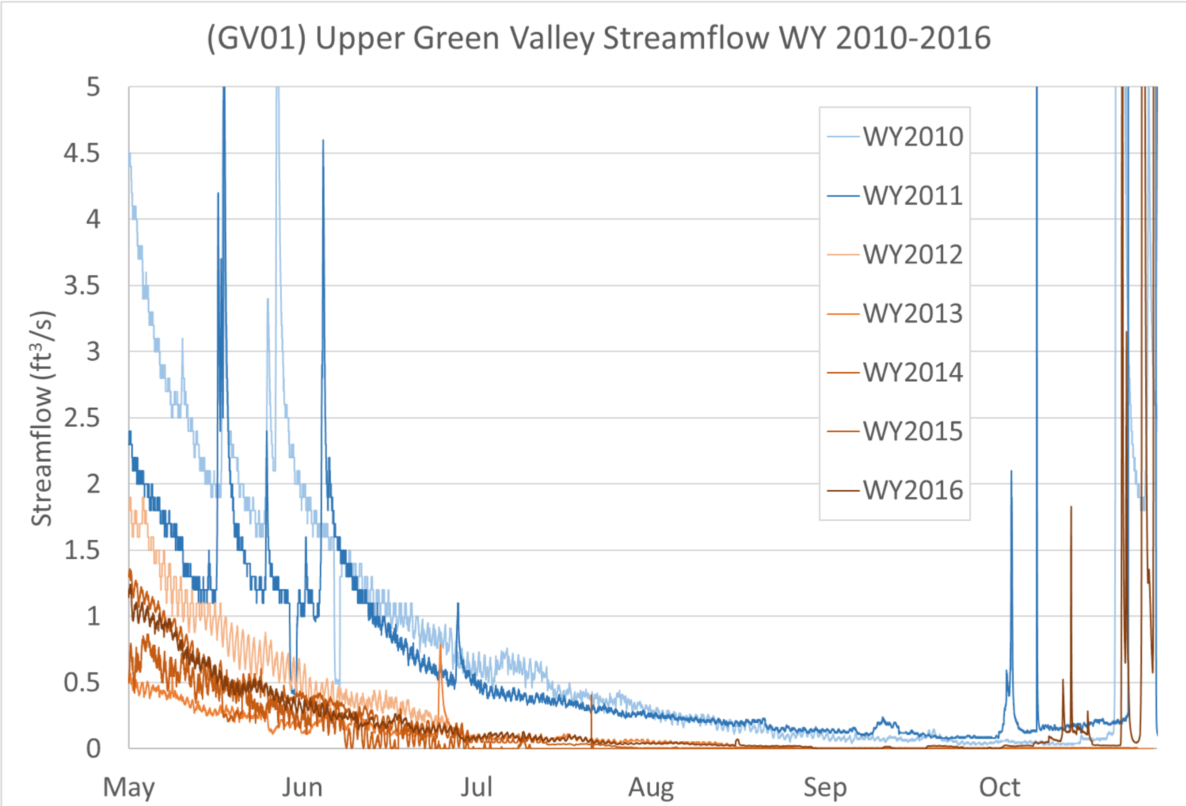

Figure 16. Summer streamflow conditions in Upper Green Valley at gage site GV01, water years 2010 thru 2016, showing streamflow conditions before (in blue) and during (in red) the 2012-2016 drought.

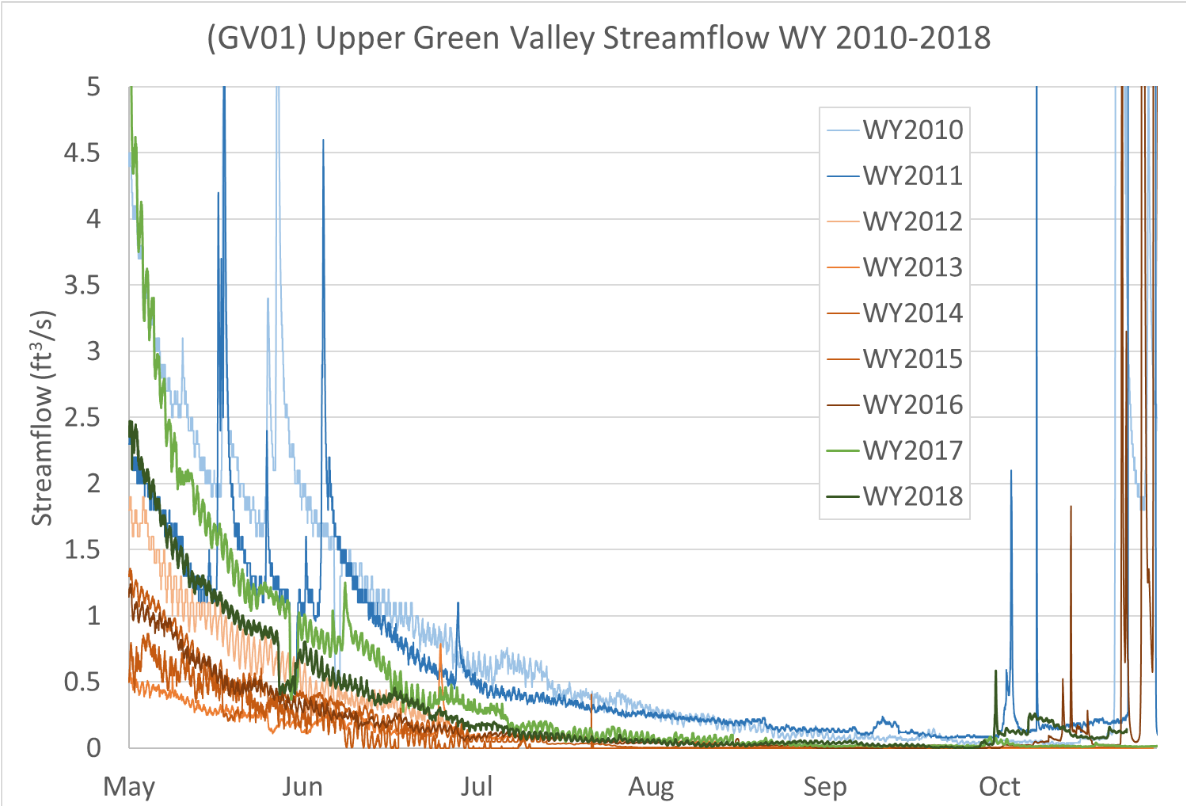

Figure 17. Summer streamflow conditions in Upper Green Valley at gage site GV01, water years 2010 thru 2018, showing streamflow conditions before (in blue), during (in red) and after (in green) the 2012-2016 drought.

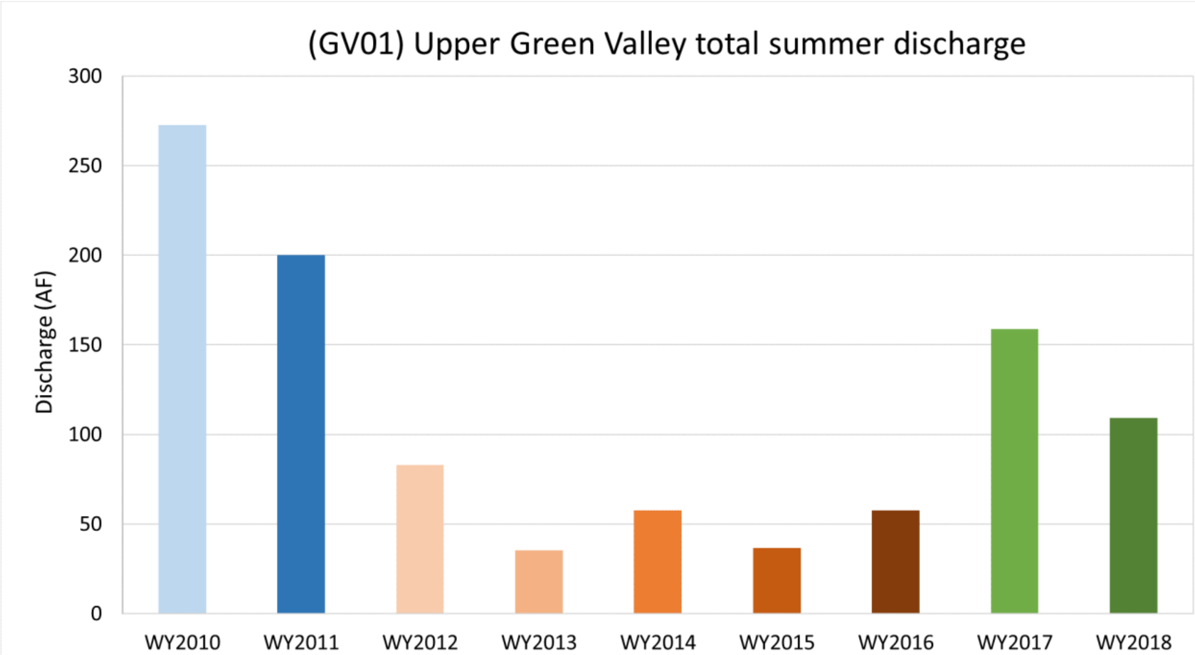

Figure 18. Total summer discharge at gage site GV01, in water years 2010 thru 2018.

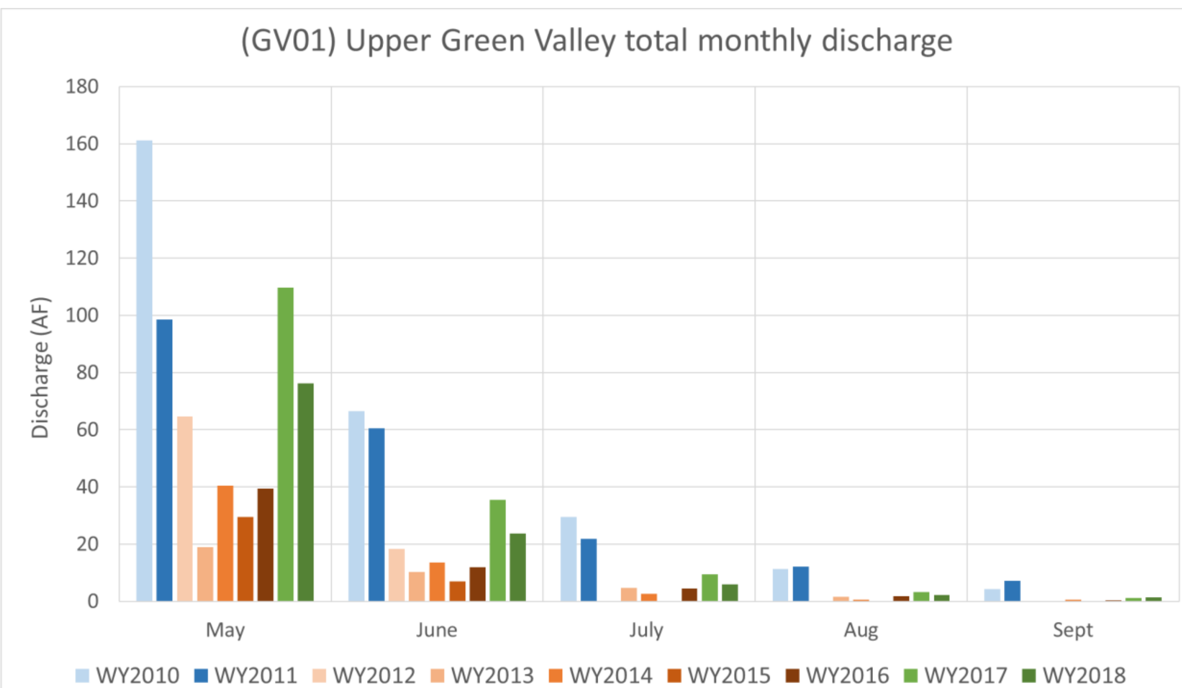

Figure 19. Total monthly discharge at GV01 in water years 2010 thru 2018.

Groundwater

In 2016, O'Connor Environmental, Inc. (OEI) created an integrated surface and groundwater model in the Green Valley/Atascadero and Dutch Bill Creek watersheds to help resource managers better understand flow availability for streamflow enhancement planning. The results of this study estimated that infiltration recharge represented the largest source of groundwater recharge in the Upper Green Valley and Purrington Creek watersheds. Approximately 53% of recharge was estimated to derive from groundwater infiltration, and approximately 47% of recharge was derived from streambed infiltration. Annual infiltration recharged during the study period (2010-2014) varied from 2.0 inches (in 2014) to 10.5 inches (in 2011). In addition, the study found that streambed infiltration varied much less, ranging from 4.8 to 6.4 inches. Groundwater baseflow discharge to streams was the largest source of groundwater outflow from aquifers, ranging from 5.5 to 6.7 inches. Groundwater pumping and groundwater boundary outflows were relatively uniform during the study period and were 1.1 and 0.3 inches per year respectively (O'Connor Environmental Inc. 2016).

In 2017 the Partnership received funding from NFWF's Freshwater Flow Restoration Accounting Fund grant program to monitor groundwater conditions in the Upper Green Valley Creek watershed. For this study, the Partnership drilled three monitoring wells along the reach upstream of Bones Road to continuously monitor groundwater conditions between TU's streamflow gages GV04 and GV01 (Figure 20). In addition, we are taking groundwater elevation measurements at a domestic supply well. This data, coupled with our streamflow records and wetted habitat surveys, will help the Partnership to better understand how groundwater pumping in Upper Green Valley Creek might be influencing surface water conditions and the timing of pool disconnection.

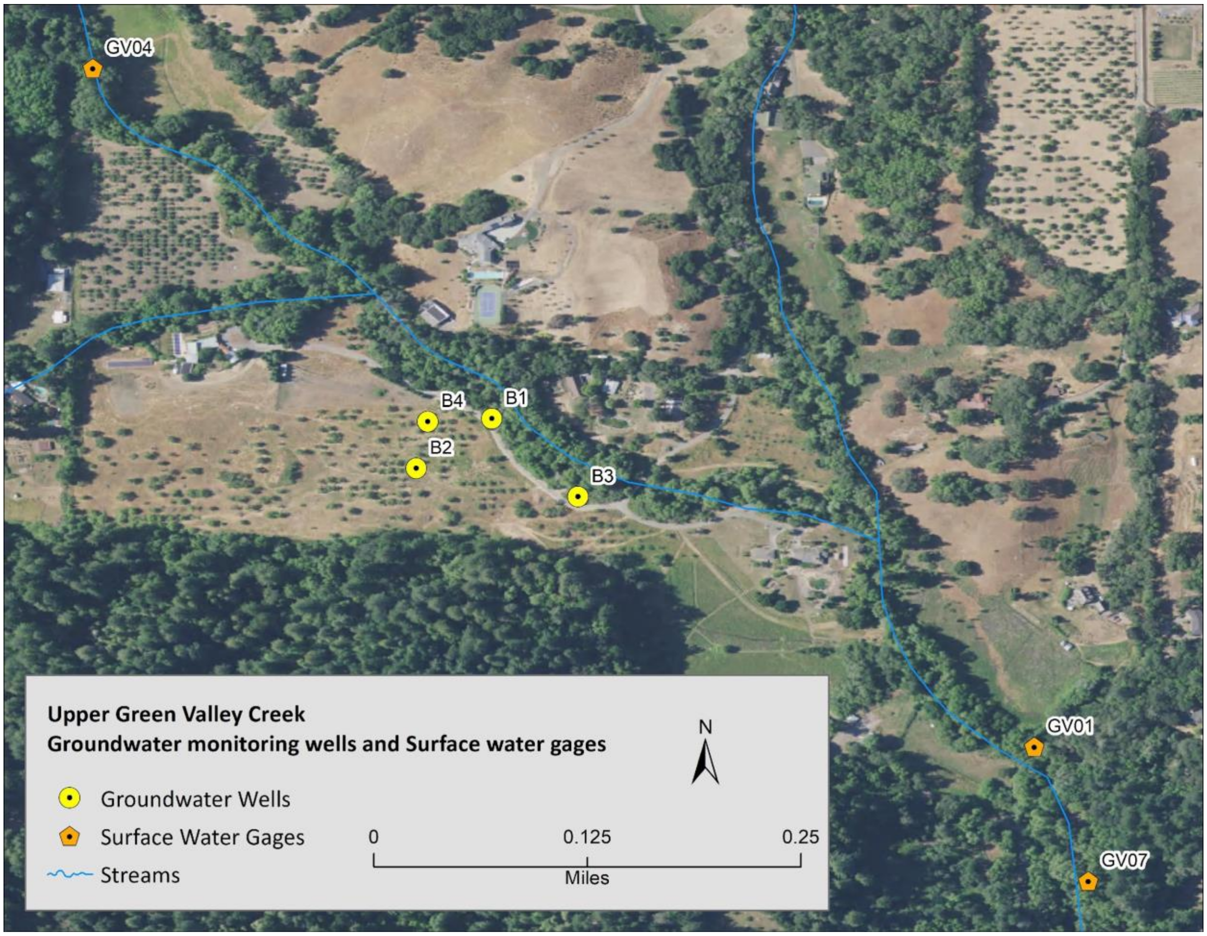

Figure 20. Upper Green Valley groundwater monitoring well and surface water gage locations.

2.4 Summary

The gage data collected from the five gages in the Upper Green Valley Creek watershed over the past nine years reflect a dry period in the systems' rainfall record and shows a flow impaired system. Streamflow conditions at all gage sites follow seasonal trends that are characteristic of a Mediterranean climate stream: winter conditions are heightened by rainfall events and, as rainfall decreases through the spring and early summer, streamflow conditions gradually decrease; in some water years reaches have disconnected pools for a significant portion of the dry season.

Streamflow data also capture the measurable impact of an instream diversion on streamflow conditions during the dry season. Gage data from GV01, GV04, GV07 and Gv08 show how a drop in streamflow conditions above the upper gage site (Gv04) propagates downstream and is detected at all downstream gage sites (Gv04, GV07 and GV08). Gage data from GV02 show that the direct diversion causes streamflow conditions to drop by as much as 0.4 ft^3/s. Lastly, groundwater pumping from shallow wells adjacent to the creek likely have a significant impact on summer baseflow conditions, but the impacts of these diversions are difficult to detect in our streamflow gage network. Analysis of our gage network data indicates that groundwater pumping may influence whether a reach is a losing or gaining stream, however additional studies are needed to confirm this hypothesis.

3 Human water use

As described above, human water management practices have a profound impact on summer streamflow conditions in the Upper Green Valley Creek watershed. Identifying and quantifying human water use allow us to gain a better understanding of where and when demand is greatest, so that we can identify opportunities for streamflow enhancement projects. As we describe below in Section 4, in small coastal watersheds such as Upper Green Valley Creek, diversion of relatively small amounts of water can negatively impact habitat conditions. Upper Green Valley Creek, for example, maintains pool connectivity with a small volume of water, approximately 0.2 ft^3/s. Therefore, developing streamflow enhancement projects — guided by a temporal and spatial analysis of both human water use and discharge in the watershed — could have a significant effect on dry season surface water conditions.

This section includes a hydrologic evaluation that compares rainfall, discharge and human water use on annual and seasonal scales to determine if there is enough water available in the watershed to meet human water need and to inform potential changes to water management practices to benefit salmonids.

3.1 Rainfall and discharge

Rainfall and discharge define the watershed's water availability for a year, season or period. Rainfall in the Upper Green Valley Creek watershed represents the total volume of water entering the system. As described the watershed conditions section of this report, the Upper Green Valley Creek watershed receives a considerable amount of rainfall in an average year, approximately 41.5 inches. This results in a total of approximately 22,683 acre-feet (AF) of water falling in the Upper Green Valley Creek watershed in an average year. To estimate average discharge in the Upper Green Valley Creek watershed, we modeled discharge using a simple drainage basin area-ratio transfer based on historical streamflow records measured at two nearby streamflow gages. Data from the USGS gage on Austin Creek (USGS Station 11467200, Austin Creek near Cazadero, CA) directed the discharge estimates calculated for Upper Green Valley Creek.

The scaling method entails multiplying discharge recorded at the USGS gage according to the ratio of catchment area and then by a ratio of average annual rainfall (based on PRISM data) in the Upper Green Valley Creek watershed to average annual rainfall above the USGS gage:

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

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 $Q_{gaged\ wshd}$, $Area_{gaged\ wshd}$, and $Annual\ ppt_{gaged\ wshd}$ refer to discharge, upstream watershed area, and average annual precipitation upstream of a historically gaged watershed (i.e., Austin Creek). This equation appears in Appendix B of the State 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 permit a new water right (SWRCB 2014). Further, an evaluation by the USGS (Mann et al. 2004) found that the basin area-ratio transfer method generally performed better than rainfall-based methods of estimating streamflow in this region. We calculated the discharge value for Upper Green Valley Creek modeled from Austin Creek for this report. The resulting streamflow information is summarized in Table 1.

Table 1. Basin hydrology characteristics Austin Creek and Upper Green Valley Creek.

Stream	Watershed area, acres	Average annual rainfall, inches	Average annual rainfall volume, ac-ft	Average annual discharge volume, ac-ft
Austin	40,384	54	181,700	118,007 (measured, 1960-2013)
Green Valley	24,333	41.5	84,152	54,645 (estimated)
Upper Green Valley	6,560	41.5	22,683	14,732 (estimated)

3.2 Human water use

Human water use describes the amount of water needed for human uses over a defined period of time (Deitch et al. 2009). For this study, we look at human water use for a one water year period (October 1 thru September 30) and on a seasonal scale (from May thru September). We assessed human water consumption using remote sensing techniques and used these values to determine if human water uses can be met from local sources on an annual, seasonal and monthly scale. TU staff digitized human land-uses in the Upper Green Valley Creek watershed using ArcGIS software and National Agriculture Imagery Program (NAIP) imagery from 2018 (Figure 2).

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

Agricultural. We digitized agricultural coverage to estimate the total acreage of vineyards, orchards, and other crops in the watershed and then calculated total agricultural water need based on regional per-area estimates of water use. Vineyard irrigation in coastal Northern California may require between 0.2 and 0.6 AF 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. Orchards in Northern California use water at rates estimated between 1.42 and 3.44 AF of water per acre annually (Lewis et al. 2008). In conversations with GRRCD, we learned that much of the orchard area in the Upper Green Valley watershed is dry-farmed, so the low-end estimate was applied to this watershed. Sports fields and turf were assigned rates based on the time of year, ranging from 1.9 to 5 AF per acre annually, and this was verified by comparison to known water use of a turf irrigator in the watershed (Hanak and Davis 2006). Other row crops were not distinguished by type and assigned regional estimates of water use totaling 2.2 AF per acre annually. All irrigation of vineyards, orchards, and marijuana was assumed to take place during the 152 days considered summer months for this report.

Industrial (wineries). We used area maps and wine industry documents to locate the one wine-producing structure in the watershed and estimate wine production water use in terms of gallons of water per gallon of wine. Winery water use is a function of production. University of California Davis researchers estimate that, on average, 6 gallons of water are used to make 1 gallon of wine, and wine production was estimated based on winery reports.

Residential. Residential water use is variable in coastal California. Based on CEMAR's review of residential water use data in coastal northern California (CEMAR 2014), we estimated rural residential water use at an average of 255 gallons of water per day per house, with variability between summer and winter use. This rate was applied to the number of households within the watershed to estimate the annual water need for residences, and thus includes consideration of greater water needs in the summer for landscaping purposes.

Camps/Conference Centers. In the Upper Green Valley watershed there is one large camp and conference center, Mt. Gilead Bible Conference Center. We have monthly and annual water use reports for the center for the years 2012 - 2016 and the average of these reports was used in estimating water demand for any given year.

Marijuana. Outdoor marijuana grows were identified using digital imagery. Each visible plant was counted, and water use was estimated based on a use rate of 6 gallons per plant per day from May through September (based on numbers described by Bauer et al. 2015).

3.2.1 Human water use results

Human water need for the Upper Green Valley Creek watershed was estimated based on the water-use rate factors described above (Table 2). We counted 640 rural residences in the watershed. The total amount of water needed for these residences is approximately 170 AF per year. The sole winery located within the sub-watershed uses approximately 0.7 AF annually based on the individual winery's estimates (listed on the company's website). The watershed has approximately 666 acres of vineyards, requiring 133 AF of water annually; 258 acres of orchards which require 366 AF of water; and 9 acres of other crops types, requiring 24 AF of water annually for irrigation. Lastly, we digitized 41 outdoor marijuana plants in the Upper Green Valley watershed which require approximately 0.1 AF of water annually. Figure 21 shows the total water use by category in the Upper Green Valley Creek watershed, on an annual and summer scale.

Table 2. Land use and total water use in the Upper Green Valley Creek watershed.

	Residences	Commercial Buildings	Conference Center/ Camps	Wineries	Vineyards	Orchards	Other Crops	Marijuana	Total water use (AF)
Land use quantities (number, and area in acres)	640	13	1	1	666	258	9	41	
Summer water use (AF)	106	2.2	10.5	0.3	133	366	10	0.1	628
Total water use (AF)	170	3.5	15.1	0.7	133	366	24	0.1	713

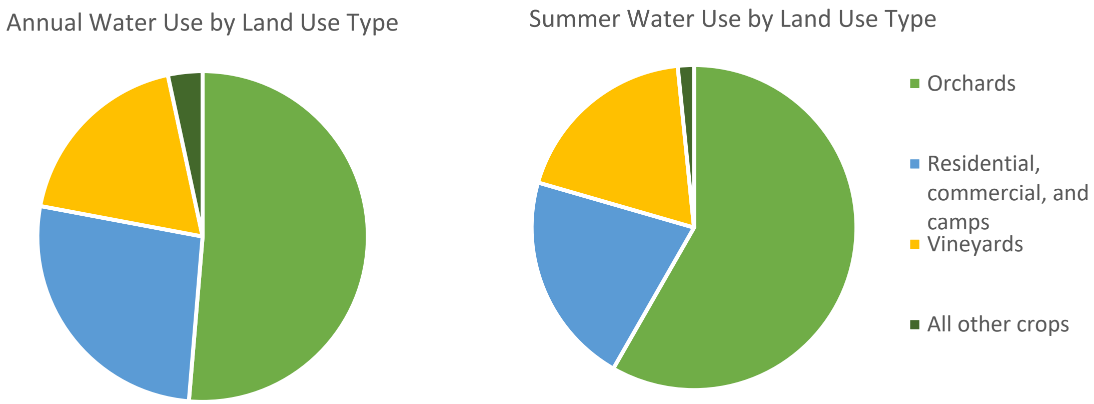

Figure 21. Total and summer water use by category in the Upper Green Valley Creek watershed.

3.2.2 Comparing human water use to water available in Upper Green Valley Creek

Comparing the human water needs in the Upper Green Valley Creek watershed to the average annual rainfall and discharge provides an initial assessment of whether these needs can be met through the water resources available, on an annual scale. Our analysis indicates that demand comprises a small fraction (approximately 5%) of the total discharge available during an average year (Figure 22).

Comparing human water use on a seasonal and monthly scale, however, shows that summer water use is significantly higher than total summer discharge in Upper Green Valley Creek (Figure 23). During the study period, human summer water use was consistently higher than summer discharge: years 2012 through 2018 all show human water use at more than double the volume of discharge for the season. 2013 and 2015 represent the most extreme of this case, with a more than 560 AF difference between human summer use and summer discharge. On a monthly scale human water use was significantly more than total monthly discharge in all study years in summer months July thru September (Figure 24). This comparison gives us a look into the importance of not only scale but also timing concerning water availability within the Upper Green Valley Creek watershed.

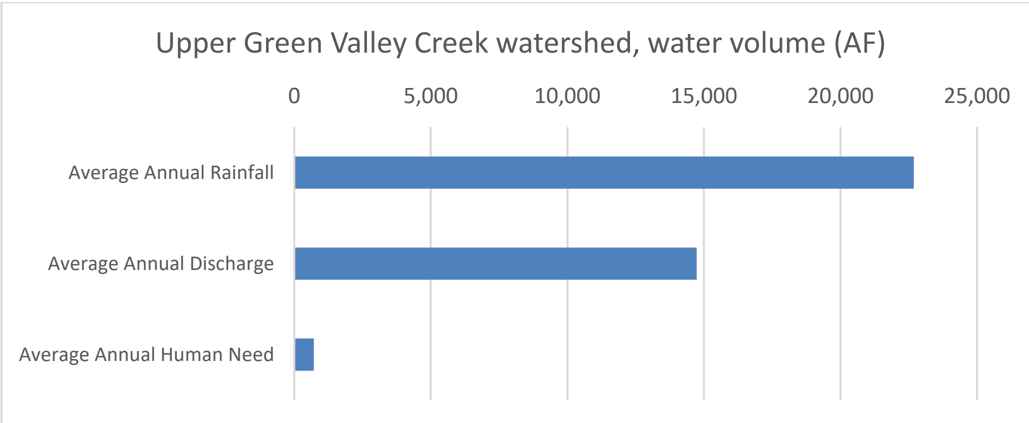

Figure 22. Comparison of average annual rainfall, streamflow, and human water need in the Upper Green Valley Creek watershed; from TU streamflow monitoring, PRISM data, and land use digitization.

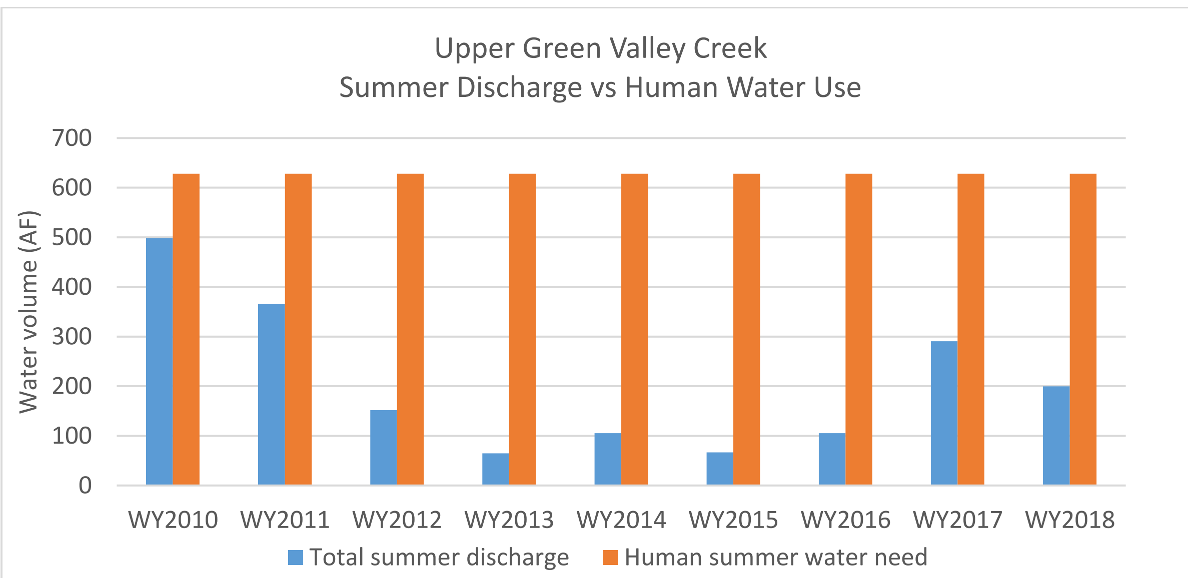

Figure 23. Comparison of total summer discharge in Upper Green Valley Creek watershed and human water use.

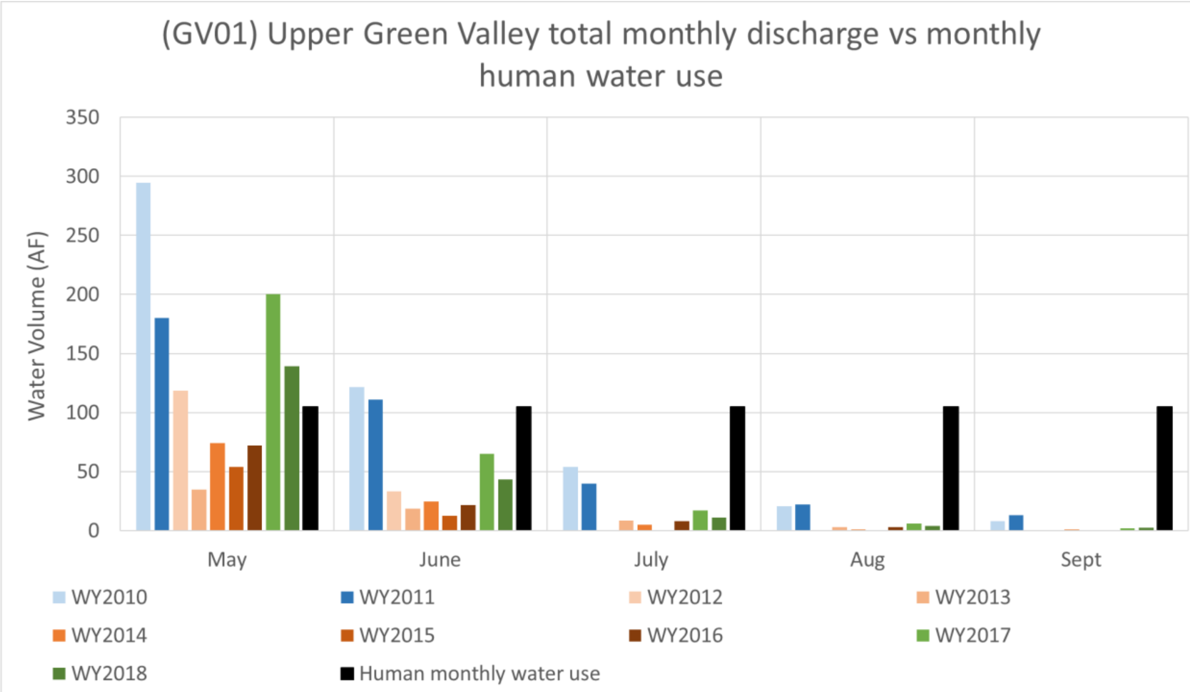

Figure 24. Comparison of total monthly discharge in Upper Green Valley Creek watershed and monthly human water use (in black).

3.3 Water rights in the Upper Green Valley Creek watershed

Water right records provide another window into scale, spatial distribution and type of human water uses across the Upper Green Valley Creek watershed, as well the methods and basis of right used to obtain and manage water across the landscape.

3.3.1 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 each user is required to submit a Statement 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 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. 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 put 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; and registration holders are required to file registrant reports annually.

3.3.2 Water rights in the Upper Green Valley Creek watershed

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 Upper Green Valley Creek watershed, as of July 2019, eWRIMS lists 29 water rights in total: nine appropriative rights, two small domestic use registrations, and 18 riparian claims (Figure 25). Analysis of eWRIMS data shows most riparian direct diversions in the watershed are located on Purrington Creek.

Water right reporting may not be the most accurate way to estimate water need in the Upper Green Valley Creek watershed, as it may under-represent the number of diversions or over estimate the total demand of some water right holders. The eWRIMS database does not capture uses for which a permit or license is not required (e.g., diversions from springs that meet certain criteria or pumping percolating groundwater), riparian or pre-1914 water rights if the water user has not submitted a Statement of Water Diversion and Use, 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.

3.3.3 Fully appropriated status

It is also worth noting that Green Valley Creek (from its confluence with the Russian River upstream) and Atascadero Creek (from its confluence with Green Valley Creek upstream) are fully appropriated from June 15 through October 31.[2] As such, the Water Board will not accept any new permits to appropriate

[2] State of California, State Water Resources Control Board, Exhibit A, Water Right Order 98-08, Declaration of Fully Appropriated Stream Systems, November 19, 1998.

water from those reaches (Water Code Sec. 1206(b)) and upstream sources which contribute to those reaches during that time period.[3]

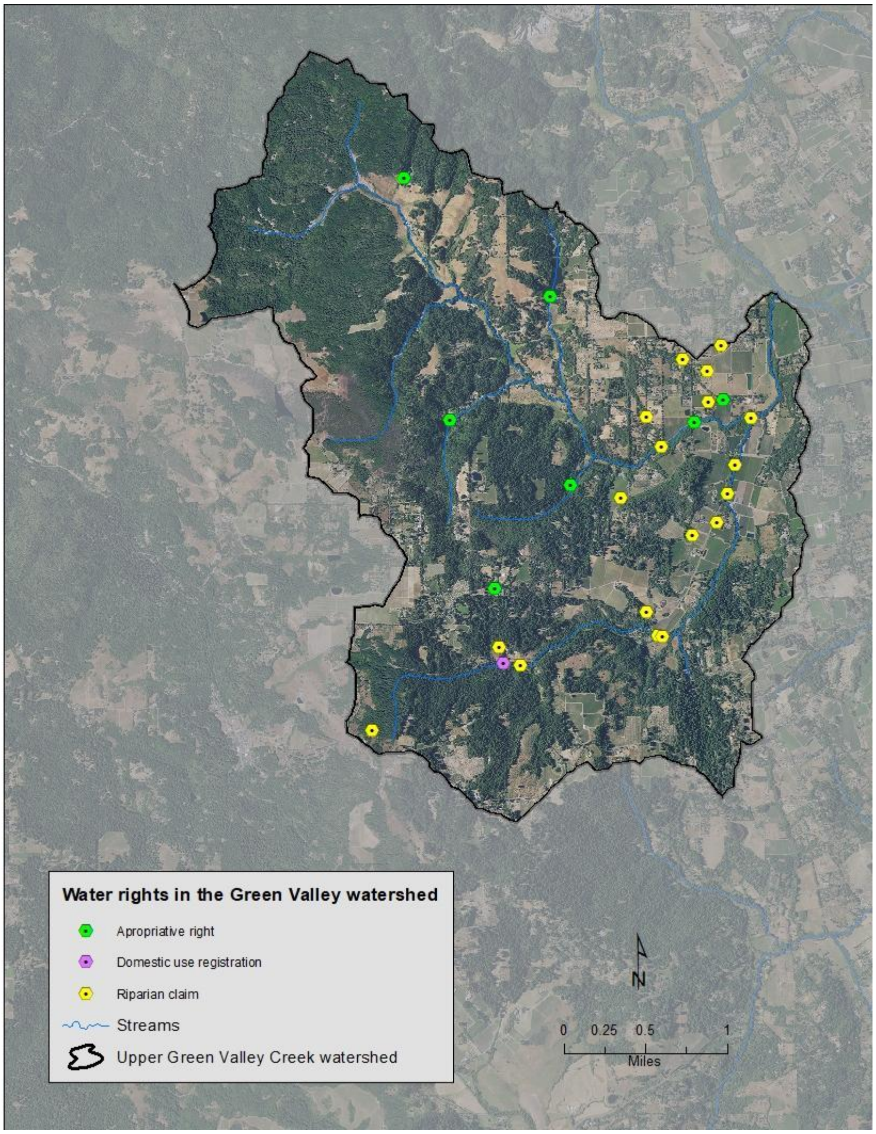

Figure 25. Locations and types of water rights in the Upper Green Valley Creek watershed in eWRIMS as of July 2019.

[3] "As described in Order 89-25 and subsequent orders, any declaration that a stream system is fully appropriated encompasses all upstream sources which contribute to the stream system if, and to the extent that, such upstream sources are hydraulically continuous to the stream system." https://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/

3.4 Summary

The human water use and water right datasets provides important insights into the complexities of water management in the Upper Green Valley Creek watershed. The watershed receives, as rainfall, approximately 30 times the total amount of water that we estimate people need for residential, institutional, and agricultural uses in the watershed. We estimate that average annual discharge is approximately 20 times the total human water need. In a dry year (i.e., a year with rainfall that is exceeded by 90% of all years), when rainfall is approximately half of the average, rainfall would still greatly exceed the amount of water needed for all of the known human uses in the Upper Green Valley Creek watershed. These results indicate that there is ample water in the Upper Green Valley Creek watershed *on an annual scale* to meet human and environmental needs, even in a dry-type year.

Despite this abundance of water, the seasonality of its availability is the greatest challenge associated with ecologically-sustainable water management. Our streamflow data corroborate this idea; many small diversions from the Upper Green Valley Creek drainage network and adjacent shallow aquifers can cumulatively reduce streamflow during the dry season. The data suggest that streamflow enhancement projects that reduce demand and/or modify the timing of diversion from summer to winter can lead to increased summer baseflow if water users are willing to store water in the wet season and use that stored water to reduce or replace water diverted in the dry season. Such projects should be conditioned to maintain environmental flows in winter and may provide additional water security for human use. Given the changes in rainfall patterns predicted in coming decades, such projects will be critical for maintaining reliable water supplies for human water needs and for maintaining ecological processes in the Upper Green Valley Creek watershed. We return to these strategies in Section 5.

4 Salmonids and flow-related habitat impacts

This section includes a brief overview of the history of salmonids in the Russian River basin, historical and recent presence within the Green Valley Creek watershed, and impacts of insufficient streamflow on fish and their habitat. More detailed information can be found at https://caseagrant.ucsd.edu/GV_SIP_FishAndHabitat.

4.1 Historical salmonid presence

The Russian River watershed historically supported native runs of anadromous coho salmon (*Oncorhynchus kisutch*) and pink salmon (*O. gorbuscha*), as well as steelhead trout (*O. mykiss*) (Steiner 1996). It is unknown whether Chinook salmon (*O. tshawytscha*) were present in the Russian River prior to the first release of hatchery fish in 1881 (Chase et al. 2007), but a self-sustaining population exists today.[4] Russian River coho salmon populations were once abundant 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).

The CCC Evolutionarily Significant Unit (ESU) of coho salmon — which extends from Punta Gorda in southern coastal Humboldt County south to Aptos Creek in Santa Cruz County, and includes the Russian River population — was estimated to have numbered in the tens of thousands as recently as the early 20th century (Steiner 1996), and the Russian River had the largest coho salmon population within this ESU (NMFS 2012). All native salmonid populations in the Russian River watershed experienced steep declines for more than a century, with records of significant decreases stemming back to the 1880s (Steiner 1996). Pink salmon are now extirpated from the watershed, coho salmon are listed as endangered under the state and federal Endangered Species Acts (ESA), and Chinook salmon and steelhead are listed as threatened under the federal ESA.

By the time coho salmon became the focus of resource agencies in the mid-1990s, the Russian River population had dwindled to the point of near-collapse. The number of coho salmon smolts migrating to the ocean from the Russian River system is estimated to have declined by 85% between 1975 and 1991 (NMFS 2012).

Coho salmon were observed in Green Valley Creek during intermittent surveys in multiple years prior to 2000 (CDFW 2000a, CDFW 2000b, CDFW 2000c). Historical coho presence was also confirmed in Purrington Creek (CDFW 2000c). Extensive surveys by CDFW in the early 2000s found coho salmon to be present in extremely low numbers in only five of 39 confirmed[5] historical coho streams within the basin.

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[4] http://www.Water Agency.ca.gov/chinook/

[5] Number of streams with coho "presence confirmed" or "high likelihood of presence," as defined in Spence et al. (2005). Another 11 streams were deemed as having "equivocal" or "unsupported evidence of presence."

Among those, Green Valley Creek was the only stream with three consecutive year classes (Conrad 2005, Spence et al. 2005), which highlights the ecological and genetic importance of Green Valley Creek as a stronghold for Russian River coho salmon.

More comprehensive coho salmon monitoring efforts began in Green Valley Creek in 2001, with a focus on the higher-quality spawning and rearing habitat upstream of the confluence with Atascadero Creek. Coho salmon were documented in Green Valley Creek each year from 2001 through 2004, though by 2004 fewer than 10 individuals were observed (Conrad 2005, Conrad et al. 2005). The last wild coho salmon documented in the Green Valley Creek watershed, prior to population supplementation by the Coho Salmon Captive Broodstock Program in 2006, were from the 2004 hatch year (Conrad et al. 2005, Obedzinski et al. 2006).

Steelhead have been observed in Green Valley Creek and all of its major tributaries (Atascadero, Purrington, and Harrison creeks) in all years where records exist (CDFW 2000a, CDFW 2000b, CDFW 2000c, CA Sea Grant unpublished data).

4.2 Coho Salmon Captive Broodstock Program

In the late 1990s, in response to the decline of Russian River salmonid populations, private landowners, organizations, and agencies engaged in efforts to conserve and enhance critical salmonid habitat within the Russian River watershed, but that effort in itself was not enough to prevent further declines. In 2001, with Russian River coho salmon populations on the brink of extinction, a collaborative effort was formed to restore self-sustaining runs of coho salmon within the watershed using a conservation hatchery approach. The Russian River Coho Salmon Captive Broodstock Program (Coho Program) was formed, representing a broad partnership between CDFW, NMFS, U.S. Army Corps of Engineers (ACOE), Sonoma Water, CSG, and hundreds of private landowners. Coho Program partners carefully capture wild juvenile coho from Russian River tributaries and Olema Creek, rear them to adulthood at the Don Clausen Fish Hatchery at Warm Springs Dam, spawn them according to a matrix that maximizes genetic diversity, release the juvenile offspring into selected tributary streams, and monitor their growth and survival through all life stages. This cycle is repeated annually.

Between 2001 and 2005, Coho Program partners captured the first coho salmon broodstock from remnant wild populations in a total of five Russian River tributaries, but only two streams had more than a small handful of coho young-of-year, Dutch Bill and Green Valley creeks (CDFW and ACOE 2017). A total of 739 juvenile coho salmon were captured in Green Valley Creek, which equated to 85% of all broodstock collected from Russian River tributaries for the Coho Program during that time period (Conrad 2005, Conrad et al. 2005, CDFW and ACOE 2017). The Coho Program began releasing the offspring of these broodstock fish as juveniles into designated streams in October 2004 (Conrad 2005, CDFW and ACOE 2017).

Without the remnant populations that persisted in Green Valley Creek into the early 2000s, there would not have been a sufficient source of native broodstock to support the Coho Program effort and, given the fact that coho numbers were well below the depensation threshold at that time, Russian River coho salmon likely would have become extinct.

Juvenile coho salmon were released into Green Valley Creek in 2006, after no wild fish were observed there in 2005, and it has been stocked each year since (CDFW and ACOE 2017, Ben White, ACOE, unpublished data). A total of 182,468 juvenile coho salmon from the Coho Program were planted into Green Valley Creek between 2006 and 2018 (Ben White, ACOE, unpublished data). An additional 21,285 fish were planted in Purrington Creek from 2010 to 2017, and 3,041 fish were planted into Redwood Creek in 2017, for a total of more than 200,000 for all streams in the watershed through the spring of 2018 (Ben White, ACOE, unpublished data).

4.3 Programmatic salmon and steelhead monitoring

CSG's Russian River Salmon and Steelhead Monitoring Program conducts ongoing monitoring of salmonid populations in several tributaries to the Russian River, including Green Valley Creek, Purrington Creek, and three small tributaries to Green Valley Creek (Figure 26). Coho and steelhead populations within the watershed are monitored year-round using a combination of methods in order to track fish at different life stages. Snorkeling surveys are conducted during the summer months to document the presence and relative abundance of wild juveniles, a smolt trap is operated on the mainstem of Green Valley Creek during the spring season to estimate coho smolt outmigration, and spawner surveys are conducted throughout the winter months to document adult salmon and steelhead returns. Snorkeling and spawner sampling efforts are focused on the reaches with relatively high-quality fish habitat upstream of the Atascadero Creek confluence (Figure 26). In addition, since 2014, CSG biologists have maintained a paired, flat-plate Passive Integrated Transponder (PIT) tag antenna array approximately six kilometers upstream of the mouth of Green Valley Creek to track the movement and survival of PIT-tagged program coho (furthest downstream antenna, Figure 26). Additional year-round antennas have been operated in the middle reach upstream of Atascadero Creek and in Upper Green Valley Creek below Harrison Creek since 2014 and 2010, respectively (Figure 26). Monitoring data have been used to generate estimates of natural production (juvenile presence and relative abundance), smolt abundance and freshwater survival, and number of returning adults.

After the 2004 broodstock collection, naturally-spawned coho yoy were not observed in Green Valley Creek until 2010 — four years after the Coho Program began planting fish there (Table 3). Since that time, the count of wild coho salmon yoy in Green Valley Creek has ranged from 13 to 4,487, and lower numbers of coho have also been observed in sampled tributaries (Table 3; see caption for count methods). Steelhead were observed in Green Valley Creek, and all tributary streams snorkeled within the watershed, each year but standardized count data were not collected until 2013 (Table 4). Steelhead observations in Green Valley Creek from 2013 through 2018 ranged from 786 to 2,086 fish (Table 4; see caption for count methods).

The estimated number of coho smolts emigrating from Green Valley Creek in the seven years that smolt trapping occurred between 2007 and 2018 ranged from 1,397 (1,153-1,641) to 23,438 (21,200-25,676). Overwinter survival probabilities of fall-released juveniles to the smolt stage in Green Valley Creek have ranged from 0.23 (0.13-0.35) to 0.52 (0.50-0.55), similar to rates observed in neighboring wild populations in Marin County (Reichmuth et al. 2006, Carlisle et al. 2008). Smolt estimates are not available for steelhead because steelhead smolts generally migrate from the stream during the winter before traps can be safely installed.

In general, coho smolts that overwinter in Green Valley Creek are notably larger at outmigration than those observed in other life cycle monitoring streams within the Russian River watershed. In 2015-2018, Green Valley Creek smolts were more than 10% greater in fork length, on average, than those that passed through the Willow Creek, Dutch Bill Creek and Mill Creek traps. Higher growth opportunity from winter through early spring in Green Valley Creek may play an important role in recovering robust salmon populations, as survival of salmonids to the adult stage is positively correlated with smolt size (Hayes et al. 2008, Bennett et al. 2015).

The number of adult coho salmon returning to Green Valley Creek has generally increased over the past ten years, peaking at an estimated 162 fish in the winter of 2017/18 (Figure 27). The distribution of salmon and steelhead redds show that coho spawning has been primarily concentrated in the uppermost reaches of Green Valley Creek between Little Green Valley and Harrison creeks, while steelhead spawning is generally evenly distributed throughout the sample reaches (Figure 28). Spawning occurs at much lower densities in Purrington Creek, with coho spawning concentrated in the downstream reaches and steelhead spawning concentrated in the higher gradient reaches further upstream (Figure 28).

Increasing returns of spawning salmon to Green Valley Creek is reflective of the larger Russian River watershed trend. After nearly two decades of concerted action by stakeholders — including the Coho Program, and coordinated habitat restoration and conservation efforts — the number of coho salmon adults returning to the Russian River basin has increased since 2000. Estimated returns each winter since 2010 have ranged from 192 to 763 fish, with the greatest numbers in 2017/18.

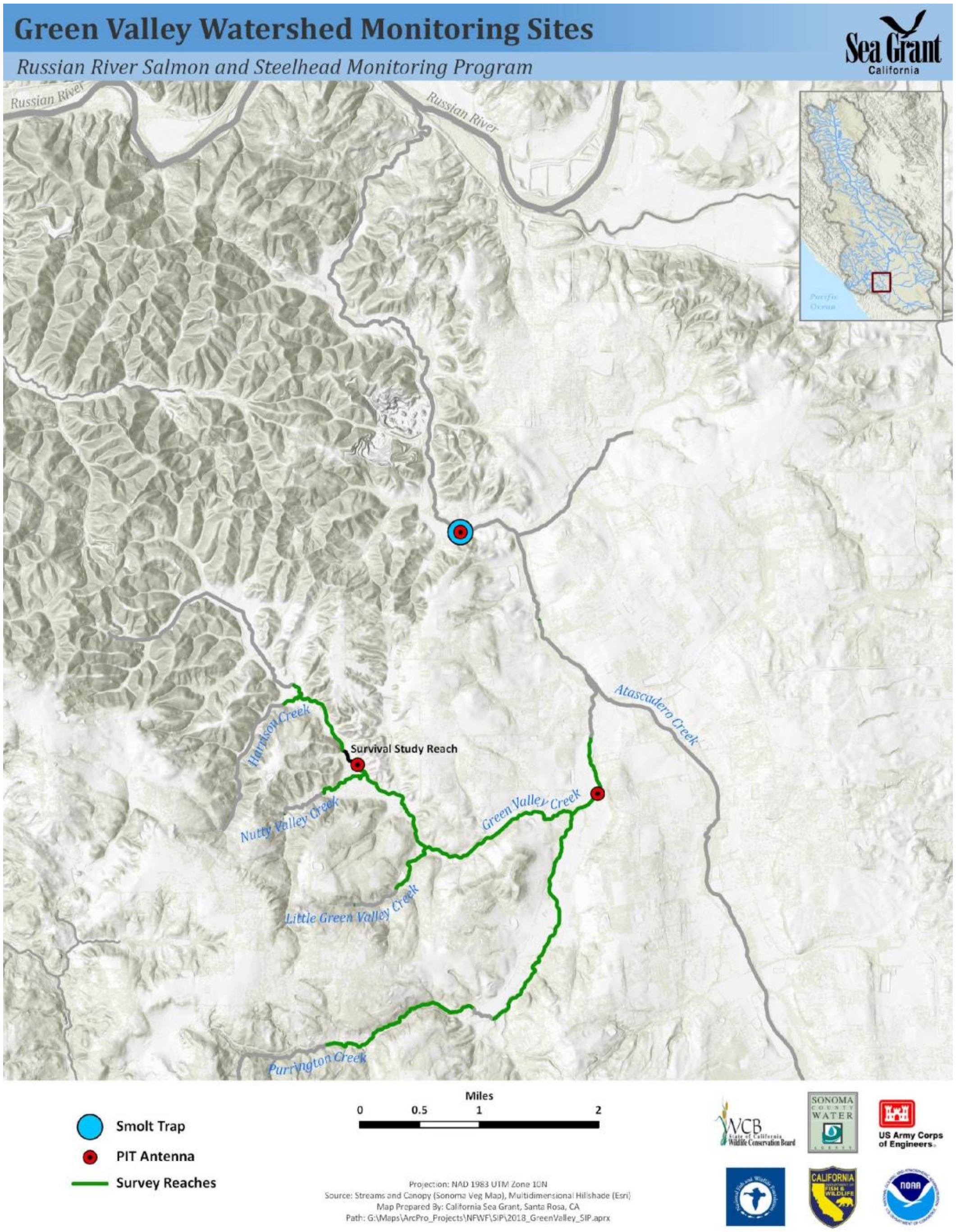

Figure 26. CSG's stationary fish monitoring sites and current survey reaches in the Green Valley Creek watershed. Includes year-round PIT tag antenna arrays and the downstream migrant smolt trap operated each spring. Survey reaches, shown in green, receive routine biological and environmental sampling.

Table 3. Wild coho salmon yoy observed during CSG and Sonoma Water presence/absence snorkel surveys in the Green Valley Creek watershed. Methods and extent of stream sampled varied between years. Prior to 2013, every pool within a reach was snorkeled and numbers represent total number of observations. Beginning in 2013, every second pool was snorkeled and numbers were doubled to generate an expanded count.

Year	Green Valley	Purrington	Little Green Valley	Nutty Valley	Harrison
2005	0	n/a	n/a	n/a	n/a
2006	0	n/a	n/a	n/a	n/a
2007	0	n/a	n/a	n/a	n/a
2008	0	n/a	n/a	n/a	n/a
2009	0	n/a	n/a	n/a	n/a
2010	170	0	n/a	n/a	n/a
2011	1,483	0	n/a	n/a	n/a
2012	1,486	0	n/a	n/a	n/a
2013	4,487 [1]	466	n/a	n/a	n/a
2014	13 [1]	0	n/a	n/a	0
2015	1,975 [1]	280	62	0	0
2016	1,584 [1]	358	16	14	0
2017	3,752	344	102	208	18
2018	1,766	126	24	32	16

[1] Approximately 200 - 500 Coho Program fish were stocked in the spring prior to snorkeling in years 2013 - 2016 (other releases occured after snorkeling was completed). Because hatchery fish could not be distinguished from wild fish in those cases, the number of stocked fish was subtracted from the expanded count, resulting in a conservative estimate of the number of wild juveniles present.

Table 4. Expanded counts of steelhead yoy observed during CSG and Sonoma Water presence/absence snorkel surveys in the Green Valley Creek watershed. Every second pool was snorkeled, and numbers were doubled to generate an expanded count. Though steelhead were observed in all streams sampled each year that surveys were conducted since 2005, count data were not collected in a standardized manner until 2013.

Year	Green Valley	Purrington	Little Green Valley	Nutty Valley	Harrison
2013	786	578	n/a	n/a	n/a
2014	2,262	1,248	n/a	n/a	20
2015	2,086	104	0	0	0
2016	1,544	834	118	0	0
2017	1,446	964	90	2	0
2018	1,504	1,734	26	4	0

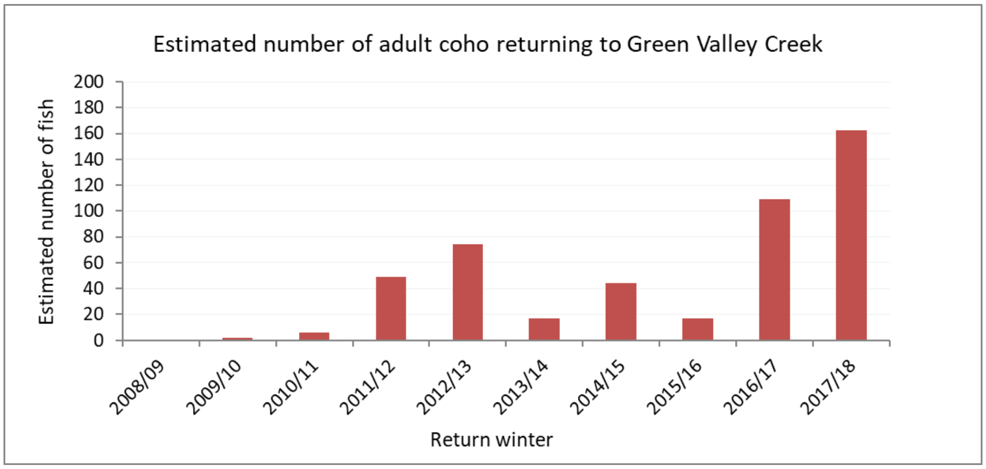

Figure 27. Estimates of adult coho returning to Green Valley Creek each winter. Numbers from 2008/09 and 2010/11 are based on spawner survey observations and the following years are derived from PIT tag antenna data. No adult fish or redds were observed during the 2009/2010 spawner surveys, but a minimum count of two adults was included to account for wild coho young-of-the-year observed in the summer of 2010.

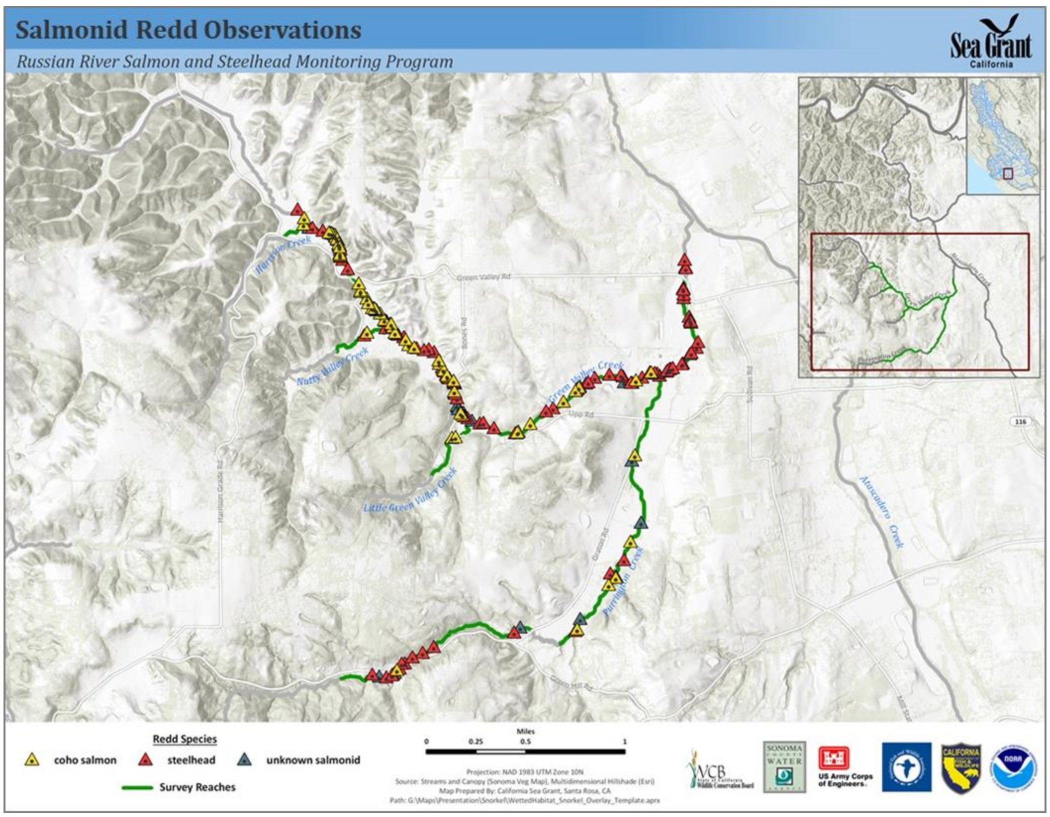

Figure 28. Salmonid redds observed in upper Green Valley Creek, winters 2010/11 through 2017/18, and in Purrington Creek, winters 2013/14 through 2017/18. No redds were observed during the first Green Valley Creek spawner surveys in 2008/09 and 2009/10. The extent of survey reaches varied by year, depending on access to streamside properties.

4.4 Flow-related bottlenecks to survival

Coho salmon need sufficient streamflow in order to complete their life cycle. During the summer season, juveniles need cool, connected pools in which to rear and grow. As one-year-old smolts, they need sufficient flows through late spring to migrate out of Green Valley Creek, down the Russian River and to the ocean. As adults returning from the ocean at age-2 or age-3, they need sufficient flows to allow migration passage upstream into Green Valley Creek to spawn in the winter, and enough water to submerge their redds and move ample flow through the gravel to oxygenate the eggs during incubation until alevin emerge in the spring. Steelhead have similar freshwater habitat needs, though they have a more flexible life history and may migrate to the ocean and back upstream to spawn at various ages and, in some cases, multiple times. They also spawn later than salmon, making steelhead redd success more vulnerable to low spring flows.

In Green Valley Creek and some of its tributary streams, including Little Green Valley and Nutty Valley Creeks, flow limitations have had detrimental impacts on salmonids rearing in the stream over the summer months and, in the driest years, threatened outmigrating smolts. Impacts to juveniles range from mortality caused by stream drying or inadequate water quality, to stress and decreased productivity as a result of sub-optimal habitat. The later may have a negative effect on fish condition and survival through later life stages. Anecdotal evidence suggests that late-spring smolt passage in Green Valley Creek has been limited by stream disconnection in relatively dry years.

The impact of low summer streamflow on salmon has been a subject of investigation by the Partnership in recent years. CSG conducted a study of oversummer survival of juvenile coho salmon in relation to flow and other environmental parameters in a 250-meter reach of Upper Green Valley Creek from 2010 to 2017. Survival was highly variable, ranging from 0.02 to 0.90. The highest fish survival generally occurred in wetter years and the lowest in the driest years. One notable study outcome was the remarkably high survival observed in 2010 (0.90), 2011 (0.88), and 2016 (0.80), despite average daily oversummer flows of just 0.20 ft^3/s, 0.19 ft^3/s, and 0.05 ft^3/s, respectively. These oversummer survival rates were higher than those observed in any study reach on the four streams sampled over that same time period. This provides empirical evidence that salmonids are able to survive at high rates in Green Valley Creek at streamflows of just tenths of a cubic foot per second. In 2015, however, when average daily streamflow fell to 0 ft^3/s, survival was only 0.02. This extreme variability in annual oversummer survival suggests that Green Valley Creek is very sensitive to drought-related environmental changes, making streamflow a critical variable.

This study also documented a positive association between oversummer survival of juvenile coho salmon and streamflow, wetted volume, and DO, and a negative association with water temperature and days of pool disconnection. Of all parameters sampled, days of disconnection — the number of days that pools were disconnected from surface flow — best explained fish survival. Green Valley Creek data were used to generate a model which demonstrates that the probability of fish survival becomes progressively lower as the number of days of disconnection increases (Figure 29). These results highlight the importance of keeping pools connected by surface flow in order to increase the probability of juvenile salmonids surviving the dry summer months.

The CSG study also defined a significant positive relationship between coho salmon survival and DO, which indicates that declines in DO correspond to a decrease in survival probability. Salmonid impairment has been observed at DO concentrations below 4.5 mg/L and mortality has been documented below 3.0 mg/L (McMahon 1983). Over all study years, average reach-scale oversummer DO concentrations below the minimum daily objective of 6.0 mg/L established by the North Coast Regional Water Quality Control Board (NCRWQCB 2015) were associated with survival below 0.50 in the Upper Green Valley Creek study reach (Figure 30). Instream DO is influenced by many biotic and hydrologic variables but is primarily replenished in coho rearing pools in Green Valley Creek through the inflow of agitated surface water (i.e., upstream riffles). The study revealed a negative correlation between days of disconnection and DO concentrations in pools, with DO declining further the longer pools were disconnected (Obedzinski et al. 2018). This evidence suggests that maintaining sufficient streamflow to support suitable DO concentrations — preferably above the regional objective of 6.0 mg/L — through surface water connection and inflow is critical for the survival of juvenile salmonids rearing in Green Valley Creek and its tributaries over the summer months.

As part of an effort to identify flow-impaired reaches of Green Valley Creek, CSG has been conducting standardized wet/dry mapping surveys since 2013 to document the wetted habitat available to fish during the driest point each year. Every September (typically the lowest flows of the year), the condition of the stream channel is characterized as wet, dry, or intermittent (wet pools with no surface flow connecting them). Late-summer wetted habitat conditions in Green Valley Creek are highly variable. The proportion of wet stream channel ranged from just 25% in the driest survey year of 2015 to 86% in 2016, when only 4% of the channel was dry in September (Figure 31; note that years 2015 and 2016 include the effects of flow augmentations). By contrast, late-summer wetted habitat conditions in Purrington Creek are remarkably stable; even in the driest sample year of 2015, 95% of the surveyed stream channel remained wet (Figure 32). It should be noted that there were significant gaps in access to the stream for those surveys (Figure 33). Nonetheless, this information highlights the importance of Purrington Creek as oversummer habitat refuge for fish within the watershed, as well as for flow contributions to the reach of Green Valley Creek downstream of the confluence.

In order to understand the impact of streamflow conditions on rearing coho salmon and steelhead, wetted habitat data were overlaid with juvenile count data for each survey year to estimate the proportion of fish that were observed in locations that remained wet through the summer, versus those that dried out or became intermittent. The numbers and locations of coho and steelhead yoy observed rearing in Green Valley Creek during June snorkeling surveys were mapped in relation to wetted habitat conditions from the same September. The outcome illustrates that the vast majority of fish experienced stream drying or disconnection (intermittency) in the driest sample year of 2015 (Figure 33). The proportion of salmon and steelhead observed in reaches that remained wet throughout the summer varied significantly between 2013 and 2017, ranging from just 16% in 2015 to 87% in 2016 (Figure 34; note that flow augmentations occurred prior to wetted habitat surveys in 2015 and 2016). In three of the five sample years, approximately half or more of the fish counted in Green Valley Creek were observed in locations that went completely dry or became intermittent (Figure 34). During the drought years of 2013 to 2015, intermittency occurred early in the summer season, so it is likely that there were high fish mortality rates in intermittent pools. This indicates that insufficient summer streamflow is a significant limiting factor to rearing juvenile salmonids in Green Valley Creek and may be acting as a bottleneck in drought years.

Not surprisingly, given the consistently high proportion of late-summer available wetted habitat, Purrington Creek provided critical refuge for juvenile salmon and steelhead rearing in the stream in all sample years. Even in the driest survey year of 2015, a full 98% of salmonid yoy observed during early summer snorkel surveys were in reaches that remained wet through the end of the dry season, and in every other survey year between 2013 and 2017, 100% of the fish counted during snorkel surveys were in locations with perennial surface flow (Figure 35). This reinforces the importance of Purrington Creek for oversummer refuge for rearing fish.

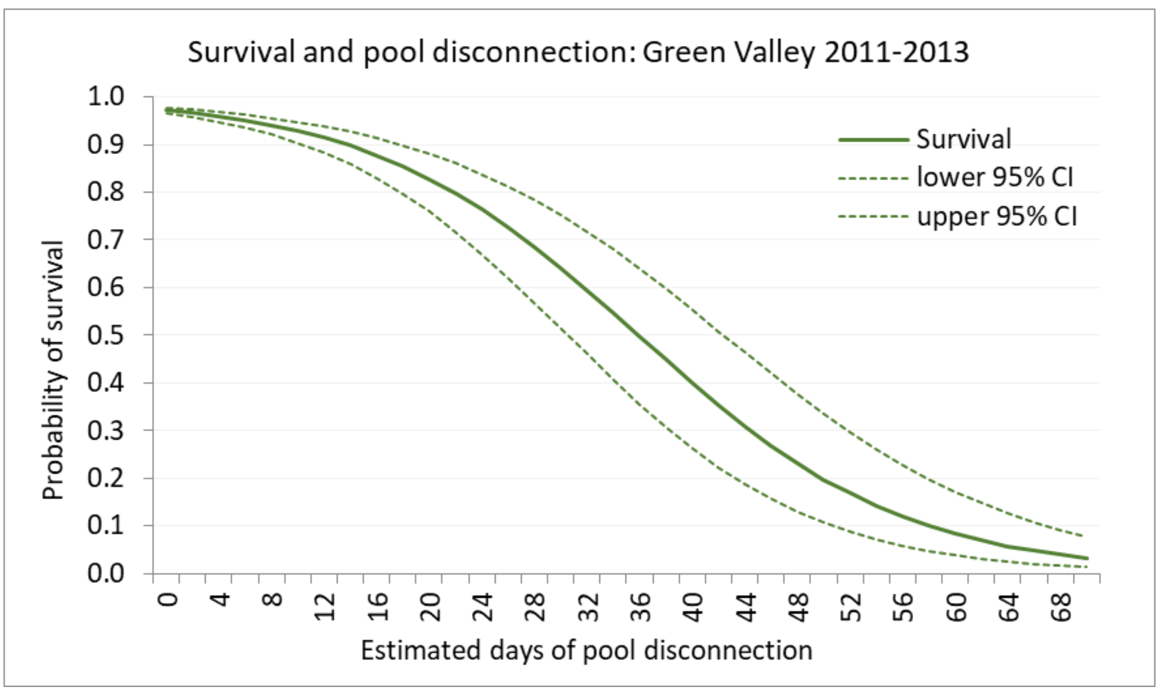

Figure 29. Predictive model showing the negative relationship between the probability of juvenile coho salmon survival and days of pool disconnection in the Green Valley Creek study reach, years 2011-2013. Disconnection was assumed on days where average daily streamflow was lower than 0.01 ft^3/s.

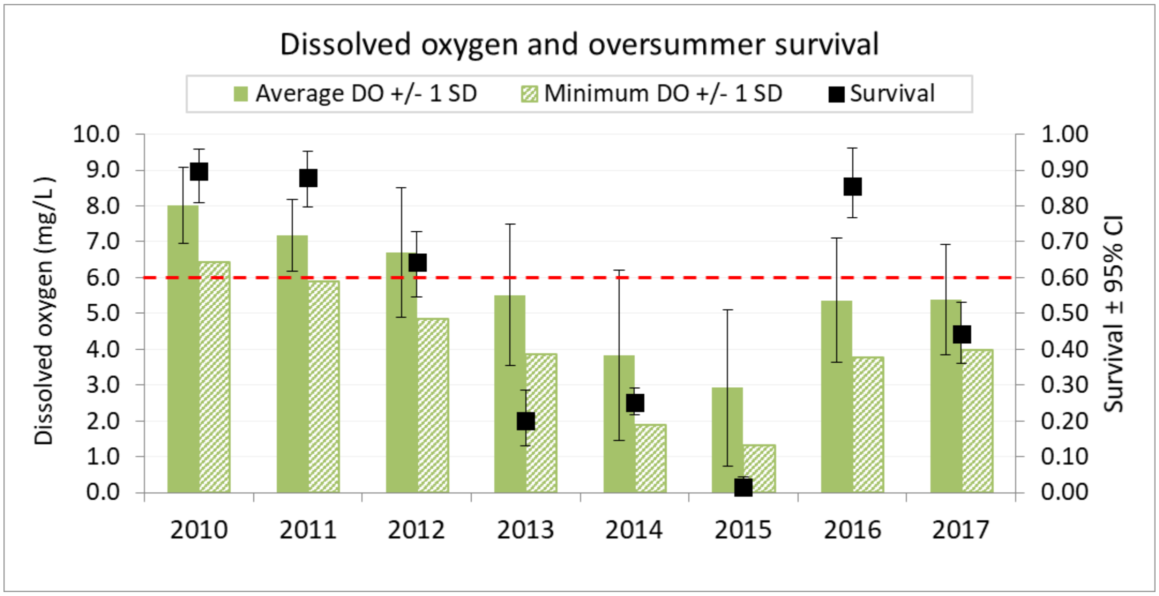

Figure 30. Oversummer, reach-scale average DO concentrations and minimum average DO at the lowest sample interval in the Green Valley Creek study reach in relation to oversummer survival of juvenile coho salmon, years 2010-2017. The red line indicates the regional minimum daily DO objective (NCRWQCB 2015).

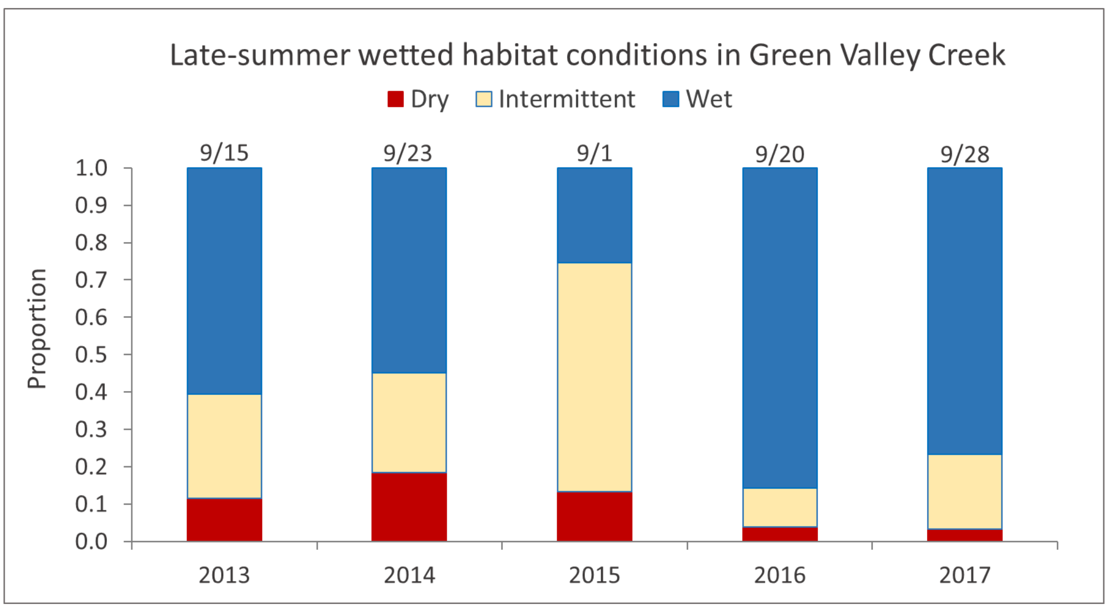

Figure 31. Proportion of dry, intermittent, and wet habitat in Green Valley Creek on September survey dates, Years 2013-2017. Only sections of stream surveyed in all years were included in calculations. Years 2015 and 2016 include effects of flow augmentations implemented prior to the sample date.

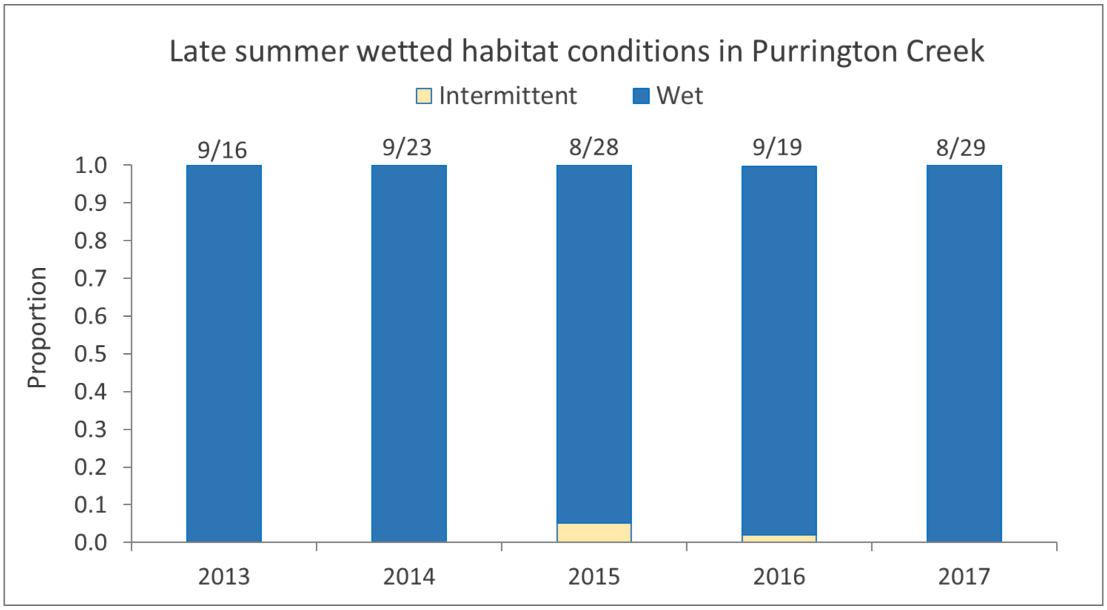

Figure 32. Proportion of dry, intermittent, and wet habitat in Purrington Creek on September survey dates, years 2013-2017. Only segments of stream surveyed in all years were included in calculations.

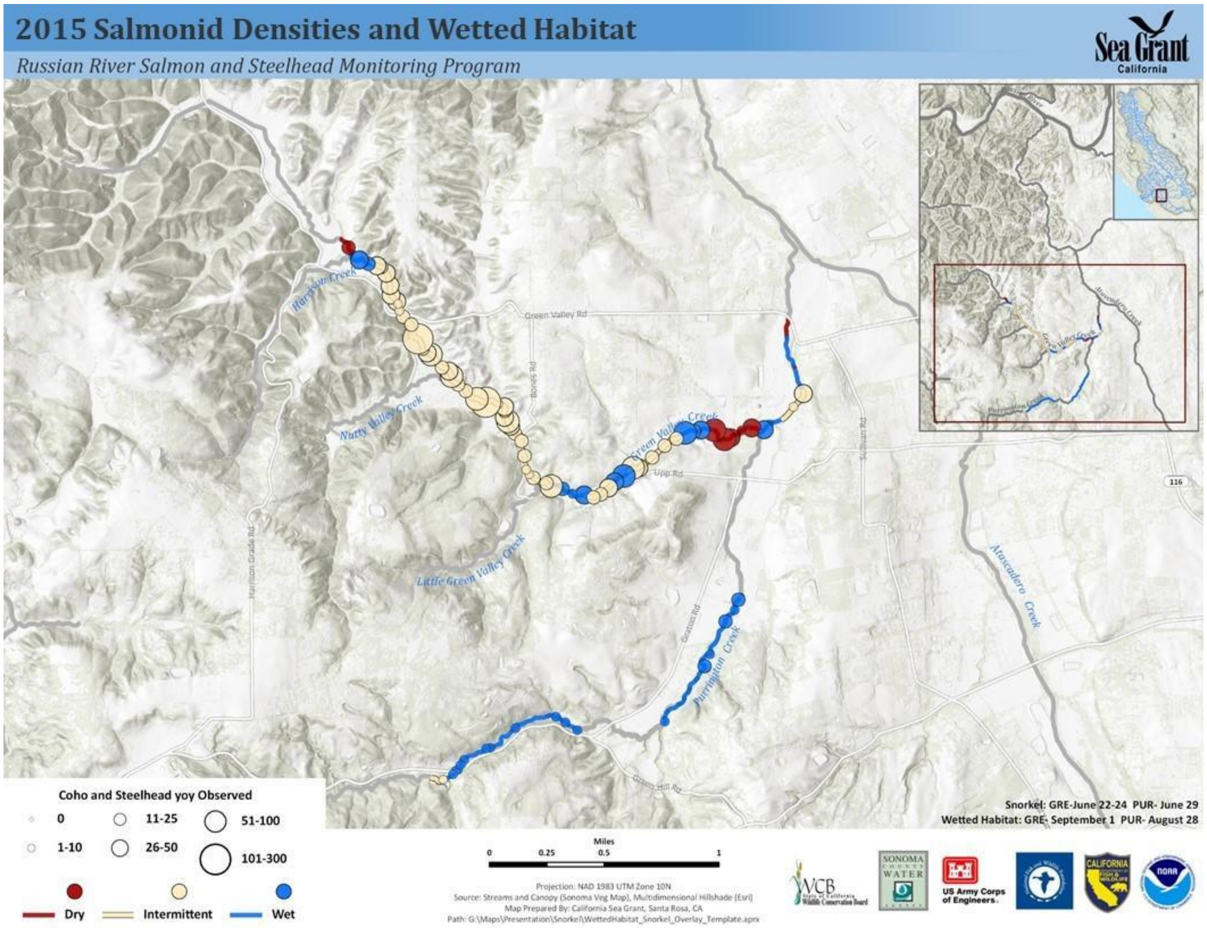

Figure 33. Early-summer salmonid yoy observations and late-summer wetted habitat conditions in Green Valley and Purrington creeks, 2015.

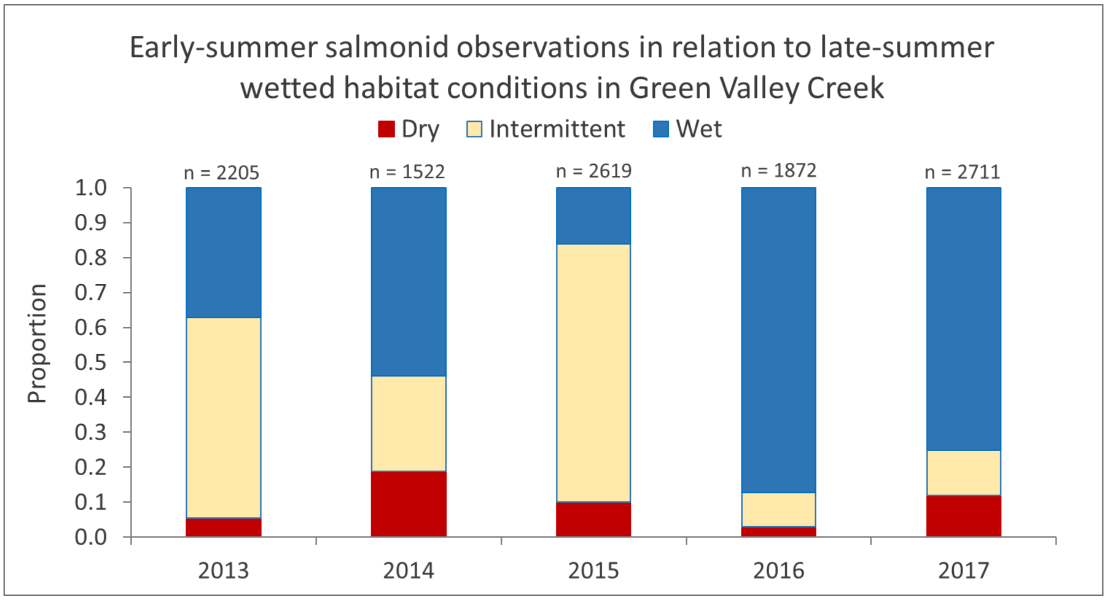

Figure 34. Proportion of coho salmon and steelhead yoy observed during early-summer snorkel surveys in Green Valley Creek in habitat that was wet, intermittent, or dry in September, years 2013 through 2017. Only segments of stream sampled in all years were included in the calculations. N = number of juvenile salmonids observed during snorkeling surveys. In 2015 and 2016, flow augmentations were implemented prior to the wet/dry mapping so the impact of drying on fish may not be accurately reflected.

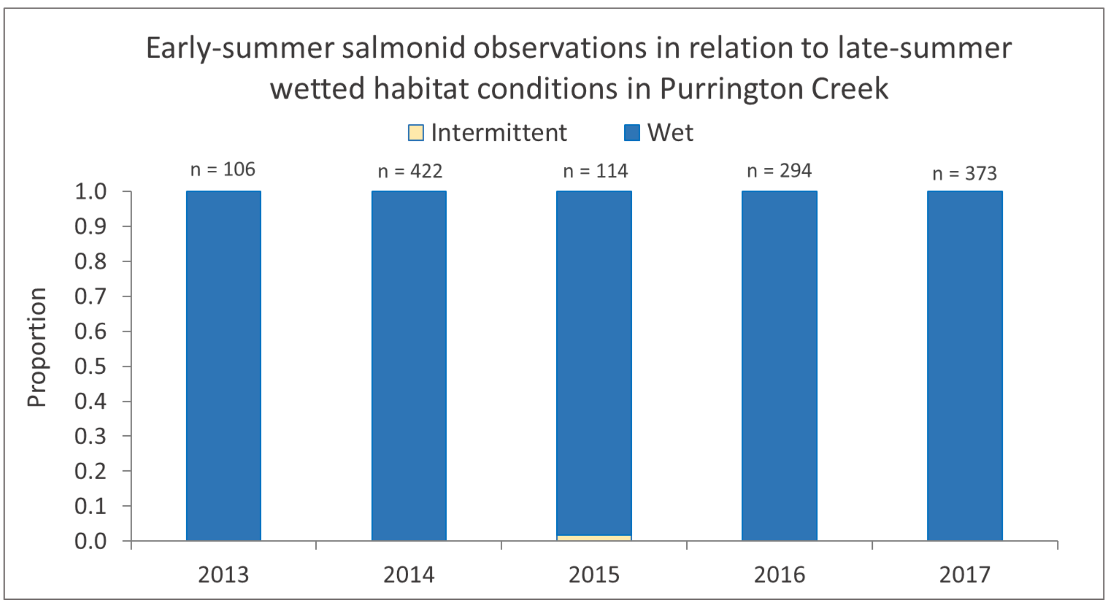

Figure 35. Proportion of all coho salmon and steelhead yoy observed during early summer snorkel surveys in Purrington Creek in habitat that was wet, intermittent, or dry in September, years 2013 through 2017. Only segments of stream sampled in all years were included in the calculations. N = number of juvenile salmonids observed during snorkeling surveys.

4.5 Survival versus thrival

Juvenile coho salmon were observed surviving in Green Valley Creek at flows that dropped well below 0.50 ft^3/s. These small surface flows, which sustain pool connectivity, should be considered only as minimum persistence flows and not levels that support high growth or sufficient production of fish. Although salmonids may be able to persist at extremely low flows, if they are in poor condition at the end of the summer (e.g., small size, disease, parasites, etc.), survival may be compromised at later life stages.

Additionally, low flow conditions reduce the habitat and benthic prey available to fish. Flow has been positively correlated with both benthic macroinvertebrate (BMI) production (Gore et al. 2001), which are the primary prey for rearing juvenile salmon, and the amount of foraging habitat in a stream (Nislow et al. 2004). Harvey et al. (2006) found that invertebrate drift and juvenile rainbow trout growth increased with increased streamflow in a small California stream. Similarly, Nislow et al. (2004) found higher growth in stream-rearing juvenile Atlantic salmon in years with higher streamflow. 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.

While smolts that overwinter in Green Valley Creek are commonly larger than those measured in other life-cycle monitoring tributaries in the lower Russian River basin, average oversummer growth in the Green Valley Creek study reach from 2010-2016 (0.05 mm/day in fork length) was below average growth for all study streams (0.07 mm/day). Based on the findings referenced above, we can expect that increasing summer discharge beyond minimum persistence flows would likely promote higher oversummer growth in juvenile salmon and, in turn, support more adults returning to spawn.

Achievement of long-term recovery goals for Russian River coho populations 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 salmon and steelhead in Green Valley Creek. Identifying such flows is beyond the scope of this study; however, these values were estimated for the Mattole Headwaters sub-basin, an area slightly smaller than the Green Valley Creek watershed (McBain and Trush, Inc. 2012). In an instream flow needs study, McBain and Trush, Inc. recommended summer juvenile rearing flow thresholds ranging from 1.5 to 5 ft^3/s (depending on location in the watershed) to avoid poor or negative growth, high risk of disease and predation, shrinking habitat availability, and heightened competition for food. The average daily streamflow observed in Upper Green Valley Creek from June 15 to October 15, over the study years of 2010-2017, was 0.08 ft^3/s. CSG research and the Mattole study suggest that current oversummer streamflow in Green Valley Creek, while able to support high survival of rearing juveniles in the wettest years, is generally insufficient to support the biological needs of rearing juvenile salmonids to full productivity.

5 Recommendations: Flow improvement strategies

5.1 Introduction

The previous sections have identified flow as a limiting factor for coho salmon in Green Valley Creek, demonstrated that pool connectivity is a key factor in supporting the persistence of juvenile fish throughout the dry season, and shown that projects that keep pools connected by collectively increasing streamflow by tenths of cubic feet per second have the potential to improve survival of juvenile coho salmon throughout the summer rearing season. Drawing from the streamflow, human water need, and fish monitoring data provided above, this section recommends strategies to achieve the Partnership's primary goal of maintaining pool connectivity within Upper Green Valley and Purrington creeks. Section 5 described our priority reaches, provides a suite of recommendations, and evaluates whether those recommendations — if and when implemented — are sufficient to improve pool connectivity.

5.2 Reach prioritization for streamflow projects

The Partnership identified priority reaches that serve as the focus of the Partnership's effort to improvement streamflow within the Upper Green Valley Creek watershed (Figure 36). These reaches were selected by evaluating habitat survey data collected by CDFW, as well as streamflow, fish distribution, and wetted habitat data collected by the Partnership. Importance as fish habitat, level of flow impairment, and feasibility of improving flows within the 12-year timeframe of NFWF's Keystone Initiative were all considered in priority reach selection.

The reaches are as follows (Figure 36):

- Green Valley Creek Reach A: The easternmost Green Valley Road crossing to the confluence of Green Valley and Purrington creeks.
- Green Valley Creek Reach B: The confluence of Green Valley and Purrington creeks to Bones Road.
- Green Valley Creek Reach C: Bones Road to the furthest upstream Green Valley Rd. crossing.
- Purrington Creek Reach A: All of Purrington Creek.

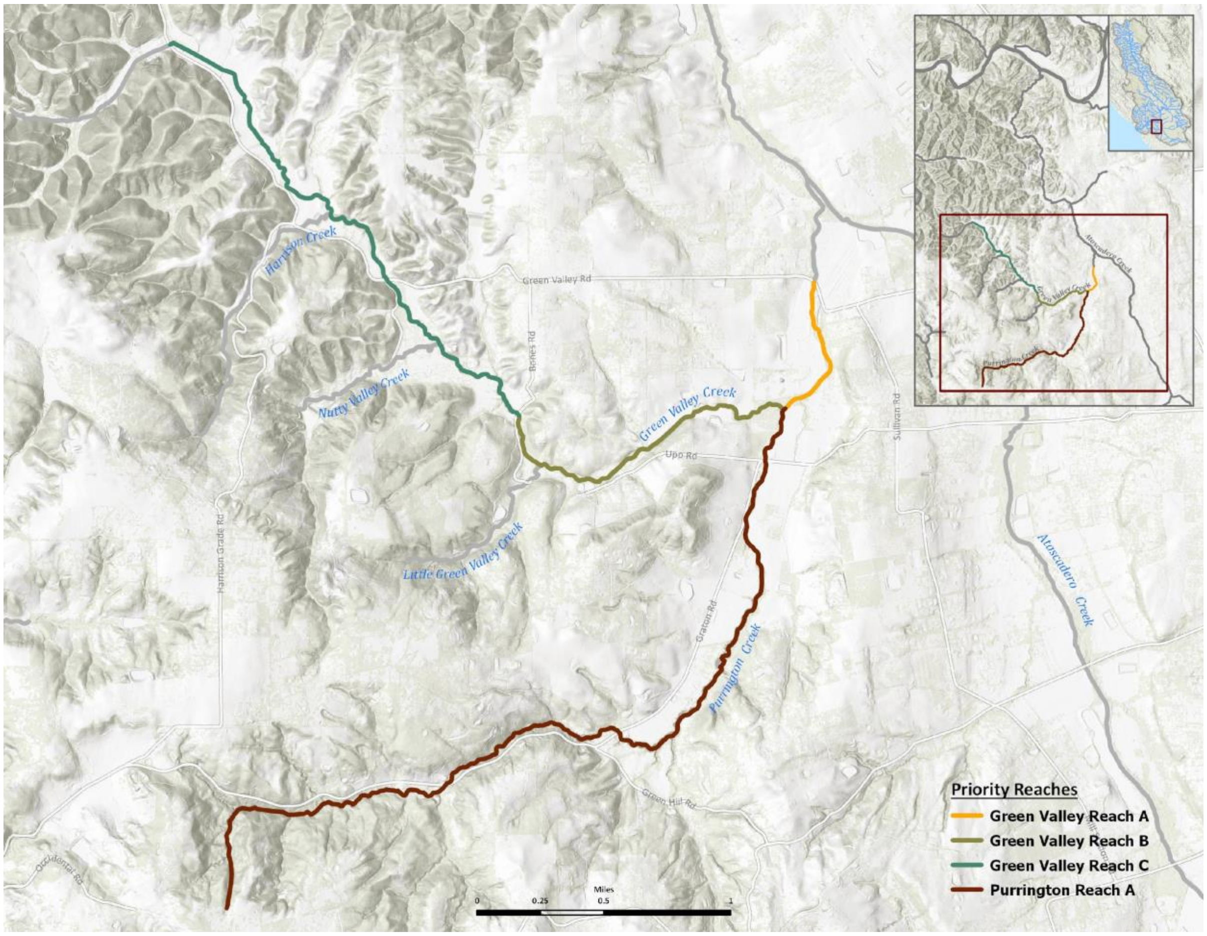

Figure 36. Green Valley Creek priority focus reaches.

5.3 Consistency with other local planning efforts

The Partnership's reach prioritization and recommendations are largely consistent with the foci and conclusions of other local planning efforts.

In 2014, GRRCD, OEI, and Prunuske Chatham, Inc. drafted Phase II of the Green Valley Creek Watershed Management Plan (GRRCD 2014). The Plan provides a robust watershed description (covering water quality, hydrology, sediment sources and impacts, flood risk, a geomorphic habitat restoration assessment, and biological resources), management considerations, and habitat restoration recommendations and priorities. The SIP dovetails with the Plan's biological resources recommendations (increase summer baseflows) and implementation actions (streamflow and water needs) and provides more focused streamflow recommendations based on the (hydrologic, fisheries, and habitat) data collected by the Partnership. Like the Plan, our focus is on the Upper Green Valley Creek and Purrington Creek subwatersheds (though the Plan also included lower Green Valley Creek).

In its 2016 report, OEI performed an analysis of "the spatial and temporal distribution of stream flow throughout [Green Valley Creek] relative to coho habitat requirements to assist in prioritizing restoration efforts and developing strategies to maintain or improve summer streamflow" (O'Connor Environmental Inc. 2016). It did so by developing and calibrating a hydrologic model that simulated surface-groundwater interactions and estimated summer baseflow across the drainage network. OEI then used the model to recommend reaches for instream habitat and streamflow projects. The SIP is largely consistent with OEI's identification of priority reaches for addressing low summer streamflow and implementing flow enhancement projects in Green Valley Creek. OEI recommended implementing streamflow projects in reaches UGV1, UGV2, and PUR1 (O'Connor Environmental Inc. 2016, p. 16) (see Figure 37). Those reaches correspond with portions of Partnership reaches Green Valley Creek C and B, and Purrington Creek Reach A.

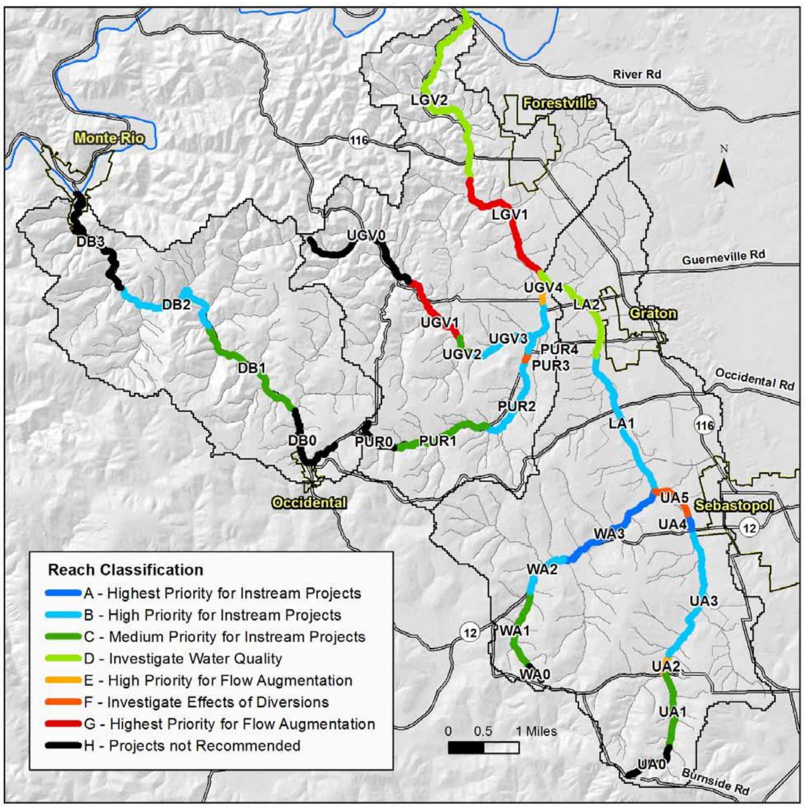

Figure 37. Flow availability and restoration recommendation reach classifications (O'Connor Environmental Inc. 2016).

5.4 Flow improvement strategies

Building off the recommendations and actions identified in GRRCD (2014), our suite of recommended strategies includes:

- Reduce or eliminate agricultural dry season diversions (surface and groundwater) from Upper Green Valley Creek and its tributaries (5.4.1)
- Reduce or eliminate rural residential dry season diversions (working especially closely with communities with shared water supply) from Upper Green Valley Creek and its tributaries (5.4.2)
- Pursue new flow releases and continue existing flow releases (5.4.3)
- Improve infiltration and recharge (5.4.4)
- Continue to pursue habitat improvement projects (5.4.5)
- Study surface-groundwater interaction (5.4.6)

5.4.1 Reduce or eliminate agricultural dry season diversions

- We recommend scoping and implementing projects that reduce agricultural water demand year-round, including irrigation efficiency and water conservation projects.

  Case study: Irrigation efficiency upgrade project. In 2011, the Partnership worked with Rued Vineyard on Purrington Creek to replace overhead sprinkler irrigation with a drip irrigation system. The project saved a minimum of 200,000 gallons per year.

- We recommend pursuing projects that reduce dry-season irrigation and frost protection water demand, including projects that switch the timing of the demand (off-stream storage and forbearance projects), and reduce the instantaneous rate of diversion from a stream (diversion rate reduction and source switches).

  Case study: Source switch from surface to groundwater. In 2017, the Partnership implemented a second phase of the Rued Vineyard project, completing piping and electrical work that enabled the vineyard to switch the source of vineyard irrigation and frost control water from a tributary of Purrington Creek to a deep well. This phase of the project eliminated surface water diversion, saving a minimum of 600,000 additional gallons of irrigation water per dry season, and ensuring that frost protection water would longer be sourced from the creek. Water savings for frost protection are difficult to calculate because of variation in frost water demand but could easily be an order of magnitude larger than irrigation water diversion, depending on weather conditions in a particular year.

- We recommend prioritizing projects located adjacent to Upper Green Valley Creek.

- In addition, we recommend thinking creatively about other institutions and users who have irrigation water demands that are not agricultural in nature, including summer camps, conference facilities and small hotels and B&Bs. Specifically, we recommend completing a project with the Mt. Gilead Camp and outreach to other similarly situated water users.

5.4.2 Reduce or eliminate rural residential dry season diversions

- We recommend continuing to develop conservation, demand reduction, alternative water source, water storage and forbearance projects, and infiltration projects with residential users.
- We recommend prioritizing projects on streamside properties with direct diversions from or alluvial wells near Upper Green Valley Creek and its tributaries.
- We recommend prioritizing projects that involve multiple users and shared supply arrangements, especially when such projects result in greater cumulative benefits to instream flow (and residents).
- We recommend continuing a program (like that provided by the Partnership in the Russian River tributaries and GRRCD/OAEC in nearby Salmon Creek) that provides technical and financial assistance to landowners whose residential water use may be impacting streamflow and who are interested in developing alternatives. A typical project would include (a) evaluating the parcel to identify water conservation opportunities, (b) installing water storage tanks to be filled with water from sources most suitable for each parcel (e.g., roofwater, surface water, springs, or wells), and (c) executing an agreement with the landowner to forbear use of his or her direct diversion or alluvial well during critical low-flow periods. 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.

Case study: Rural residential rainwater catchment project. Since 2013, the Partnership has constructed a series of rainwater catchment systems in cooperation with rural residential landowners in the area of Bones Road. In this area, nearly all residential parcels source their water from shallow alluvial wells located adjacent to Green Valley Creek. One such case is the Shaw Rainwater Catchment Systems project, constructed in 2018. The Partnership worked with the landowner to identify opportunities for water conservation and designed two rainwater catchment systems to provide for all outdoor non-potable water demand, including landscape and garden irrigation and water for horses. The landowner implemented the water conservation measures independently, while the Partnership constructed the rainwater systems. The two rainwater systems save a minimum of 70,000 gallons per year, with the larger of the two capturing and storing 60,000 gallons each rainy season. This represents well over half of the total water use for the property.

- In addition, we recommend developing some type of rebate program, akin to the former Flow-for-Fish Rebate Program in the Russian River, which provided a rebate payment to water users working with the Partnership or acting on their own to offset the cost of storage tanks and accompanying permits.

5.4.3 Flow releases

Beginning in 2015, at the height of the drought, streamflow augmentation emerged as a key strategy for preventing coho mortality. Multiple opportunities exist for flow augmentation to Upper Green Valley Creek, in the form of cold-water releases from private storage ponds. The Green Valley Partnership (now Green Valley Farm and Mill) and Jackson Family Wines (JFW) released water from agricultural ponds in the summers of 2015-2017 (Table 5), when stream disconnection threatened coho salmon rearing in downstream pools. A case study of the 2017 Green Valley Creek flow releases is included below. Monitoring data have demonstrated beneficial impacts to instream habitat from these releases, particularly when implemented prior to extensive disconnection or drying.

Our recommendations concerning flow releases are as follows:

- We recommend that the previously-implemented flow releases continue as a supplement to long-term, comprehensive efforts to restore dry-season baseflow, to the extent that landowners are willing and it is logistically feasible.
- We recommend that potential opportunities for additional flow releases from off-channel ponds and other sources within the watershed be explored.
- We recommend that, whenever possible, all flow releases occur as early as is feasible in the summer season, prior to DO impairment and stream disconnection, in order to maximize the benefits to salmon and steelhead rearing in Green Valley Creek over the dry season.
- We recognize it is challenging to manage releases from limited-quantity sources and recommend that releases receive close oversight and careful management by resource managers, in close communication with CSG and other monitoring parties. Additional recommendations about how to structure and permit flow release projects are included in Section 6.2.

Table 5. Record of summer flow releases into Green Valley Creek, 2015-2017.

Year	Release Site	Location	Release dates	Amount
2015	Lower	Below Bones Road	8/26 -12/8	0.04 ft^3/s
2015	Upper	Above Harrison Creek	8/18 -10/27	0.05 ft^3/s
2016	Lower	Below Bones Road	8/16 -10/28	0.06 - 0.075 ft^3/s [1]
2016	Upper	Above Harrison Creek	8/22 -10/14	0.05 - 0.075 ft^3/s
2017	Lower	Below Bones Road	9/28 -11/1 [2]	0.10 ft^3/s [1]
2017	Upper	Above Harrison Creek	9/29 -10/8	0.05 - 0.10 ft^3/s

[1] *Only active during 12-hour overnight period*

[2] *Exact end date in November unknown*

Case study: 2017 Green Valley Creek flow releases

The primary challenge of managing flow releases to maximize potential instream benefits from a limited water source is timing the release to occur prior to extensive stream disconnection and DO impairment, while also late enough to ensure that there is sufficient water available to support a release through the driest late-summer months. Instream DO concentrations typically exhibit a general downward trend over the summer season but the date at which DO drops near or below fish impairment levels in different stream reaches varies annually, depending on weather and environmental conditions, so the "best" initiation date for a limited-quantity release is a moving target.

CSG conducted biweekly surveys of wetted habitat availability and DO concentrations in Upper Green Valley Creek over the summer of 2017. DO readings in Green Valley Creek were at or above the regional objective of 6.0 mg/L (NCRWQCB 2015) through the mid-August survey. By the August 30-31 survey, flow at the Bones Road crossing was 0.06 ft^3/s and, despite very little stream disconnection, the stream-scale average DO concentration was 5.3 mg/L (Figure 38). Twenty-eight percent of sample pools had fallen below known salmonid impairment levels of 4.5 mg/L and 3% had concentrations below the established mortality threshold of 3.0 mg/L (McMahon 1983).

During the 2017 June snorkeling survey, CSG biologists had documented more than 3,700 juvenile salmon and steelhead distributed throughout Green Valley Creek. At the time of observation, there was not sufficient flow for fish to move out of the stream reaches in which they were rearing, and with DO steadily decreasing as the stream grew drier, it was clear that thousands of fish were facing potential mortality or, at the least, production impairment, stress and/or disease. Given the above-average rainfall over the winter of 2016/17, there were no plans in place to release water into the stream initially; however, due to the high number of fish and the risk associated with prolonged DO impairment persisting for several weeks before the onset of the rainy season, NOAA and CDFW resource managers began working with streamside landowners to facilitate both the Green Valley Partnership (now Green Valley Farm and Mill) and JFW flow releases.

By September 13-14, Green Valley Creek streamflow at Bones Road was just 0.03 ft^3/s, disconnection had increased, and DO had dropped to a stream-scale average of 3.9 mg/L (Figure 39). Sixty-five percent of sample pools had fallen below known salmonid impairment levels, 21% of sample pools had concentrations below the mortality threshold and fish were observed gasping at the water's surface. On September 28 and 29, respectively, agency partners were able to implement the flow release below Bones Road at a rate of 0.01 ft^3/s and the release above Harrison Creek at a variable rate of approximately 0.05-0.10 ft^3/s (Table 5, Figure 40 and Figure 41).

The first wet/dry mapping surveys after the flow releases were conducted on October 17. By that time, stream-scale average DO had risen to 5.4 mg/L, with just 36% of sample pools below impairment thresholds; a 28% and 45% increase, respectively (Figure 40). It should be noted that, on a stream-scale, it was not clear how much of this improvement could be attributed to the releases, versus the seasonal change in environmental conditions associated with fall cooling and deciduous plant leaf loss; however, we observed a greater improvement in wetted habitat conditions in Green Valley Creek in late October as compared to two other nearby streams. This suggests that improvements in stream-scale conditions reflected an overall benefit from the flow releases.

To determine the effects of the releases on a finer scale, data from continuous DO loggers in pools closest to the release points were evaluated to determine whether pool DO concentrations increased around the time of the augmentations. The logger deployed 120 meters downstream of the release below Bones Road (lower) recorded an increase in DO beginning two days after the release, after upstream riffles had reconnected (Figure 42). At the time of the release, average daily DO in that pool was 4.0 mg/L. A week after the release had started, DO peaked at 8.5 mg/L — well above the regional objective — and remained above impairment thresholds until the October rains (Figure 42). The logger deployed 830 meters downstream of the release above Harrison Creek (upper) showed a spike in DO almost immediately following the release (Figure 43). Average daily DO in that pool went from 1.4 mg/L the day before the release to 9.8 mg/L the day after and remained slightly higher than pre-release concentrations until the onset of rain in mid-October (Figure 43). These data indicate that the increased instream flow from both Green Valley Creek flow augmentations in 2017 led to increases in DO concentrations, providing critical relief for fish rearing in stream reaches within relatively close proximity to the release sites. Similar results were observed in previous years (CA Sea Grant, unpublished data). Had these releases occurred earlier in the season, it is highly likely the effects would have benefitted more fish prior to them experiencing stressful conditions.

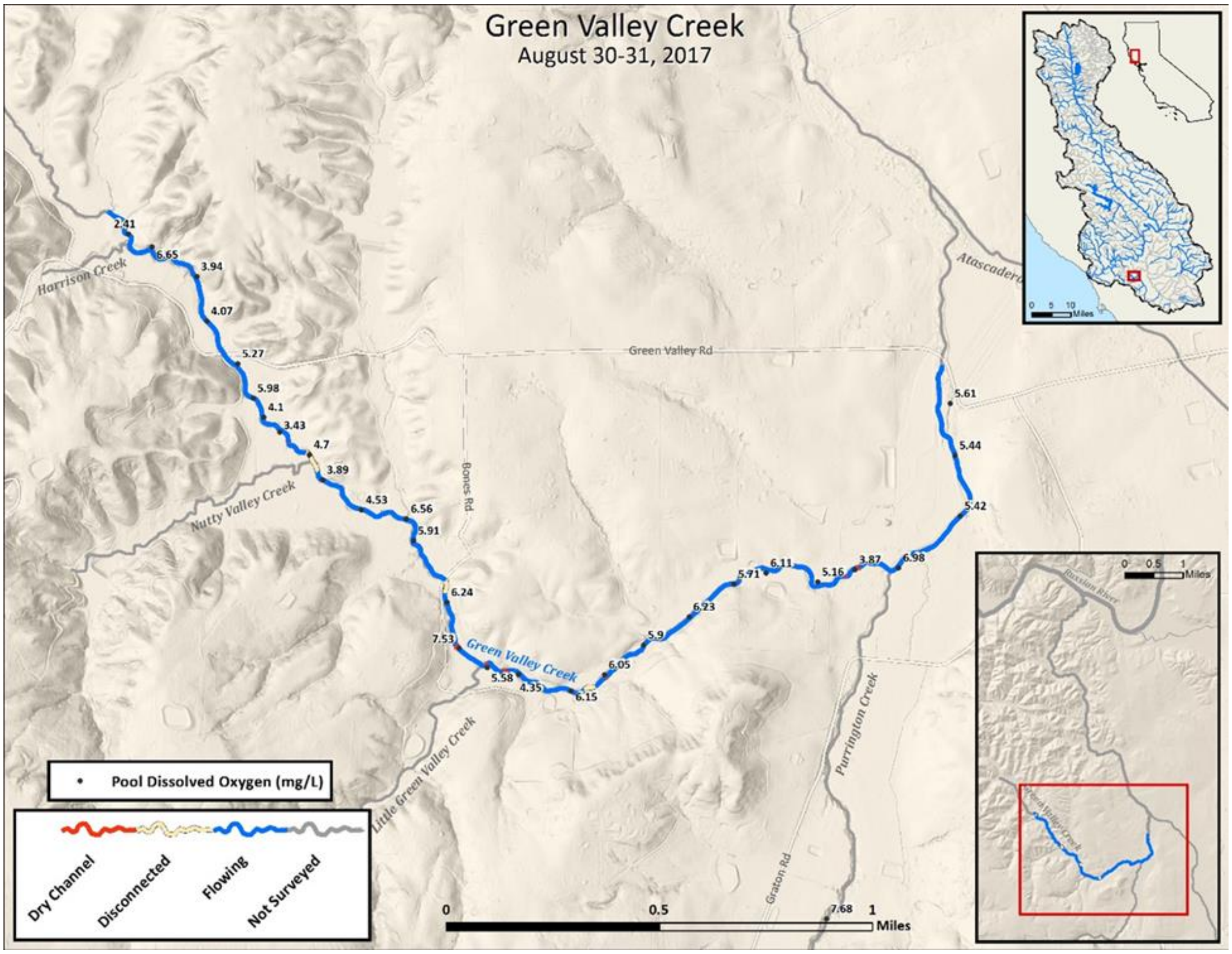

Figure 38. Green Valley Creek wetted habitat conditions and DO measurements on August 30-31, 2017.

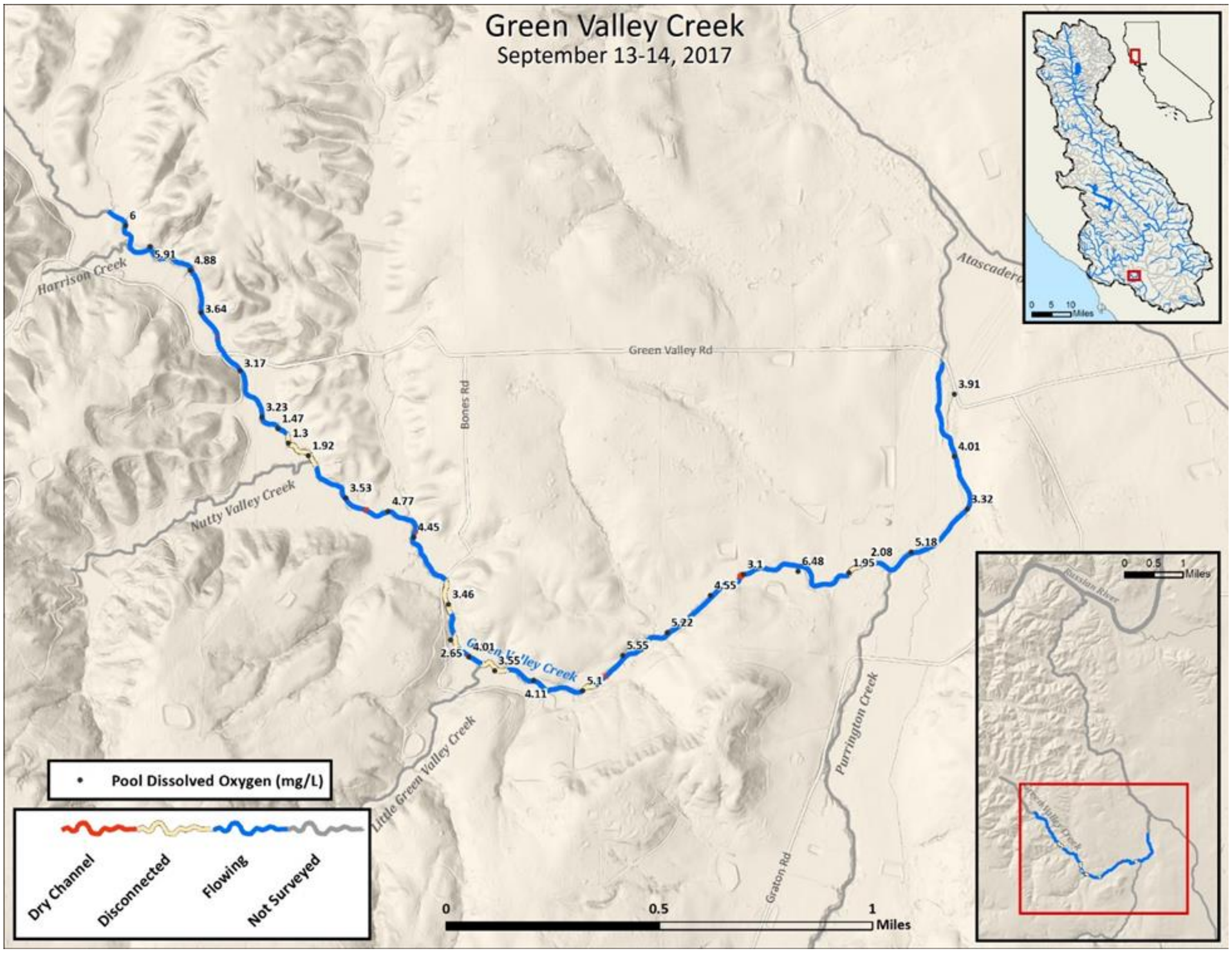

Figure 39. Green Valley Creek wetted habitat conditions and DO measurements on September 13-14, 2017.

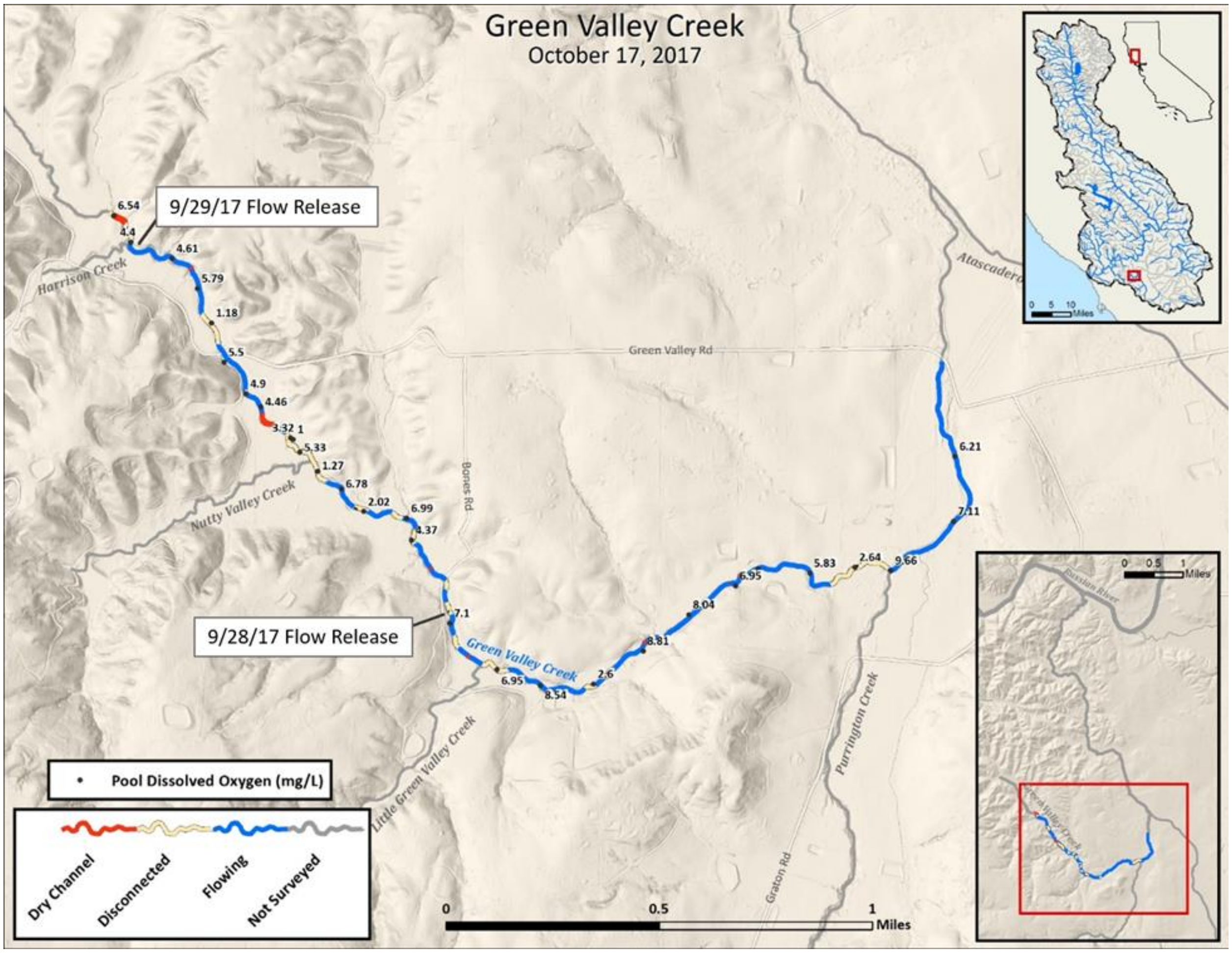

Figure 40. Green Valley Creek wetted habitat conditions and DO measurements on October 17, 2017, and locations and dates of flow releases.

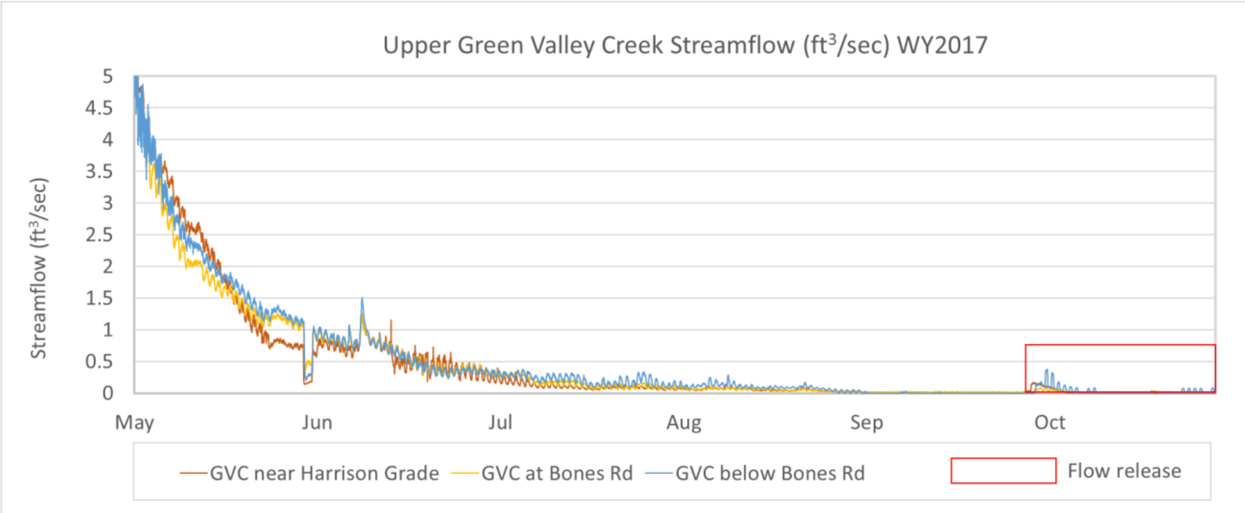

Figure 41. Streamflow conditions in Upper Green Valley Creek, showing water release in late September/early October 2017.

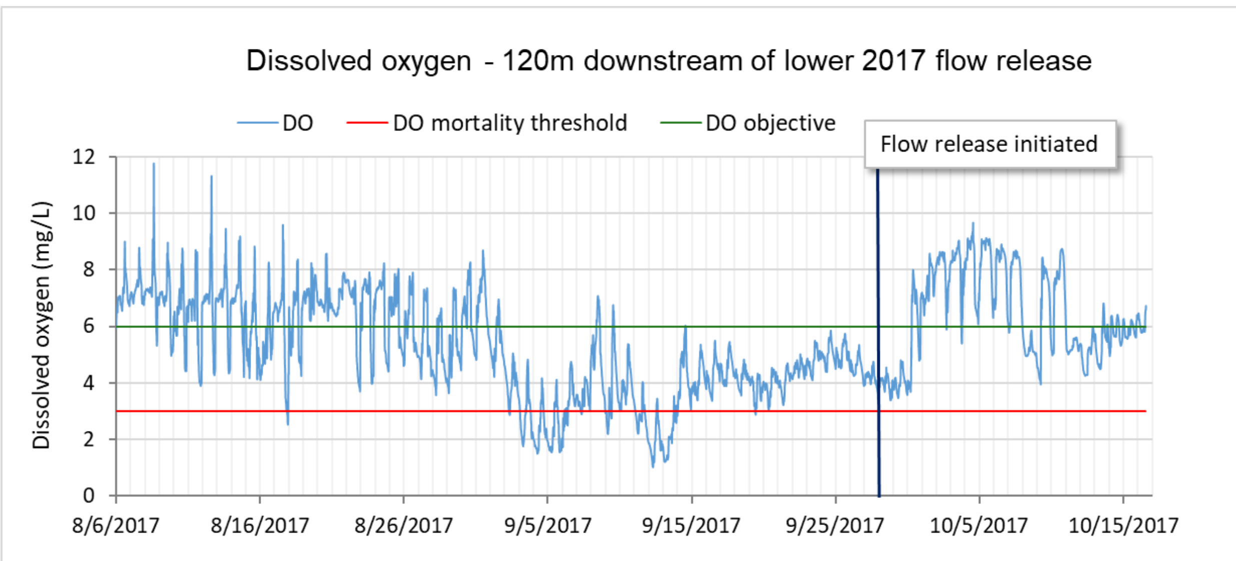

Figure 42. DO readings from continuous logger in a pool 120 meters downstream of the lower flow release initiated on Upper Green Valley Creek on September 28, 2017. Note increase in DO after flow augmentation.

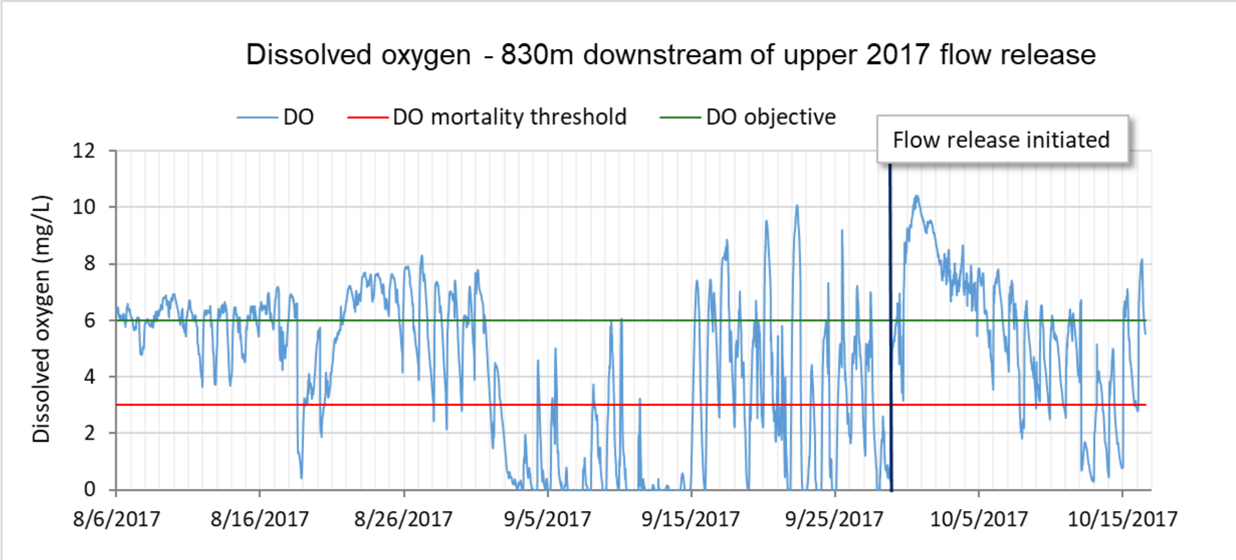

Figure 43. DO measurements from continuous logger in study pool 830 meters downstream of the flow release initiated on Upper Green Valley Creek on September 29, 2017. Note increase in DO after flow augmentation.

5.4.4 Improve infiltration and recharge

The Partnership's analysis of the location and magnitude of known and suspected water diversions and impoundments in the Upper Green Valley Creek watershed leads us to believe that reducing or eliminating dry season water extraction, both directly from streams and indirectly via alluvial wells, may not be sufficient by itself to maintain sufficient flows for oversummer survival of juvenile coho in Green Valley Creek and Purrington Creek during severe multi-year droughts. Land use impacts on a widespread scale are likely impacting both the infiltration of rainfall into the soil column and the landscape's capacity to generate summer baseflow. These include:

- Hardening of the landscape through urban and rural residential development and agricultural conversion, which creates larger areas of impervious and semi-permeable surfaces, along with a denser drainage network. These changes reduce infiltration and cause a greater proportion of rainfall to be converted to runoff, resulting in less water entering the soil column and becoming available for baseflow.
- The presence of a dense, greatly extended drainage network, primarily in the form of poorly drained roads. GRRCD (2014) states, "The Upper Green Valley subwatershed has a medium/high frequency of roads on steep slopes and the Purrington subwatershed is categorized as having a high frequency of roads on steep slopes (LMA 2003)." When constructed using methods almost universally accepted over the past century or so (insloped, with undersized and inadequately spaced drainage structures), roads become hydrologically connected to the stream network and act as extensions of that network. Road cutslopes intercept overland and shallow subsurface flow, while compacted or paved road surfaces generate runoff, and inboard ditches collect runoff generated on adjacent

impervious or semi-permeable surfaces. Inboard ditches and poorly shaped and maintained road surfaces convey that water (and abundant fine sediment) to stream channels quickly and efficiently. Besides damaging instream habitat through erosion and sediment delivery, this process results in the rapid removal from the landscape of a greater proportion of rainfall than was the case historically. The ubiquitous presence of roads on the landscape means that few areas of the watershed have been left untouched by these impacts.

- Stream channel incision, the process whereby a stream erodes its bed and entrenches itself over time in response to multiple processes (including those listed above), which is extensive and severe in the Upper Green Valley Creek watershed. Channel incision of up to 35 feet below the former floodplain level has been documented throughout Upper Green Valley and Purrington creeks (O'Connor 2010, O'Connor and Rosser 2003). Incision causes hydrologic disconnection of the floodplain from the stream and lowering of the adjacent alluvial water table occurs in response to the lowering of the streambed. In effect it reduces the capacity of the stream's alluvial aquifer, resulting in less groundwater to provide dry season baseflow. Channel incision also causes confinement of high flows in a narrow channel, degrading instream habitat and causing more frequent mobilization of bed load sediment. Incision is very difficult and expensive to arrest or mitigate, as it requires reducing peak storm flows, dramatically increasing channel roughness or implementing extensive channel grade control measures. Addressing the impacts of land cover conversion and decommissioning or hydrologically disconnecting road networks act to both improve infiltration of rainwater and reduce runoff (which lowers peak flows), but both must be carried out on a watershed scale to be effective in arresting or reversing channel incision.

To address this landscape-scale desiccation, we recommend the following actions:

- A broad-scale effort to improve upland recharge: Opportunistic actions to reduce the area of impervious surface and improve permeability of hydrologically disconnected impervious surfaces, as well as the construction of retention basins and decommissioning of unnecessary drainage systems that concentrate surface and shallow subsurface flow.
- A road drainage improvement program, on both paved and unpaved roads throughout the watershed, with a focus on areas that drain to reference and treatment reaches. Such efforts have been criticized in the recent past as being overly expensive and only benefitting road owners, but we believe the hydrologic and erosion control benefits are both significant and self-evident.
- A concerted effort to limit and if possible reverse stream channel incision throughout Upper Green Valley and Purrington creeks. This includes taking immediate steps to prevent further headcutting and incision on both mainstem and tributary streams, stabilize expanding gully systems draining to stream channels, and implement projects to increase stream channel roughness to aggrade the beds of incised channels. Any broad-scale effort to aggrade channels and reconnect abandoned floodplains is likely to encounter public opposition, as extensive development has occurred in many

of these areas. But opportunities exist for smaller projects aimed at reconnecting former floodplain areas on a limited scale.

We note that because the impacts described above are widespread on the landscape, a program to mitigate their impacts must necessarily be implemented on a landscape scale. It will therefore be expensive relative to the discrete projects undertaken by the Partnership to date, and progress will likely be measurable only on a longer time scale.

5.4.5 Habitat improvement

As a complement to flow improvement efforts, we recommend continuing to implement habitat projects that improve instream conditions for coho and steelhead, as well as projects that increase off channel habitat in Green Valley Creek. The Green Valley Creek Watershed Management Plan (GRRCD 2014) provides an extensive analysis of needs, actions and priority projects. We recommend that emphasis be placed on developing and implementing projects that counter the habitat impacts of stream channel incision, and that project proponents continue to consider and integrate flow information and instream flow project locations into their project selection and design.

5.4.6 Groundwater

The Partnership recommends updating and using the integrated surface and groundwater modeling and flow availability analysis conducted by OEI to continue to study surface-groundwater interactions and inform future project development. In 2017 the Partnership was awarded a NFWF Flow Accountability Restoration Accounting Fund grant to develop a groundwater monitoring study plan, drill groundwater monitoring wells, and collect groundwater data. The purpose of this study is to gain a better understanding of groundwater dynamics in the watershed, and how groundwater interacts with summer streamflow in the Upper Green Valley watershed.

5.5 Evaluation and metrics

The Partnership has developed metrics to help us estimate the flow benefit of projects and to evaluate our progress in restoring flow in Upper Green Valley Creek with the primary flow restoration goal of improving juvenile salmonid oversummer survival. In this section, we discuss the use of pool connectivity as a predictor of oversummer survival, present the pool connectivity thresholds for Upper Green Valley Creek, estimate the flow benefits of the projects recommended above, and compare the estimated collective benefit of those projects to the connectivity thresholds.

5.5.1 Partnership objectives and pool connectivity thresholds

As explained in Section 4.4, pool disconnection is an important predictor of juvenile salmon survival; as the number of days of disconnection increases, the probability of fish survival becomes progressively lower. Due to the importance of connectivity in supporting fish persistence through the dry season, a primary objective of the Partnership is to develop, and advocate for, streamflow improvement projects that increase the number of days that pools remain connected in any given year. In order to do this effectively, we need to understand how much water is required to maintain pool connection.

The measured surface discharge at which pools become disconnected does not always equate to zero ft^3/s, depending on the physical characteristics of the dynamic streambed, site-specific micro-hydraulics, and reference gage location in relation to the disconnection point(s). We investigated the amount of water required to keep all pools connected by continuous surface flow within each of the Green Valley Creek priority reaches (Figure 36) by comparing field observations of the onset of disconnection each summer season with hydrographs generated from representative flow gages (Figure 7). In this way, we were able to determine the approximate flow level at which one or more pools within each reach became disconnected. Average daily streamflow on the last known date of full connection was identified as the *connectivity threshold.*

When assigning connectivity thresholds, we used a relatively conservative value that represents the flow prior to which we observed even a single point of disconnection within a given stream reach, rounded up to the nearest 0.05 ft^3/s. In this manner, a connectivity threshold of 0.20 ft^3/s was assigned for each of the Partnership priority reaches on Green Valley Creek (see Figure 36). While individual pools, or sub-reaches, within a reach can have lower connectivity thresholds than those identified at the reach scale (e.g., not become disconnected until flow reaches 0.05 ft^3/s or less), the more conservative value of 0.20 ft^3/s applies to the entire stream.

This threshold was used to calculate the number of days of estimated pool disconnection (flow below connectivity thresholds) in each priority stream reach from June 15 to October 15 for all years of data collection (Table 6). In all but two reach/year combinations, streamflow on 60-100% of days fell below the connectivity threshold during the summer period. Extent and patterns of disconnection varied by reach and year (Figure 44 - Figure 46). To date, connectivity thresholds have only been estimated for the mainstem priority reaches of Green Valley Creek, not the tributary streams.

Though precise connectivity thresholds might vary slightly over time based on geomorphological changes or other dynamic factors, they are useful in setting values for target flows to support the persistence of coho salmon. The Partnership is working to implement projects that will cumulatively contribute flow that is greater than or equal to the 0.20 ft^3/s connectivity threshold in Green Valley Creek. We recognize that the impact of doing so may vary by year, depending on weather and other environmental factors, but empirical evidence demonstrates that reducing the number of days that pools are disconnected, to any degree, will positively affect the probability of fish survival.

Table 6. Days below connectivity threshold in the Green Valley Creek priority reaches between June 15 and Oct 15 each year (123 days/year), based on data from representative streamflow gages.

Reach name	Connectivity threshold (ft^3/s)	Priority reach range (river km from mouth)	Flow gage river km	Number of days below threshold								
				2010	2011	2012	2013	2014	2015	2016	2017	2018
Green Valley Reach A	0.20	9.78 -10.76	9.39	21	22	82	118	115	n/a	n/a	n/a	n/a
Green Valley Reach B	0.20	10.76 -13.03	12.70	n/a	n/a	n/a	n/a	n/a	123	119	90	119
Green Valley Reach C	0.20	13.03 -16.76	14.12	75	83	123[1]	123[2]	123	123	118	105	112

[1] *Missing 54 days of flow data (after 8/23); total number of days extrapolated based on flow on end date and neighboring flow conditions through end of season.*

[2] *Missing 49 days of flow data (after 8/28); total number of days extrapolated based on flow on end date and neighboring flow conditions through end of season.*

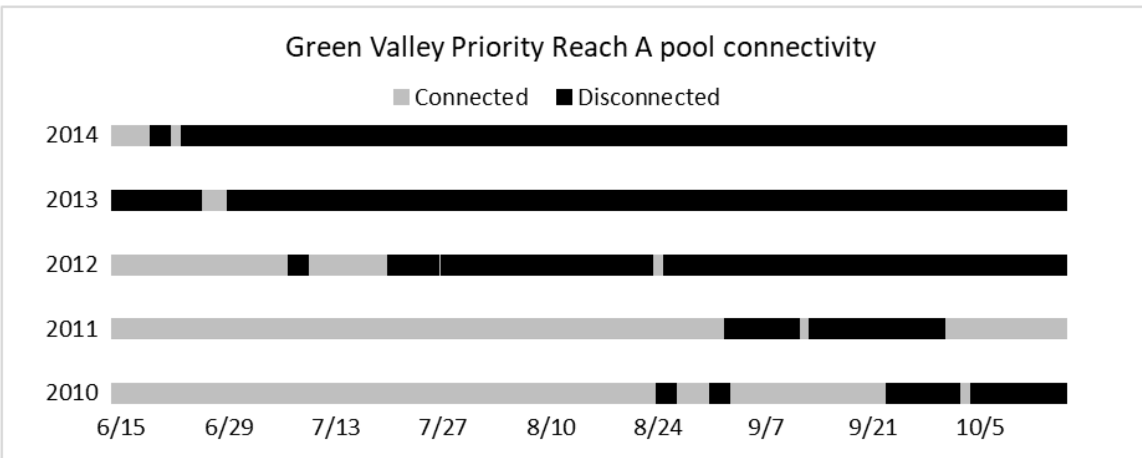

Figure 44. Days of pool disconnection in Green Valley Creek Priority Reach A between June 15 and October 15, years of flow gage operation, 2010-2014. Disconnection of one or more pools was assumed when surface flow was below a connectivity threshold of 0.20 ft^3/s.

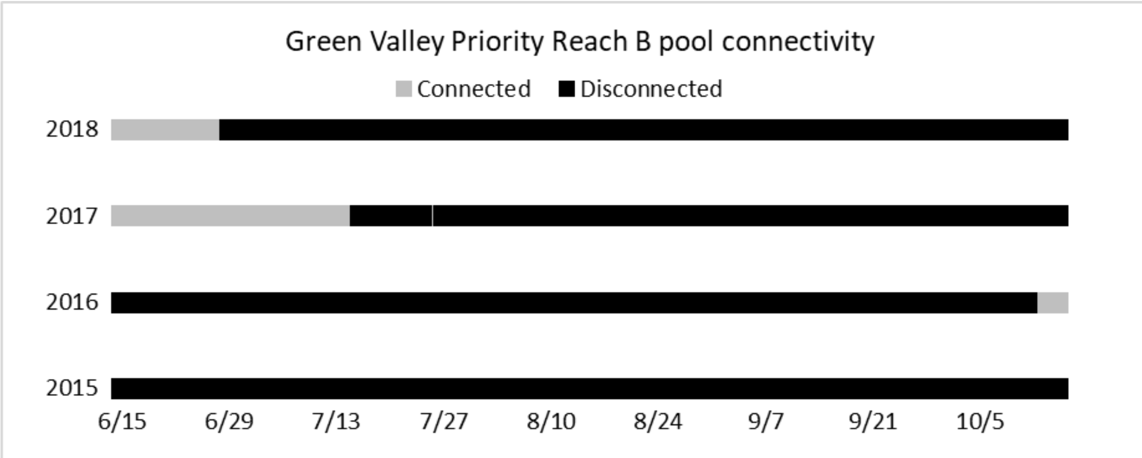

Figure 45. Days of pool disconnection in Green Valley Creek Priority Reach B between June 15 and October 15 in years of flow gage operation, 2015-2017. Disconnection of one or more pools was assumed when surface flow was below a connectivity threshold of 0.20 ft³/s.

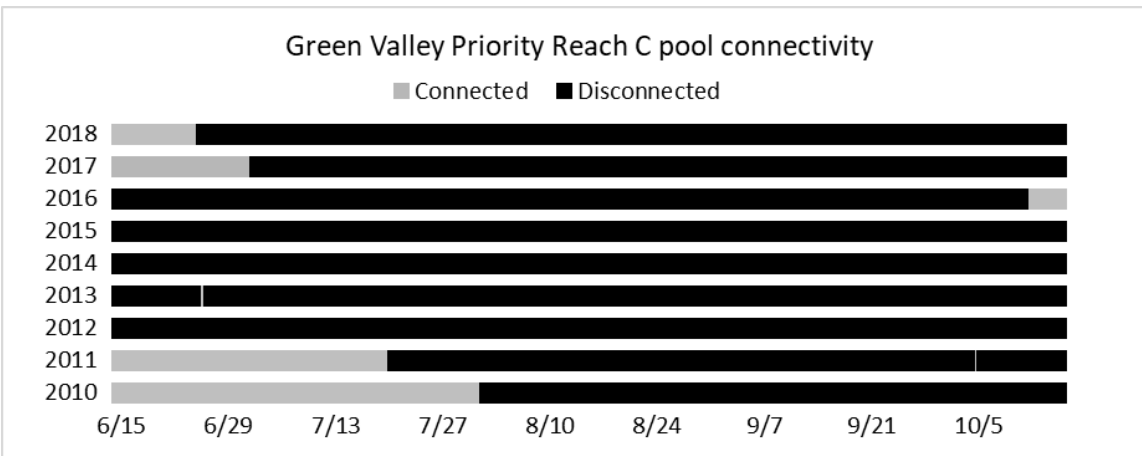

Figure 46. Days of pool disconnection in Green Valley Creek Priority Reach C between June 15 and October 15, years 2010-2017. Disconnection of one or more pools was assumed when surface flow was below a connectivity threshold of 0.10 ft3/s. No discharge data available for 8/24/12-10/15/12 and 8/29/13-10/15/13, so values extrapolated based on flow on end date and data from neighboring gages.

5.5.2 Evaluation of recommended actions and potential projects

Table 7 lists the implemented streamflow enhancement projects in the Upper Green Valley and Purrington Creek watersheds. There are several additional projects not included in this table that are in varying stages of development: some are in the planning phase and some have only been identified as potential projects. For each implemented project, we estimated the quantity of water repurposed to the stream in ft^3/s as an average daily flow over the period of benefit or forbearance. The assigned average daily flow values were determined based on the landowner's previous pumping rate before project implementation, or on the discharge of water being released from a reservoir. Table 7 also distinguishes between project types. Of the project types listed, water release projects have the highest benefit to flow, followed by water conservation and rainwater catchment.

Table 8 lists the implemented streamflow enhancement projects in the GV A, GV B and GVC reaches. The average daily flow values for each project are calculated following the same methods described for Table 7, and are also expressed as a percentage of the connectivity threshold goal met. As noted above, the connectivity threshold is 0.2 ft^3/s for all study reaches. To illustrate how these projects spatially influence summer streamflow conditions, we created a schematic for Upper Green Valley Creek and Purrington Creek (Figure 47). This schematic includes only implemented projects and assumes that any flow contributed by a project remains instream through the treatment reach. In other words, the schematic does not account for losing reaches or other factors that could result in a decrease in streamflow conditions. Losing reaches and/or the impacts of groundwater pumping near the stream channel could negate any gains made by these projects (depending on the type of water year, the level of the groundwater table, and the amount of groundwater pumping occurring in the area). However, this schematic is useful in understanding how implemented streamflow enhancement projects could impact streamflow conditions spatially in the watershed.

Table 7. Implemented streamflow enhancement projects in the Upper Green Valley and Purrington Creek watersheds.

Project Name	Watershed	Project Type	Avg. Daily Flow (ft^3/s)
Green Valley Ranch Irrigation Efficiency (Rued)	Purrington Creek	Water Conservation	0.35
Campbell	Upper Green Valley Creek	Rainwater catchment	0.044
Shook	Upper Green Valley Creek	Rainwater catchment	0.022
Shaw	Upper Green Valley Creek	Rainwater catchment	0.022
JFW reservoir release	Upper Green Valley Creek	Water release	0.05
Green Valley Farm and Mill reservoir release	Upper Green Valley Creek	Water release	0.1

Table 8. Implemented streamflow enhancement projects in the Upper Green Valley Creek watershed included in evaluation.

Project Name	Project Type	Avg. Daily Flow (ft^3/s)	% Treatment Reach Goal
Campbell	Rainwater catchment	0.044	22%
Shook	Rainwater catchment	0.022	11%
Shaw	Rainwater catchment	0.022	11%
JFW reservoir release	Water release	0.05	25%
Green Valley Farm and Mill reservoir release	Water release	0.1	50%
Total		0.238	119%

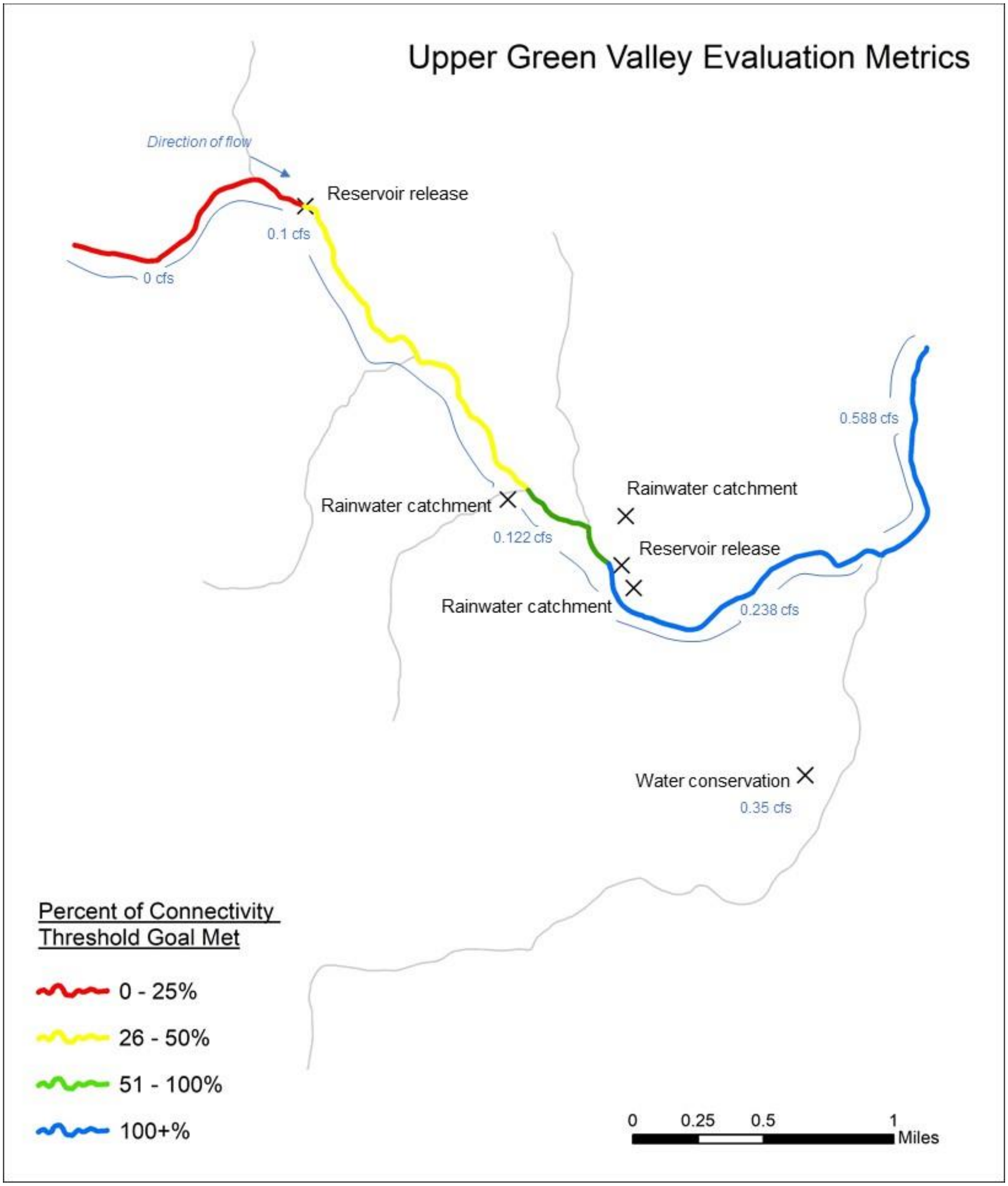

Figure 47. Project Evaluation Metrics: Daily average flow contributed by and percent of connectivity goal met through implemented projects in the Upper Green Valley and Purrington creek watersheds.

Figure 47 is also useful in identifying priority reaches where projects are needed in order to achieve connectivity. For example, the Partnership might prioritize projects located in the watershed where the percent of the connectivity threshold goal met is less than 50%. This would allow us to meet 100% of our goal throughout the full extent of the study reaches.

Through future streamflow gaging, we will continue to document days of pool disconnection in each reach in response to different types of water years. These data will aid in determining whether projects are increasing the probability of juvenile survival during the summer season or whether additional work is required.

6 Permitting and long-term considerations

This section (a) provides an overview of permitting considerations for the streamflow improvement projects recommended above, (b) includes a preliminary Water Availability Analysis (WAA) for Upper Green Valley Creek (preparation of a WAA is necessary for any new water right application), and (c) describes two mechanisms for ensuring that water saved through streamflow projects remains instream.

This SIP is not intended to be a comprehensive guide to permitting requirements. It should be viewed as information only, and not as legal advice. Anyone considering an instream flow project — or any change to a water right — should consider seeking the advice of an attorney with expertise in water right law.

6.1 Permitting considerations for storage and forbearance projects

Some of the projects recommended above will require new water rights and/or changes to existing water rights. For example, projects that encompass seasonal storage of water (e.g., diversion in winter for summer use) will require an appropriative water right if the source is a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 6.1.4). Water users may also be required to notify CDFW as part of the Lake and Streambed Alteration program (Fish and Game Code Section 1600). Below we provide an overview of some of the likely water rights permitting pathways for various project types.[6]

As described above, Green Valley Creek (from its confluence with the Russian River upstream) and Atascadero Creek (from its confluence with Green Valley Creek upstream) are fully appropriated from June 15 through October 31.[7] As such, the Water Board will not accept any new permits to appropriate water from those reaches, or upstream sources which contribute to those reaches, during that time period.[8] Since the goal of the streamflow improvement projects is to reduce rather than encourage

[6] Addition information is available in TU's Guide to Water Rights for Small Water Users at https://www.tu.org/wp-content/uploads/2019/05/Trout-Unlimited.-A-Guide-to-CA-Water-Rights-final-full-resolution.pdf and on the Salmonid Restoration Federation's website at https://www.calsalmon.org/programs/guidance-complying-californias-water-laws (Guidance on Complying with California's Water Laws) and https://www.calsalmon.org/programs/water-rights-education (Water Rights Education).

[7] State of California, State Water Resources Control Board, Exhibit A, Water Right Order 98-08, Declaration of Fully Appropriated Stream Systems, November 19, 1998.

[8] See Water Code Sec. 1206(b); "As described in Order 89-25 and subsequent orders, any declaration that a stream system is fully appropriated encompasses all upstream sources which contribute to the stream system if, and to the extent that, such upstream sources are hydraulically continuous to the stream system." https://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/

water diversion during the June through October time period, it is unlikely that Upper Green Valley Creek's fully appropriated status would hinder project permitting efforts, but it is nevertheless an important permitting consideration.

6.1.1 Roofwater harvesting

As described above, rainwater harvesting can 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 California legislature has clarified that a water right permit is not required for rainwater capture and storage.[9] For projects that reduce the quantity of water that users divert in the dry season with the intention of improving streamflow, landowners, project partners, and funders should take steps to ensure that reductions in water use under existing water rights are realized as instream benefit (e.g., through an instream dedication and/or forbearance agreement) (see Section 6.4).

This approach has been implemented successfully in Salmon Creek (Sonoma County)[10] where GRRCD, OAEC, Prunuske Chatham Inc., and NOAA Restoration Center (NOAA-RC) piloted an approach to offset dry season use through winter rainwater harvesting,[11] in Chorro Creek where Morro Bay National Estuary Program and NOAA-RC installed rainwater tanks on Cal Poly San Luis Obispo campus, [12] and throughout the Russian River tributaries through the work of the Partnership. In these cases, landowners typically agreed to cease or reduce dry season use of water from extractive sources and signed forbearance agreements (covenants that run with the land restricting use of water from these sources) with the project proponent.

6.1.2 Residential tank storage

Many residential water users adjacent to streams divert under riparian rights, which by their nature do not allow for seasonal storage. As such, storage and forbearance projects with residential water users who divert water from a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 6.1.4) will require an appropriative water right. Most residential diversions will be small enough to qualify for an expedited permitting pathway under the Small Domestic Use Registration (SDU) program. The registration program provides a faster, easier, and less costly way to obtain an appropriative water right that allows for storage, and SDUs are one of four types of registrations in California.[13] A SDU allows the water user to obtain the right to directly divert up to 4,500 gallons per day and to store up to 10 acre-feet per year. This could be a viable pathway for projects with residential

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[9] Water Code §10574; 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; "Restoring Salmon Creek" video at https://videos.fisheries.noaa.gov/detail/video/3447931845001/salmon-creek-restoration

[12] https://issuu.com/cafes.calpoly.edu/docs/agriview_fall_2013 (see page 11)

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

users in Upper Green Valley Creek, provided the diversion season falls outside the window in which Green Valley Creek (and its tributaries) are fully appropriated, June 15 through October 31.

This residential tank storage approach has been implemented successfully in the Mattole River watershed through Sanctuary Forest's Water Storage and Forbearance Program (and elsewhere), and more information is available in Legal Options for Streamflow Protection (Sanctuary Forest 2008). Sanctuary Forest's approach has included installing tank storage sufficient to satisfy residential potable water demand for the dry season, restricting diversion during the dry season (while the water user relies on the stored water), and establishing rotation schedules among multiple diverters when streamflow falls below certain thresholds. These terms and conditions are implemented through the combination of a forbearance agreement, an SDU issued by the State Water Board, and a Streambed Alteration Agreement issued by CDFW.

6.1.3 Agricultural water storage

Storage and forbearance projects with agricultural water users who divert water from a stream, a spring that flows off the water user's property, or a subterranean stream (see Section 6.1.4) will also require an appropriative water right. If a new right is required, water users may be able to obtain a Small Irrigation Use Registration (SIU) for diversions to storage that do not exceed 20 acre-feet per year for irrigation, frost protection, or heat control of currently cultivated lands. Again, the diversion season must fall outside the window in which Green Valley Creek (and its tributaries) are fully appropriated, June 15 through October 31. A summary of the registration options is provided in Table 9.

Table 9. Summary of water right registrations.

	Small Domestic Use Registration (SDU)	Small Irrigation Use Registration (SIU)
Max Quantity	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	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	Only for (1) offstream reservoirs existing or proposed on cultivated lands or (2) onstream reservoirs on Class III streams
Geography	No restriction	Currently limited to North Coast Instream Flow Policy Area**
Renewal	Every 5 years	Every 5 years

More information: https://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).

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

6.1.4 Groundwater use

For storage and forbearance projects where the source of the water is groundwater, an appropriative water right may or may not be required. Permitting requirements depend on the nature of the groundwater being pumped. The two legally-recognized categories of groundwater are percolating groundwater and subterranean streams. If water pumped from a well is percolating groundwater, it is not subject to the permitting jurisdiction of the State Water Board. But where well water is being pumped from a subterranean stream, it is treated like surface water. As such, if a water user seeks to pump and store water from a subterranean stream, a water user would be required to obtain an appropriative water right for seasonal storage and use, as in the cases above.

It is often unclear whether a well is extracting from percolating groundwater or a subterranean stream. Making this determination with any certainty requires at least site-specific data and the opinion of qualified professionals. For the area of Upper Green Valley Creek, the Water Board has prepared draft maps delineating the likely extent of known subterranean streams based on available data and best professional judgment. Although the SWRCB has not formally adopted the maps,[14] SWRCB has made clear that they can provide guidance:

> "The State Water Board can consider the delineation maps and supporting information on a case-by-case basis to assist in determining whether a particular groundwater well is subject to the State Water Board's permitting authority even if the delineation maps are not adopted."[15]

In areas where no such maps are available, it may be safe to assume that the closer a given well is to a surface stream, and the more influence it has on surface streamflow, the more likely it is to be determined to draw from a subterranean stream and thus be subject to surface water permitting requirements. That said, all groundwater is legally presumed to be percolating groundwater unless and until sufficient evidence is developed to show that it is, in fact, a subterranean stream.

The uncertainty around whether groundwater diversions are considered percolating groundwater or subterranean streams makes it difficult for water users to understand what is required of them and hinders the ability of project proponents to anticipate permitting requirements in advance. This is especially important for projects that employ a storage and forbearance approach, as how the source of groundwater is categorized can be the difference between a simple, low-cost project or a high-cost, lengthy, and potentially infeasible project. Greater clarity would improve the ability of project proponents to conduct outreach, weigh pros and cons with landowners, assess project feasibility, estimate timelines and cost, and hedge against the sentiment that "no good deed goes unpunished" in the application of permitting requirements, especially with landowners who are willing to pilot these approaches.

6.1.5 Water right permitting challenges

As described above, one of the best strategies for enhancing streamflow and increasing water supply resilience in the Russian River and other coastal watersheds is to help water users switch the timing of diversion from the dry season (when demand is highest and flow is lowest) to the wet season (when demand is lowest and flow is highest). Most of these projects require a new appropriative right

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[14] They include this disclaimer: "Because the delineated areas on this map were based on information readily available at the time of its development, this map does not claim to represent all of the subterranean streams or potential stream depletion areas that exist in the area. Site specific investigations will be needed to verify the existence of subterranean streams or potential stream depletion areas."

[15] Division of Water Rights, State Water Resources Control Board, California Environmental Protection Agency, 2013, Revised Sections 6.2, 6.9, and 7 and Supplement to Appendix D of the Substitute Environmental Document Prepared for the Policy for Maintaining Instream Flows in Northern California Coastal Streams.

authorizing the new wintertime diversion to storage. A robust strategy for salmonid recovery requires working with many private water users at scale, and one of the major challenges to working at scale is the expense and length of the appropriative water rights process, which is oftentimes just as labor-intensive for small projects as it is for larger ones.

Storage and forbearance projects typically create a small decrease in proportional streamflow during the winter, coupled with a much larger proportional increase in the summer months. Unfortunately, the existing water right process is set up to closely scrutinize the wet season impacts, but not provide applicants credit for the dry season benefits. The registration pathway (described above) is a viable option for moving through the permitting process more expeditiously, but if a water user does not fit neatly within that program or opts to obtain a full appropriative right (which may be preferable under some circumstances), the wintertime diversion is subject to a level of scrutiny similar to a project that does not improve instream flow. This negatively impacts the ability to achieve benefits at scale because it makes it difficult to implement projects. Water users may be reluctant to get involved in a potentially lengthy and unpredictable process, water right permitting is unlikely to fit neatly within public grant timelines, and restrictive wintertime permit terms provide an incentive for water users to simply continue diverting, legally, throughout the summer (usually under riparian rights).

There are ways to navigate these challenges. Some – like expediting the review of streamflow enhancement projects, waiving fees for Section 1707 petitions, and providing staff support throughout the process – are being employed by the State Water Board and CDFW, and are critical to reducing timelines and transaction costs. The North Coast Instream Flow Policy also contains a provision (Section 3.3.2.5) which is designed to give the State Water Board staff broad discretion to waive the regular process for projects that will have net beneficial effects on streamflow (SWRCB 2014). We recommend that, to the extent that agencies can apply existing authorities (such as the one available under Section 3.3.2.5) in ways that can help users make these changes, they should do so.

6.2 Flow release projects

6.2.1 Flow release permitting

The permits required for a flow release will vary depending on the source of the water being released and the nature of the release. At a minimum, a water user interested in a flow release should consult with the State Water Board, the Regional Water Board, CDFW, and NOAA/NMFS to determine what permits are necessary.

A water user or project proponent will first want to confirm that the water intended for release was obtained legally. Water right permitting requirements will vary depending on (a) the nature of the water being released (the source, the method in which it was obtained, whether it was stored, and the basis of right under which it was obtained), and (b) the nature and purpose of the flow release. One of the major

questions is whether a water right change is necessary to implement the flow release. Traditionally, this has included adding a new purpose of use (fish and wildlife preservation and enhancement) and a new place of use (a reach of stream). For more information about these types of changes (which occur under Water Code Section 1707), see Section 6.4.2. Examples of water rights changes for flow release projects include the Gallo Glass Company's flow release on Porter Creek (a Russian River tributary) and the Camp Meeker Recreation and Park District's release on Dutch Bill Creek.
Regional Water Board permits may or may not be required, depending on the nature of the discharge. Water that has been previously captured and stored pursuant to a water right (e.g., in an agricultural pond) may not require a discharge permit, though it may be necessary to perform some water quality testing to ensure that the release will not adversely impact the receiving stream (by increasing water temperature, for example). The Regional Board may also want to inspect the source pond for blue-green algae and other water quality concerns. Discharges of groundwater to surface water may require a discharge permit. In many places in Sonoma County, most associated with ultramafic geology, wells yield water with relatively high arsenic, chrome, copper, nickel and other constituents that may pose a concern. The Regional Board encourages projects involving flow releases that benefit the environment, has waived fees for flow releases to benefit salmonids in the past, and will collaborate with parties to streamline permitting that is required.

Water users should consult with NMFS regarding the federal ESA, and with CDFW regarding the California ESA. Depending on the nature of the release, it could also fall under CDFW's authority under Fish and Game Code Section 1600.

Section 9 of the federal ESA prohibits the taking of any species listed as either "threatened" or "endangered" under the Act. "Taking," in this context, means to kill, harm or otherwise interfere with individuals of a listed species. While the objective of a flow release program has quite the opposite intention (i.e., to protect species), some program participants may elect to acquire incidental take coverage from NMFS to protect themselves from potential legal liability in the event something unintentionally goes wrong that results in harm to the fish. Several incidental take permitting options are available to NMFS, and the agency is currently working with CDFW on recommendations for the most efficient permitting pathway for flow release projects. Those interested in obtaining such permits should contact a NMFS or CDFW representative.

6.2.2 Flow release challenges

The release of stored water into a stream for the benefit of aquatic species is a relatively new strategy. Yet to be determined is a practical and scientifically sound process for determining when a release should start and end, what the release rate should be, and how to monitor and evaluate potential threats to water quality, as well as who will take responsibility for making these determinations. The Partnership has attempted to address questions of release rate and duration in consultation with various agencies on a case-by-case basis, but transforming this from an ad hoc approach to a longerterm and more widespread solution requires addressing the risks to involved parties and identifying a stable funding source for the entities charged with flow release coordination, permitting, monitoring, and reporting.

During the 2011-15 drought, some flow release projects obtained regulatory assurances from NMFS and CDFW by signing Voluntary Drought Initiative (VDI) Agreements. These agreements described conditions under which the agencies would exercise enforcement discretion, without actually providing an incidental take permit, and they were limited to the emergency drought declaration period established by the State of California. The VDI agreements clarified the roles and responsibilities of each party as they related to the flow release and specified the decision-making process used to determine the timing (start and end dates) and rate of the release. The VDI program was discontinued once the state drought declaration was terminated. The Partnership and cooperating landowner partners have succeeded in continuing the flow releases initiated during the drought, but — ironically — the flow releases have become harder to implement in the absence of the tools, like the VDI, that the drought period provided. The end of the VDI program highlights a major obstacle to implementing water release projects in a timely, reliable and scientifically sound manner.

As noted above, the VDI program was tied to the state's emergency drought declaration. But that declaration was largely based on the condition of the state's drinking water supplies as affected by the drought, rather than on its landscape and fisheries impacts. As Section 2.3.3 illustrates, the drought had a cumulative and lingering impact on streamflow conditions in Upper Green Valley Creek that persisted after the drought declaration was rescinded. Future drought-related programs intended to address streamflow to benefit fisheries should consider how long drought-related impacts on streamflow tend to persist and should continue to provide expedited pathways and tools to address those impacts.

As described above, the permitting pathway for a flow release can be uncertain, cumbersome, time-consuming and potentially expensive. Inter-agency coordination on flow release permitting is essential in continuing on-going flow releases and encouraging future projects. Over the past year, staff from the Santa Rosa NOAA Fisheries office have initiated an effort to develop a programmatic safe harbor agreement to provide a structure for water releases in the Upper Green Valley Creek watershed, collaborating with Partnership members to define this structure and identify issues to be addressed. But CDFW has declined to participate in this process, so it would only provide regulatory certainty on the federal level, leaving state-level requirements to continue to be worked out for each proposed release individually. And while it is generally agreed that the RCDs are best situated to act as the permittee and coordinate any water release program, many questions remain. Not least among these is identifying a source of funding for program administration and coordination, monitoring and reporting. The Partnership strongly supports the concept of a safe harbor agreement for water releases, but we question the value and longevity of a program that is not coordinated among all of the pertinent regulatory agencies.

6.3 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 existing 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 Upper Green Valley Creek watershed, we performed a preliminary set of calculations required for a Water Availability Analysis.

These calculations represent 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 in the watershed — in this case, the entire Green Valley Creek watershed — 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[16] to the amount of water requested by existing documented water rights holders (including appropriative and riparian rights). The resulting statistic of this analysis is the 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 five percent of unappropriated discharge, it is possible for more water to be appropriated.

We calculated Water Supply Table 10 for the water rights in the Green Valley Creek watershed (similar to those which would be required for submission to the State Water 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 information:

- Each water right is given an ID number (Application ID); this is a unique identifier for each water right application in the watershed.
- 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 USGS gage on Austin Creek (USGS Station 11467200, Austin Creek near Cazadero, CA) 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 SWRCB (2014).
- 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 gage scaled to the watershed of interest.

[16] Using an average of discharge from a USGS streamflow gauge such as the nearby Austin Creek gage, number 11467200, which was operated from 1960 to the present.

- 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.
- 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.

Our analysis indicates that there is additional water available for appropriation during the winter diversion season of December 15 through March 31: the percentage of remaining unappropriated water remains above 98 percent at all existing diversion points along Green Valley Creek and its major tributaries. The data presented in the first table indicate that additional appropriations from Green Valley Creek may be possible during this winter diversion season. Along with the analysis of human water needs described in Section 3, these data indicate that there is substantial opportunity to store water in winter for use in summer in the Green Valley Creek watershed while maintaining water needed for environmental processes.

Table 10. Water supply table for the winter season (December 15 thru March 31) for the 78 water rights in the Green Valley Creek watershed (sorted from upstream to downstream).

POD (Application ID)	watershed area above POD (sq mi)	Avg Annual precip of wshd above POD (in)	Ratio1	Diversion Season	Seasonal Unimpaired flow volume (AF)	Seasonal Water Right demand volume (AF)	Senior Demand Volume Along Path (AF)	Remaining unimpaired discharge, ac-ft, BEFORE NEW WATER RIGHT	Percentage of remaining unappropriated water BEFORE NEW WATER RIGHT
S025236	0.12	47.7	0.00	Dec 15 - Mar 31	147	0.179	-	147	100.00%
D031555	0.03	46.3	0.00	Dec 15 - Mar 31	38	0.06	-	38	100.00%
D031555	0.03	46.3	0.00	Dec 15 - Mar 31	38	0.10	0.06	38	99.85%
D030353	0.19	46.6	0.00	Dec 15 - Mar 31	224	1.25	-	224	100.00%
S025893	0.49	46.5	0.01	Dec 15 - Mar 31	572	0.00	1.25	571	99.78%
S025227	0.62	46.3	0.01	Dec 15 - Mar 31	716	0.19	1.25	715	99.82%
S025847	0.62	46.3	0.01	Dec 15 - Mar 31	717	0.00	1.45	715	99.80%
S016134	0.63	46.3	0.01	Dec 15 - Mar 31	736	0.21	1.45	735	99.80%
S025834	0.98	46.3	0.01	Dec 15 - Mar 31	1,136	0.03	1.66	1,135	99.85%
S025833	0.99	46.3	0.01	Dec 15 - Mar 31	1,143	0.02	1.69	1,142	99.85%
S025703	1.10	46.2	0.01	Dec 15 - Mar 31	1,275	0.03	1.71	1,273	99.87%
S025792	0.18	46.9	0.00	Dec 15 - Mar 31	217	0.24	-	217	100.00%

S025590	0.88	48.4	0.01	Dec 15 - Mar 31	1,062	0.11	0.24	1,062	99.98%
POD (Application ID)	**watershed area above POD (sq mi)**	**Avg Annual precip of wshd above POD (in)**	**Ratio1**	**Diversion Season**	**Seasonal Unimpaired flow volume (AF)**	**Seasonal Water Right demand volume (AF)**	**Senior Demand Volume Along Path (AF)**	**Remaining unimpaired discharge, ac-ft, BEFORE NEW WATER**	**Percentage of remaining unappropriated water BEFORE NEW WATER RIGHT**
A010915	1.18	47.8	0.02	Dec 15 - Mar 31	1,409	0.00	0.38	1,409	99.97%
A010915	1.32	46.2	0.02	Dec 15 - Mar 31	1,526	0.00	0.38	1,526	99.98%
S015906	1.18	47.8	0.02	Dec 15 - Mar 31	1,409	0.00	0.38	1,409	99.97%
S025890	1.14	47.9	0.02	Dec 15 - Mar 31	1,368	0.00	0.38	1,367	99.97%
S026853	0.11	42.3	0.00	Dec 15 - Mar 31	118	0.60	-	118	100.00%
S025889	1.15	47.9	0.02	Dec 15 - Mar 31	1,374	0.09	0.98	1,373	99.93%
S027435	1.17	47.8	0.02	Dec 15 - Mar 31	1,401	0.12	0.83	1,400	99.94%
A011315	3.01	46.5	0.04	Dec 15 - Mar 31	3,501	0.00	0.84	3,500	99.98%
S025983	3.02	46.5	0.04	Dec 15 - Mar 31	3,522	0.00	0.81	3,521	99.98%
S025354	6.03	45.5	0.08	Dec 15 - Mar 31	6,875	0.00	0.81	6,874	99.99%
S017651	13.04	44.5	0.17	Dec 15 - Mar 31	14,538	5.60	3.26	14,535	99.98%
NJ000022	13.15	41.4	0.16	Dec 15 - Mar 31	13,620	0.00	8.86	13,611	99.93%
NJ000005	13.78	43.8	0.18	Dec 15 - Mar 31	15,103	0.00	8.86	15,094	99.94%
NJ000005	13.89	41.7	0.17	Dec 15 - Mar 31	14,504	0.00	8.86	14,496	99.94%
A029502	0.03	44.5	0.00	Dec 15 - Mar 31	34	12.60	-	34	100.00%
A029502	0.03	44.5	0.00	Dec 15 - Mar 31	34	12.60	12.60	22	63.24%
S022777	17.89	43.7	0.23	Dec 15 - Mar 31	19,559	18.49	52.55	19,506	99.73%
S019193	0.07	41.6	0.00	Dec 15 - Mar 31	69	0.80	-	69	100.00%
A030796	0.07	41.6	0.00	Dec 15 - Mar 31	69	48.00	0.80	69	98.85%
D031651	0.05	41.1	0.00	Dec 15 - Mar 31	53	1.30	-	53	100.00%
A032961	18.18	43.6	0.23	Dec 15 - Mar 31	19,854	21.32	102.65	19,752	99.48%
POD (Application ID)	**watershed area above POD (sq mi)**	**Avg Annual precip of wshd above POD (in)**	**Ratio1**	**Diversion Season**	**Seasonal Unimpaired flow volume (AF)**	**Seasonal Water Right demand volume (AF)**	**Senior Demand Volume Along Path (AF)**	**Remaining unimpaired discharge, ac-ft, BEFORE NEW WATER RIGHT**	**Percentage of remaining unappropriated water BEFORE NEW WATER RIGHT**
S022557	18.18	43.6	0.23	Dec 15 - Mar 31	19,854	0.24	124.29	19,730	99.37%
A032961	18.18	43.6	0.23	Dec 15 - Mar 31	19,858	21.32	124.53	19,734	99.37%
A031955	18.18	43.6	0.23	Dec 15 - Mar 31	19,854	21.32	145.85	19,709	99.27%

A031955	18.18	43.6	0.23	Dec 15 - Mar 31	19,858	21.32	167.17	19,691	99.16%
S022558	18.18	43.6	0.23	Dec 15 - Mar 31	19,858	12.03	188.49	19,670	99.05%
S025714	0.04	52.0	0.00	Dec 15 - Mar 31	50	0.05	-	50	100.00%
D032713	0.11	50.4	0.00	Dec 15 - Mar 31	145	0.60	-	145	100.00%
S027297	0.11	50.4	0.00	Dec 15 - Mar 31	145	0.19	-	145	100.00%
D032464	0.78	51.9	0.01	Dec 15 - Mar 31	1,017	1.00	0.85	1,016	99.92%
S025263	0.87	51.8	0.01	Dec 15 - Mar 31	1,126	0.05	1.79	1,124	99.84%
S025243	1.86	50.6	0.03	Dec 15 - Mar 31	2,358	0.39	-	2,358	100.00%
S025594	1.87	50.6	0.03	Dec 15 - Mar 31	2,373	0.00	2.28	2,371	99.90%
S025690	1.89	50.5	0.03	Dec 15 - Mar 31	2,387	26.40	2.28	2,384	99.90%
A032936	2.99	48.7	0.04	Dec 15 - Mar 31	3,648	11.66	-	3,648	100.00%
S027791	2.99	48.7	0.04	Dec 15 - Mar 31	3,648	7.73	11.66	3,637	99.68%
S027330	3.39	48.1	0.05	Dec 15 - Mar 31	4,085	2.40	19.39	4,066	99.53%
A012330	3.44	48.0	0.05	Dec 15 - Mar 31	4,138	0.00	21.79	4,116	99.47%
S008502	3.44	48.0	0.05	Dec 15 - Mar 31	4,138	1.44	21.79	4,116	99.47%
S012930	3.56	47.8	0.05	Dec 15 - Mar 31	4,262	2.96	23.23	4,239	99.46%
A020798	0.07	48.5	0.00	Dec 15 - Mar 31	83	14.08	-	83	100.00%
A021919	0.53	50.3	0.01	Dec 15 - Mar 31	672	45.00	-	672	100.00%
A025325	0.64	52.2	0.01	Dec 15 - Mar 31	839	1.41	-	839	100.00%
A021658	0.30	45.5	0.00	Dec 15 - Mar 31	344	180.00	-	344	100.00%
A029610	0.47	48.3	0.01	Dec 15 - Mar 31	568	9.50	-	568	100.00%
POD (Application ID)	**watershed area above POD (sq mi)**	**Avg Annual precip of wshd above POD (in)**	**Ratio1**	**Diversion Season**	**Seasonal Unimpaired flow volume (AF)**	**Seasonal Water Right demand volume (AF)**	**Senior Demand Volume Along Path (AF)**	**Remaining unimpaired discharge, ac-ft,**	**Percentage of remaining unappropriated water BEFORE NEW WATER RIGHT**
S026037	5.60	48.7	0.08	Dec 15 - Mar 31	6,830	0.00	256.14	6,574	96.25%
S025250	5.62	48.7	0.08	Dec 15 - Mar 31	6,851	0.00	-	6,851	100.00%
S008709	5.94	48.4	0.08	Dec 15 - Mar 31	7,201	0.16	-	7,201	100.00%
A029333	5.86	48.5	0.08	Dec 15 - Mar 31	7,109	7.12	256.30	6,853	96.39%
S003106	5.94	48.4	0.08	Dec 15 - Mar 31	7,201	1.64	-	7,201	100.00%
S002720	5.94	48.4	0.08	Dec 15 - Mar 31	7,201	0.04	1.64	7,199	99.98%
A029333	5.86	48.5	0.08	Dec 15 - Mar 31	7,109	7.12	1.69	7,108	99.98%
S015923	6.11	48.2	0.09	Dec 15 - Mar 31	7,378	0.00	272.23	7,106	96.31%
S025237	5.94	48.4	0.08	Dec 15 - Mar 31	7,200	0.00	-	7,200	100.00%
A024780	5.94	48.4	0.08	Dec 15 - Mar 31	7,198	9.06	-	7,198	100.00%
A024761	31.37	44.8	0.41	Dec 15 - Mar 31	35,149	119.04	536.68	34,612	98.47%

A012877	2.05	41.6	0.03	Dec 15 - Mar 31	2,138	0.00	-	2,138	100.00%
A012877	2.05	41.6	0.03	Dec 15 - Mar 31	2,135	0.00	655.72	1,479	69.29%
A018522	33.90	44.5	0.44	Dec 15 - Mar 31	37,801	23.00	-	37,801	100.00%
S027648	0.04	47.5	0.00	Dec 15 - Mar 31	52	0.00	-	52	100.00%
D032989	0.04	47.5	0.00	Dec 15 - Mar 31	42	9.82	-	42	100.00%
S028035	0.03	47.5	0.00	Dec 15 - Mar 31	40	5.81	9.82	31	75.66%
Lowest point in the watershed	37.68	44.6	0.49	Dec 15 - Mar 31	42,057	0.00	694.35	41,363	98.35%

6.4 Mechanisms for keeping water instream

As mentioned above, water users, project proponents, and funders should take steps to ensure that the water secured through streamflow enhancement projects remains instream. We describe two ways to do so — executing forbearance agreements and completing water right changes — below. More information is available in A Practitioner's Guide to Instream Flow Transactions in California (SWIFT Working Group 2016) and at TU's Instream Flow Resources website.[17]

6.4.1 Forbearance agreements

Forbearance agreements are agreements between the water user and the project proponent that at a minimum specify the terms and conditions under which diversions can take place and those under which they must be ceased. They often include information regarding other project elements (e.g., project implementation details, roles and responsibilities for long-term maintenance, etc.). If a forbearance agreement is recorded on the deed, it would run with the land and bind future owners of the property. It does not apply to other water users who are not party to the agreement. Forbearance agreements have been widely used across coastal California.

6.4.2 Instream dedications (Water Code Section 1707)

Under Water Code Section 1707, water users may file a petition to change their existing water right to add fish and wildlife preservation and enhancement as a purpose of use and a stream reach as a place of use. Doing so enables the user to dedicate a water right — or a portion of a water right — to instream beneficial uses.

There are two primary benefits of making a change pursuant to California Water Code Section 1707. First, it protects appropriative water right holders against a claim of abandonment or forfeiture. If a water user is diverting under an appropriative water right and ceases diversion during the dry season,

[17] https://www.tu.org/california/resources/

the right could be lost due to non-use. As such, it is important to ensure that the water use for fish and wildlife is a recognized purpose of use and reported as such. Second, doing so provides legal recognition of the water being used instream. This is critical for ensuring that the water is not considered to be available for appropriation by new permittees and, if enforced, can protect against use by other (junior) water users.

There may be cases where a water right change is not as necessary — for example, where the landowner has a riparian water right (the risk of loss through non-use is negligible), where the water no longer diverted is geographically protected from diversion by others (now and in the future), or on small projects where cost is a factor (if the transactions costs of the change are high relative to the overall project cost).

These two tools are often presented as either-or, but they are two entirely different instruments, and their utility depends on what a project proponent and water user intend to accomplish. A water right change provides for recognition of an instream right and the ability to constrain the behavior of other water users, which are unachievable with use of a forbearance agreement alone. Since a forbearance agreement typically provides for a direct and enforceable relationship between the project proponent and water user, which is not part of a water right change, it affords benefits that are unachievable through a water right change alone. In many cases, a project proponent may decide that the prudent path is to use both.

7 Conclusion

Upper Green Valley Creek is a critical stream for endangered coho in the Russian River basin. It was the last stream within the watershed to support three consecutive year classes of wild coho salmon and was the primary source of broodstock fish used to initiate the Coho Program's effort to restore native coho salmon populations. Green Valley Creek also appears to be important in terms of overwinter growth and commonly produces the largest outmigrating coho smolts observed in the life cycle monitoring streams within the lower Russian River basin. This size advantage may improve the chances of coho completing their life cycle by returning to spawn as adults.

Insufficient dry-season streamflow in Green Valley Creek has had a considerable negative impact on rearing juvenile salmonids in most recent years and is a significant limiting factor to local coho salmon recovery. On average, approximately 40% of the fish-bearing reaches of Upper Green Valley Creek sampled by CSG between 2013 and 2017 became dry or intermittent during the summer months, impacting nearly half (46%) of the juvenile salmon and steelhead rearing in Green Valley Creek in those years.

In contrast, Purrington Creek was completely wet for the entire summer in all sample years but 2015, when just 5% of the stream became intermittent. This underscores the importance of Purrington Creek as a flow refuge for salmonids rearing in the Green Valley Creek watershed during the dry summer season, as well as for flow contributions to the reach of Green Valley Creek downstream of the confluence.

CSG documented a positive association between oversummer survival of juvenile coho salmon and streamflow, and also that juvenile coho salmon were able to survive the summer at high rates at streamflows of just tenths of a cubic foot per second. Remarkably high oversummer survival — 80 to 90% — was observed in the Upper Green Valley Creek study reach in multiple years despite relatively low average daily streamflows of just 0.05 to 0.20 ft^3/s. In 2015, however, when average daily flow fell to 0 ft^3/s, survival was only 2%. This extreme variability suggests that, while fish may do well in the wetter years, the system is sensitive to small changes in streamflow and may be particularly vulnerable under drought conditions.

CSG research suggests that current oversummer streamflow in Green Valley Creek, while able to support high survival of rearing juveniles in the wettest years, is generally insufficient to support the biological needs of rearing juvenile salmonids to full productivity.

As has been observed in other Russian River tributaries, a strong environmental predictor of summer survival of juvenile coho salmon in Green Valley Creek is the number of days of pool disconnection, with increased days of disconnection having a negative effect on survival. Comparisons of streamflow data with wetted habitat data have indicated that flows as low as 0.20 ft^3/s are sufficient to keep all pools connected within the Partnership's focus area on Green Valley Creek. The impact of returning streamflow equivalent to the connectivity threshold of 0.20 ft^3/s may vary significantly by year, depending on environmental conditions. In all cases, however, doing so will decrease the number of days that pools would otherwise be disconnected in any given dry season, thereby increasing the probability of fish survival.

Maintaining sufficient streamflow to support suitable DO concentrations — preferably above the regional objective of 6.0 mg/L — through surface water connection and inflow is critical for the survival of juvenile salmonids rearing in Green Valley Creek and its tributaries over the summer months. Because of the negative correlation between days of pool disconnection and DO, it is highly likely that maintaining pool connectivity through increased streamflow would also improve DO conditions in stream reaches that currently become intermittent over the summer months.

CSG's research provides strong evidence that increasing daily discharge, pool connectivity, wetted volume, and DO concentrations in salmonid-rearing reaches of Green Valley Creek would support increased survival of salmonids through the juvenile life stage. Each of these parameters would be positively affected by enhancing streamflow.

The Partnership's monitoring work suggests that human water use and diversion have an impact on streamflow during the dry season and that there is sufficient water in the Upper Green Valley and Purrington Creek watersheds to meet human needs on an annual basis if water use is managed according to seasonal variability.

The Partnership's work to restore a more natural flow regime and address the threat to summer rearing juvenile fish from water diversions complements other restoration planning and implementation efforts in the watershed. We recommend — and are pursuing — projects that reduce or eliminate direct dry season diversions from Upper Green Valley and Purrington creeks and its tributaries by agricultural, institutional, and residential users; release flow for anadromous fish; and explore infiltration and groundwater recharge opportunities.

As noted above, one of the major challenges to working at scale is the expense and length of permitting processes, which are oftentimes just as labor-intensive for small projects as they are for larger ones. Water users may be reluctant to get involved in a potentially lengthy and unpredictable process; restrictive wintertime permit terms provide an incentive for water users to continue diverting, legally, throughout the summer; permitting uncertainty makes projects harder to fund; and, as project costs increase, less work can be completed. It is critical that regulatory and funding agencies take a hard look at the bottlenecks and disincentives that water users trying to keep water instream face, and work with project proponents and water users to ease the permitting hurdles that projects must clear before implementation. The evaluation and regulation of beneficial, restoration-focused projects under the same set of rules as those for projects lacking such benefits only serves to hinder efforts to improve streamflow.

A primary goal of the Partnership is to complete projects that will keep pools connected by surface flow throughout the summer dry season (June through October), and in turn increase the probability of juvenile coho surviving the summer season. The connectivity threshold of 0.20 ft^3/s is being used by the Partnership to identify, prioritize, and evaluate projects in terms of their cumulative ability to attain pool connectivity throughout priority reaches. We estimate that the Partnership's suite of current and anticipated future projects could cumulatively add sufficient flow for the creek to meet estimated pool connectivity thresholds through our priority reaches.

While returning or forbearing streamflows equivalent to connectivity threshold will increase the probability of fish survival, flows greater than those required to maintain minimum connectivity will ultimately be necessary to increase juvenile production and achieve full population recovery. The literature shows that increasing summer discharge beyond minimum persistence flows would likely promote higher growth in juvenile salmon and, in turn, more adults returning to spawn. Efforts to improve streamflow in Upper Green Valley Creek are a critical step towards coho salmon recovery in the watershed.

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Appendix A. Recovery Plan actions implemented by the Coho Partnership

The 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 identifies the Upper Green Valley Creek subwatershed, the Purrington Creek subwatershed, and the Lower Green Valley Creek subwatershed as a Core Priority Area and a portion of the Atascadero Creek subwatershed as a Phase I Expansion Area for CCC coho. The Plan deems 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 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 oversummer 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 Partnership's efforts are consistent with DFW'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).

California Water Action Plan

This Partnership implements the following actions in the California Water Action Plan (California Natural Resources Agency et al. 2014):

- Action 4 – Protect and Restore Important Ecosystems.
    - Restore Coastal Watersheds: "The Department of Fish and Wildlife in coordination with other state resource agencies and other stakeholders, as appropriate, will develop at least 10 off-channel storage projects…along the California coast in strategic coastal estuaries to restore ecological health and natural system connectivity, which will benefit local water systems and help defend against sea level rise."
    - Enhance Water Flows in Stream Systems Statewide.

Wildlife Conservation Board, Strategic Plan Update, 2019-2024

The Partnership advances the Wildlife Conservation Board's Strategic Plan Update, 2019-2024 (Wildlife Conservation Board 2019):

- Goal B (Environmental Restoration and Enhancement).
    - Objective SI 1.6: Collaboratively identify and fund five upper watershed improvement projects each year that have a primary or secondary purpose of providing resilience to climate change.
    - Objective SI 2.3: Implement at least 10 projects each year that enhance stream flow, increase water resiliency and meet priorities in the California Water Action Plan).

Green Valley Creek Watershed Management Plan, Phase II

The project implements the following recommendations and actions in the Green Valley Creek Watershed Management Plan, Phase II (GRRCD 2014):

- Biological Resources Recommendations: Increase summer base flows.
    - Reduce water withdrawals and increase spring flow during summer rearing season while ensuring water security by developing alternative sources of water.
    - Improve riparian cover over the stream channel to reduce evaporation.
    - Monitor streamflows.
    - Educate landowners on water rights, water conservation, and conservation strategies designed to effectively use water.
    - Develop and implement a long-term water conservation program for agricultural and residential landowners within the watershed to improve summer base flows.

- Implementation Actions: Streamflow and Water Needs.
    - SWN1: Develop an Upper Green Valley Watershed water conservation program and task force.
        - SWN1a: Build upon existing water conservation efforts.
        - SWN1b: Assist agricultural producers in acquiring support through NRCS and RCD programs to develop water conservation measures.
        - SWN1c: Conduct watershed-wide workshops and encourage water conservation practices.
    - SWN2: Develop alternative water storage systems to reduce the dependency on diversions.
        - SWN2a: Rainwater catchment systems.
        - SWN2b: Review timing of diversions.
        - SWN2c: Develop off-channel ponds and distribution systems for agricultural producers.
    - SWN3a: Funding for recharge and groundwater study.
    - SWN5: Monitor effectiveness of water supply enhancement projects.