Lagunitas Creek Salmonid Habitat Restoration Priorities (SHaRP) Action Plan

2022

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Participating Organizations

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Acronyms

AGOL - ArcGIS Online

CCC - Central California Coast

CESA - California Endangered Species Act

CDFW - California Department of Fish and Wildlife

DPS - Distinct Population Segment

ESA - Endangered Species Act

ESU - Evolutionarily Significant Unit

GIS - Geographic Information System

HUC - Hydrologic Unit Code

LFA - Limiting Factors Analysis

NGO - Non-Governmental Organization

NOAA - National Oceanic Atmospheric Administration

NMFS – National Marine Fisheries Service

NPS - National Parks Service

OC-LC - Olema Creek-Lagunitas Creek

RCD - Resource Conservation District

SG-LC - San Geronimo-Lagunitas Creek

SHaRP - Salmon Habitat Restoration Prioritization

SIS - Species in the Spotlight

SPAWN - Salmon Protection and Watershed Network

Executive Summary

The Need to Set Restoration Priorities

Over the past 150 years, Pacific salmon and steelhead populations across the West Coast have declined to the point of requiring protections. In California, many of these species have been listed under the California Endangered Species Act and the federal Endangered Species Act. Much of this decline is from widespread loss and degradation of aquatic and riparian habitat caused by various human activities, including development, agriculture, logging, ranching, roadbuilding, and creation of fish passage barriers.

The California Department of Fish and Wildlife (CDFW) and the National Oceanic and Atmospheric Administration (NOAA) Fisheries salmonid recovery plans describe the many actions needed to recover the Central California Coast (CCC) Coho Salmon (*Oncorhynchus kisutch*) Evolutionary Significant Unit and CCC steelhead (*O. mykiss*) Distinct Population Segment. Given the all-encompassing nature of recovery actions described in the plans, they do not provide practitioners the detail needed to plan and implement the highest priority habitat restoration at the project and stream-reach scale.

The vast scale of landscapes in need of watershed and fish habitat restoration combined with the broad scope of recovery plans has often led to diffuse implementation of restoration projects across the landscape. While each individual project is often effective at improving conditions at the project site, the benefits of combined watershed-scale restoration efforts are often not realized given the space, both geographically and temporally, between projects. The resources needed to address watershed-scale impacts across the landscape greatly exceed those currently available.

About the Salmonid Habitat Restoration Priorities (SHaRP) Process

The Salmonid Habitat Restoration Priorities (SHaRP) process provides for a structured collaboration between representatives of resource agencies, non-governmental organizations (NGOs), California Native American tribes, academia, restorationists, landowners, and land managers to collaboratively identify the most limiting attributes for each salmonid life stage. Then the SHaRP effort builds upon the restoration actions described in recovery and local watershed plans, resulting in a reach-scale priority restoration plan with broad support from the organizations and individuals that participated in the process.

SHaRP in Lagunitas Creek

Lagunitas Creek is an independent population and is currently the largest persistent population of CCC Coho Salmon south of the Noyo River (Ketcham et al. 2004, NMFS 2012, Spence et al. 2015). The resilience of Lagunitas Creek Coho Salmon towards the southern extent of the species range is largely attributed to the concerted efforts of local stakeholders, NGOs, and agencies that monitor and perform restoration in the watershed (NMFS 2012). Lagunitas Creek has benefited from several important planning efforts that have helped shape restoration focus and implementation in the watershed. The focus area for SHaRP is the two hydrologic unit code (HUC) 12 watersheds with salmonids, which are the San Geronimo-Lagunitas Creek HUC 12 (SG-LC) and the Olema Creek-Lagunitas Creek HUC 12 (OC-LC).

Collaborative Decision Making

The SHaRP planning process leverages all available data and expert knowledge in a transparent and collaborative process to provide site and reach scale recommendations for restoration efforts. The Lagunitas Creek steering team is made up of NOAA Fisheries and CDFW representatives. The Lagunitas SHaRP meeting was attended by NOAA Fisheries, CDFW, California Department of Parks and Recreation, San Francisco Bay Regional Water Quality Control Board, Federated Indians of Graton Rancheria, Marin County, Marin Resource Conservation District, Marin Water, National Park Service, Turtle Island Restoration Network/SPAWN, Trout Unlimited, and the University of California at Berkeley. Participants that attended the SHaRP meeting were also given the opportunity to review this action plan and priority action maps.

Restoration Themes and Action Maps

The major themes for Lagunitas Creek were the need to: (1) increase the complexity of instream, floodplain, and off-channel habitat, (2) reduce fine sediment input, (3) increase water quantity during the dry season, and (4) remove barriers.

This action plan focuses on installing large wood and creating off-channel and floodplain habitat to address the lack of stream complexity. Diversifying the stream by creating instream and off-channel habitat was the primary restoration action developed during the SHaRP process. Creating off-channel and floodplain habitats provides additional rearing habitats for juvenile and smolt life stages. The significant spatial coverage suggested for this recommendation highlights expert opinion that while certain areas in the watershed have more complexity than others, overall, most of the watershed would benefit from returning to a more natural and complex functioning system. In Olema Creek there is a mobile knickpoint, a steep area caused by various downstream processes that is migrating upstream as it erodes, and is contributing to significant incision. It is a priority to add large wood and develop a project to investigate and treat the knickpoint and stop it from moving further upstream.

Sediment conditions were also determined to be a limiting attribute for the egg-fry life stage. Exclusion fencing in areas with active grazing is recommended and riparian restoration should be focused in areas where grazing is decreasing or has stopped to limit sediment inputs that jeopardize egg-fry life stage. Riparian restoration is a critical restoration need moving forward, as riparian vegetation keeps streams cooler, reduces sediment input into the stream, and is essential given current climate change scenarios. The addition of large wood will aid in the sorting of sediment. Gravel augmentation is recommended to develop more spawning areas and address the deficit of gravel supply due to dams in the watershed.

A lack of instream water also ranked as severely limiting the survival of adults, smolts, and summer juvenile. Restoration action recommendations include rerouting a Marin Water pipe to provide some additional flow to San Geronimo Creek and water infiltration projects at Roy's Redwoods to recharge groundwater. Participants recommended exploring beaver reintroduction in lower Lagunitas Creek below Nicasio Creek. Reintroducing beaver or creating beaver dam analogs has been shown in other salmonid bearing streams to slow down and spread-out water, recharge groundwater, and provide sustained flow during dryer months. Climate resiliency should be a focus in restoration designs and instream habitat restoration should be built to function during wet and dry years.

Barriers on Arroyo Creek, Larsen Creek, Upper San Geronimo Creek (locally known as the Dixon Weir), Quarry Gulch, and John West Fork should be remediated. With habitat improvement recommended around these barriers, treating these barriers is essential in ensuring access across life stages and during various environmental conditions.

How to Use This Plan

This plan describes the SHaRP process and provides a focused list of recommendations that stakeholders and agency staff agree are the highest priority restoration actions to recover Coho Salmon and steelhead. Voting and the discussions included provide background on the limiting attributes affecting the life stages. The high priority restoration actions to address the identified limiting factors are mapped in the priority Action tables (Table 2, Table 3) and maps (Figure 6, Figure 9). The Action maps point to specific areas on the landscape that would benefit from the identified restoration treatments.

- Chapter 1: Understanding SHaRP: This chapter introduces the reader to the SHaRP process and its application in Lagunitas Creek. It also gives background information about salmonids in Lagunitas Creek.
- Chapter 2: Methods: This chapter includes information about the Lagunitas SHaRP meeting, including the data collection and availability, the limiting attribute analysis process, and how restoration solutions were developed.
- Chapter 3: Lagunitas Creek Action Plan: This chapter begins with an overview of Lagunitas Creek and then discusses the San Geronimo-Lagunitas Creek Watershed limiting attributes, restoration action tables, and action maps. It ends with a discussion of the Olema Creek-Lagunitas Creek limiting attributes, restoration action tables, and action maps.
- Appendix A: Web Layer Glossary: A glossary of all the web layers available in the Lagunitas SHaRP ArcGIS online webmap.

Understanding SHaRP

1.1 What is SHaRP?

The Salmon Habitat Restoration Prioritization (SHaRP) project was initiated by California Department of Fish and Wildlife and National Oceanic Atmospheric Administration (NOAA) Fisheries for coastal Northern California. The SHaRP process (1) identifies potential high-quality salmon and steelhead habitat and strong extant populations (strongholds) at the watershed scale and (2) recommends restoration treatments to strengthen these areas.

1.2 The Need for SHaRP

In response to overall declines in salmonid populations, agencies and restoration professionals have focused restoration efforts on freshwater and estuarine life stages of salmon and steelhead. These restoration efforts have sought to address degraded habitat, reduced water availability, and poor water quality. Recovery plans have provided a framework to guide restoration and recover listed species by identifying the habitat needed to sustain species at the population level. Project proponents select actions from recovery plans to design projects, solicit funding, and implement work.

NOAA Fisheries and CDFW have recognized a need to provide more focus than what is included in the recovery plans. Thus, a collaborative planning process, known as Priority Action Coho Team (PACT), was initiated in 2012 for the Central California Coast (CCC) Evolutionarily Significant Unit (ESU) of Coho Salmon (*Oncorhynchus kisutch*) to prioritize recovery actions. This effort listed focused actions for specific watersheds based on the professional judgment of agencies and partners and included recommendations for habitat restoration, water management, and hatchery supplementation. While PACT was officially published in 2019, many of the restoration recommendations were developed closer to the 2012 initiation of the process, and many of the actions outlined have been partially addressed.

With continued declines in salmonid abundance and an urgent need to improve rates of recovery with finite resources, the agencies initiated a new approach to focus habitat restoration in coastal Northern California. In 2017, SHaRP was piloted on the South Fork Eel River.[1] The SHaRP effort was then expanded to Mendocino Coast watersheds, Lower Eel River, lower Russian River, and Lagunitas Creek. A steering team for Lagunitas was formed in early 2020 to tailor SHaRP to the specific needs and opportunities in the Lagunitas Creek watershed.

SHaRP builds on concepts and efforts identified in PACT and the recovery plans. However, SHaRP includes other listed salmonids, focusing on specific watersheds and projects with a more fine-scaled approach. The goal of SHaRP is to identify near-term habitat restoration actions as part of a watershed-level planning effort over a 10-year time horizon. The SHaRP process selects salmon and steelhead strongholds at the watershed scale and provides recommendations for specific restoration actions. This process is guided by the Pillars of SHaRP, described in the next section.

[1] SHaRP Webpage: https://www.fisheries.noaa.gov/west-coast/habitat-conservation/identifying-salmon-habitat-restoration-priorities-northern

1.3 Pillars of SHaRP

Regional differences in available data and stakeholders result in SHaRP efforts that will vary slightly across the watersheds. These pillars guide and define SHaRP as a process and are key to its successful implementation.

Social: SHaRP is a community planning effort. Fisheries agencies guide the process but do not dictate or determine the outcomes. NGOs, landowners, restorationists, fisheries experts, and habitat experts all contribute throughout the process.

Management: Fisheries agencies (CDFW and NOAA Fisheries) are heavily involved and aligned in SHaRP efforts. The resulting products will also be consistent with State and Federal Recovery Plans.

Multi-Species: All listed salmonid species in a focal area are explicitly considered in the SHaRP process, although one species may direct the initial focus.

Data and Science: Through the SHaRP process, the steering team seeks out all data and local expertise that may be relevant and makes it accessible to the SHaRP participants. Decisions are based on the (1) available regional data, (2) relevant scientific literature, and (3) expert opinions. These data are used to determine factors limiting salmonid growth and survival and, in turn, influence the recommendations for the type and location of the most appropriate restoration actions.

Decision: Decisions should be made while acknowledging data gap uncertainty rather than waiting until the optimal data are available. Decisions are based on a thoroughly described and documented transparent processes bounded by data and science.

Focus and Scale: Salmon populations are restored by identifying and enhancing areas of relative strength, which will ultimately seed surrounding areas. The SHaRP approach intends to produce a restoration plan that can most effectively focus limited restoration capacity and funding on the habitat that will most benefit salmon populations. The resulting SHaRP plan should identify sub-watersheds and smaller areas with potential for high-quality habitat and strong extant populations and recommend further strengthening of these areas.

1.4 Salmonids in Lagunitas Creek

CCC Coho Salmon and CCC steelhead (*O. mykiss*) are native to Lagunitas Creek. CCC Coho Salmon ESU and CCC steelhead Distinct Population Segment (DPS) are listed on the Federal Endangered Species Act (ESA). Occasionally non-listed salmonid species such as chum, pink, and stray Chinook salmon enter Lagunitas Creek. SHaRP focuses on only the ESA listed salmonid species (Coho Salmon and steelhead).

CCC Coho Salmon ranges from Punta Gorda in Mendocino County southward to Aptos Creek in Santa Cruz County. In 1994, the California Fish and Game Commission found that Coho Salmon south of San Francisco to Monterey Bay warranted listing as endangered under the California Endangered Species Act (CESA) (CDFG 2004). CCC Coho Salmon was first Federally listed as threatened in 1996 (61 FR 56138) and then subsequently reclassified as endangered in 2005 (70 FR 37160). In March 2005, Coho Salmon were listed as a CESA endangered species from Punta Gorda south to San Francisco (14 CCR § 670.5).

CCC Coho Salmon are a part of NOAA's Species in the Spotlight (SIS) initiative.[2] The SIS initiative, launched in 2015, focuses on nine species that NOAA Fisheries manages that are on the brink of extinction. Five-Year Priority Action plans were developed as part of a strategy to marshal resources to immediately targeted efforts that are vital for stabilizing CCC Coho Salmon populations and preventing their extinction. SHaRP is identified in the 5-Year action plan[3] as a high priority effort towards stabilizing the decline of Coho Salmon.

CCC steelhead were first listed as a federally threatened species in 2000 (65 FR 36074). On January 5, 2006, after an updated status review on several West Coast salmonid ESUs, NOAA Fisheries reaffirmed the threatened status of CCC steelhead and applied the DPS policy to the species. NOAA Fisheries noted that the resident and anadromous life forms of *O. mykiss* remain "markedly separated" as a consequence of physical, physiological, ecological, and behavioral factors and may thus warrant delineation as separate DPSs (71 FR 834). The listed DPS includes all naturally spawned anadromous steelhead populations in California streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun Bays eastward to Chipps Island at the confluence of the Sacramento and San Joaquin rivers.

1.5 Why SHaRP in Lagunitas Creek

Pacific salmon and steelhead have experienced a marked decline in abundance over the past 150 years. Lagunitas Creek CCC Coho Salmon are one of the most vulnerable populations of Pacific salmonids to the impacts of climate change (Crozier et al. 2019). Lagunitas Creek is an independent population and is currently the largest persistent population of CCC Coho Salmon south of the Noyo River (Ketcham et al. 2004, NMFS 2012, Spence et al. 2015). Over 17 years, the average number of adults is about 500, approximately 20% of this population's recovery target of 2600 (Spence et al. 2015). While the abundance of Coho Salmon in the watershed remains well below the 2600 individual target set by NOAA Fisheries, the resilience of Lagunitas Creek Coho Salmon towards the southern extent of the species range is largely attributed to the concerted efforts of local stakeholders, NGOs, and agencies working in the watershed (NMFS 2012).

Lagunitas Creek has benefited from several important planning efforts that have helped shape restoration focus in the watershed. CDFW released the "Recovery Strategy for California Coho Salmon" in 2004 which covered all actions needed to recover CCC Coho Salmon (CDFW 2004). NOAA Fisheries also released the "Final Recovery Plan for Central California Coast Coho Salmon Evolutionarily Significant Unit" and the "Coastal Multispecies Recovery Plan", which includes CCC steelhead and other coastal salmonids (NFMS 2012, NMFS 2016). A limiting factors analysis performed in 2008 by Stillwater Sciences identified winter habitat as the most limiting factor for Coho Salmon abundance (Stillwater Sciences 2008). Other efforts have covered specific aspects or spatial areas within the watershed (for example the "San Geronimo Valley Salmon Enhancement Plan" published in 2010 and the "Lagunitas Creek Watershed Unpaved Roads Sediment Source Site Assessment" in 2013 (Prunuske Chatham Inc. 2010, Stetson Engineers Inc. 2013). Marin Water also produced the "Lagunitas Creek Stewardship Plan" in 2011 which outlines regulatory and restoration actions that the water district and other stakeholders in

[2] Link to NOAA Fisheries Species in the Spotlight Webpage
[3] Link to the 2021-2025 CCC Coho Salmon Action Plan

the watershed should conduct to mitigate impacts that the operation of Kent Lake has on fishery resources (Marin Water 2011). These efforts have contributed significantly to focus of restoration projects implemented in the watershed.

In discussions with Lagunitas stakeholders regarding SHaRP, it became clear that the Lagunitas Creek SHaRP process could leverage the knowledge from previous planning efforts and look towards the next steps in restoration priorities through a SHaRP process. During early meetings with watershed experts, it was decided that the two HUC 12 watersheds that currently have salmonids should be treated as independent planning areas (Figure 1). The two HUC 12s with salmonids are the San Geronimo-Lagunitas Creek HUC 12 (SG-LC) and the Olema Creek-Lagunitas Creek HUC 12 (OC-LC) watersheds.

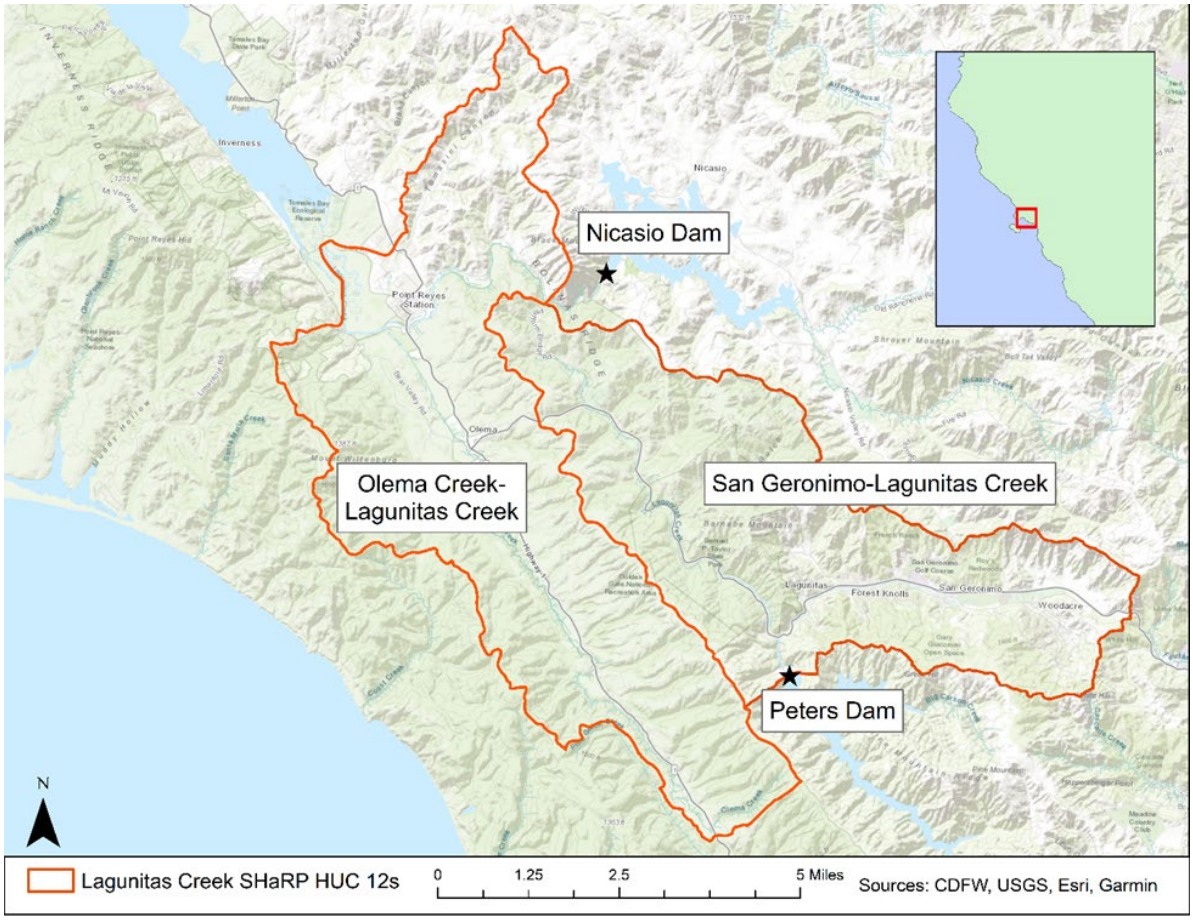

Figure 1. HUC 12 watersheds in Lagunitas Creek that currently support Coho Salmon and steelhead.

Methods

1.6 Preparing for Lagunitas SHaRP Meeting: Gathering Data

The steering team based its data-gathering strategy around the approach used for the South Fork Eel River SHaRP (South Fork Eel River SHaRP Collaborative 2021). One of the major differences between the two SHaRP processes was a transition to using ArcGIS Online (AGOL) as, unlike the South Fork Eel River SHaRP, the Lagunitas Creek SHaRP meeting was conducted virtually. AGOL allowed participants to virtually access all the compiled datasets on a single webmap. This webmap was controllable by individual users simultaneously, and participants could explore combinations of datasets at different spatial scales to suit their individual preferences.

Datasets that pertained to habitat conditions or salmonid population condition were collated. Some data already existed in a spatially represented form, while other data were transformed to be included in the AGOL webmap. An initial search relied on publicly available datasets, especially ones that CDFW and NOAA manage. The steering team easily included datasets like NOAA Fisheries' Coho Salmon and steelhead intrinsic potential, species distribution, and watershed boundaries in this search. Along with incorporating publicly available data, the steering team worked with stakeholders who conduct monitoring in the watershed to include the most current and Lagunitas-specific data. Marin Water and the National Parks (NPS), who conduct annual monitoring in the two HUC 12 watersheds, supplied biological and habitat data. Other stakeholders in the watershed, such as Marin Resource Conservation District (RCD), contributed local datasets that were developed into AGOL spatial layers. For a complete list of layers included in the Lagunitas SHaRP webmap, refer to the glossary in Appendix A.

After the initial effort by the steering team to compile relevant data into AGOL layers, a small group of watershed experts was asked to review and provide feedback. Changes to the AGOL layers were made based on its feedback. For example, certain habitat data in Olema initially displayed over the entire time series were changed to be expressed in three-year time steps to capture environmental fluctuations that may impact individual years of data and align with the three cohorts of Coho Salmon.[4] This review stage also helped spur discussion on additional datasets that may be important. After this meeting, additional habitat metrics, such as riffle frequency and primary pools in SG-LC, were added to AGOL. This collaborative step helped build on the foundation of data similar to that used in the South Fork Eel River and develop a more Lagunitas Creek-specific online tool that could ensure stakeholders had the data available to them to inform conversations during the SHaRP meeting.

1.7 Lagunitas SHaRP Meeting

The steering team moved forward with the stakeholders' recommendation and had one meeting covering both the SG-LC and OC-LC HUC 12 watersheds. The SHaRP meeting occurred on October 19-20, 2021. Due to COVID-19, the meeting occurred virtually. The invited participants included experts with specific salmonid habitat restoration experience or knowledge of Lagunitas Creek. Invited experts

[4] Coho Salmon exhibit a three-year life history and are thus often thought of and tracked as distinct cohorts within populations corresponding to when that group is at various life stages.

consisted of members from Federal, State, and Local governmental agencies, California Native American tribes, researchers, non-profits, academia, restoration practitioners, private landowners, and watershed groups with specific expertise in salmon and their habitat needs. The SHaRP meeting aimed to provide the maximum opportunity for participants to evaluate the available data and local observations and determine the best course for restoration in each area.

Watershed experts gave presentations to aid in the SHaRP participants' knowledge and shared understanding of the Lagunitas Creek watershed. The presentations were:

- Lagunitas Creek: Monitoring and Restoration of the Southern Stronghold for Coho Salmon (Eric Ettlinger, Marin Water)
- Olema Creek: Habitat and Juvenile Monitoring of Coho Salmon (Mike Reichmuth, National Park Service)
- Assessing habitat heterogeneity and intrapopulation diversity in Coho Salmon in the Lagunitas Creek watershed (Rachael Ryan, UC Berkeley)
- Lagunitas Creek Habitat Modeling and TUCP Monitoring (Jonathan Koehler, Marin Water)

Participants had access to the AGOL webmap (linked here) made for this effort. The steering team gave a presentation that reviewed all the AGOL data available. This information aided the participants in evaluating limiting factors and assigning restoration treatments to address those limiting factors.

1.7.1 Limiting Factor Analysis

Participants rated habitat attributes to determine what was most limiting in the survival of each life stage in the individual watersheds. To accomplish this virtually, the participants accessed a Mural developed by the steering team. Mural is a web platform that allows people to collaborate virtually. To ensure that all participants had a common understanding, the steering team presented salmonid life stage and attribute definitions at the meeting. This allowed for participants to be more consistent in their limiting factors determination.

1.7.2 Coho Salmon and Steelhead Life stages

Pacific salmon and steelhead exhibit complex life histories involving distinct life stages (Figure 2). Those life stages use nearly every portion of a watershed network, balancing risks with rewards; however, many of the habitats these fish have evolved to use have been drastically altered. Each life history faces challenges and risks, from habitat degradation in small tributaries to cumulative effects of watershed processes, estuarine conditions, from variable ocean productivity to predation and competition with other native and non-native species (Good et al. 2007). Given the wide range of habitats and ecological conditions that salmon and steelhead utilize and are dependent upon, identifying the restoration actions that will most effectively aid in recovery can be challenging.

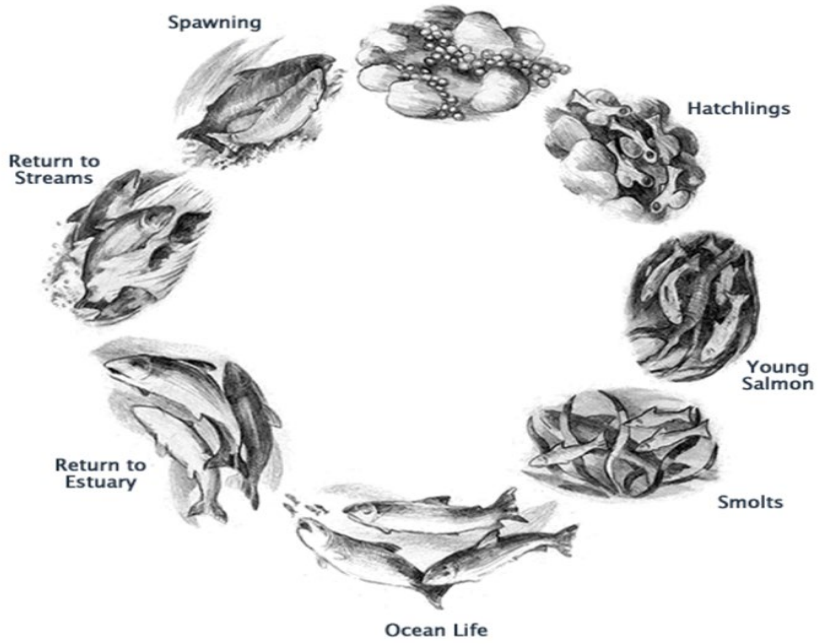

Figure 2. General salmonid life cycle. Credit: NOAA Fisheries

The life stage table (Table 1) was distributed before the meeting and was available in the Mural for participants to reference when voting on attributes.

Table 1: Description of Coho Salmon and steelhead life stages and habitat needs

Life Stage	Description	Habitat Needs
Egg-Fry	Refers to emergence of eggs in the gravels (redds) to young of the year (YOY). Eggs incubate for 1-2 months then hatch into alevins. Alevins remain in the gravel for another month. YOY emerge between December-May.	The redd site must remain stable throughout the egg incubation period and allow water to percolate through the gravel to supply oxygen to the developing embryos. Incubation requires continuous and stable surface flow of clean water, free of pollution and siltation. Egg and alevin are vulnerable to: -poor water quality -high water temperatures -scour from high flow events -early season reduction of surface flow resulting in drying of gravels prior to fry emergence
Summer Juvenile	Rearing summer juvenile salmonids include YOY (the previous spring's hatched juveniles) and parr (one year old juvenile fish). Parr are defined by size class criteria (fork length>= 100mm). They redistribute into available habitat and begin feeding. Coho Salmon prefer low velocity with woody debris cover, and steelhead prefer riffles and faster moving water.	Deep cool pools with cold water temperatures and high dissolved oxygen, available food sources, and shelter from predation, are critical for the survival of summer rearing juveniles. Riparian vegetation helps support some of the insects consumed by juveniles, provides cover from predators, limits solar radiation to streams keeping water temperatures cool, stabilize stream banks, and create habitat structures. Summer juvenile fish are vulnerable to: -poor water quality -low dissolved oxygen -poor accessibility to more habitat due to surface flow disconnections that occur during this season
Winter Juvenile	Rearing winter juveniles include YOY (the previous spring's hatched juveniles) and parr (one year old juvenile fish). It is a period when instream movement begins in an effort to access new habitat.	Large woody debris or downed wood in pools creates cover and refugia for the juvenile salmon to reside within the active stream channel during high velocity flows. Connectivity to off-channel, floodplain, wetland, and marsh habitat provide another source of refuge from high winter flow velocity, shelter from predators, and provide a rich food source for juvenile salmon. Winter juveniles are vulnerable to: -high flow velocities and poor access to flow refuge areas -access to rich food sources -predation from other aquatic animals and poor access to shelter

Life Stage	Description	Habitat Needs
Smolt	Juvenile salmon undergo a physiological change known as "smoltification" enabling them to transition, in estuaries or lagoons, for a life adapted to saltwater. Smolt outmigration to the lower river and estuary typically occurs from March-June.	Smolts need adequate flow and unobstructed passage from upstream rearing areas to migrate downstream to the lower river and estuary. Lower river habitat should provide habitat complexity and shelter from predators, refuge from high velocity storm events, and a primary food source for smolts. Estuaries should be deep to provide cool temperatures and buffered with freshwater to dilute seawater (Groot and Margolis 1991) facilitating the transition into the ocean. <u>Smolts are vulnerable to</u>: - disconnection from lower river because of low surface flow -high flow velocities with no access to flow refuge areas -predation from other aquatic animals and no access to shelter -high water temperatures; -poor water quality
Adults	Migrating adults return from the ocean or nearshore environment to spawn. Coho Salmon typically return from Nov-Jan usually after heavy rains, and steelhead typically return from late Dec-May. Steelhead adult life history uniquely requires continuously connected surface flow and unobstructed passage for upstream & downstream migration.	Adult spawners need adequate connected stream surface flow, cool water temperatures, deep pools, and shelter to rest and hide as they migrate upstream to spawning areas. Females seek clean, loose gravels of a specific size in highly oxygenated riffle habitats for laying their eggs. Maintaining continuous and stable surface flow connection throughout the spawning season provides access to upstream spawning areas and maintains cold oxygenated water for egg-fry life stage. <u>Returning adults are vulnerable to</u>: -poor water quality -high water temperatures - limited access to the river and upstream spawning habitat because of extended and periodic river mouth closures - poor access to spawning habitat because of early season disconnection of surface flow; -predation from other aquatic animals and poor access to shelter

1.7.3 Attributes

An attribute is a factor or process that influences multiple life stages. The steering team used recovery plans and watershed knowledge to identify attributes prior to the Lagunitas SHaRP meeting. During the meeting, participants agreed that an additional attribute, Food Availability and Primary Production should be considered for how limiting it was for each life stage. That attribute was added to the voting table during the meeting.

- **Anthropogenic Barriers:** Insufficient quantity of total habitat due to a human derived barrier. Includes partial or ephemeral anthropogenic barriers.
- **Instream Structural Complexity:** Decline of the instream habitat quality. Based on the degree of habitat complexity, and variety, includes the quantity and variability of stream depth and pools of varying sizes and depth
- **Off-Channel Habitats:** Loss and/or degradation of the peripheral habitat of streams and rivers, including floodplains, connected channels and areas that are periodically inundated during high flows.
- **Riparian Condition:** Degradation of the habitat adjacent to stream. Impairment of the near-bank environment to support plants including large trees whose roots help stabilize stream banks. Trees which provide shade, add primary production to the aquatic ecosystem. Includes the supply of mature trees into streams as large wood.
- **Sediment Conditions:** Reduction of the quantity or quality of spawning habitat due to changes to the background (natural) quantity, rate, and size of sediment inputs to the stream system. Includes input of fine sediment to the streams, and loss of gravel recruitment due to dams.
- **Water Quality:** Degraded water temperature, dissolved oxygen, turbidity with respect to its suitability for a salmon or steelhead, including toxins and pathogens.
- **Water Quantity:** Detrimental effects of deviations to the background (natural) amount and timing of water quantity instream, including low water flow and associated barriers to access, and high-water flows in the winter.
- **Food Availability and Primary Production:** Salmonid prey available for consumption

1.7.4 Attribute Rating

After all the information was shared and discussed among participants, they rated the attributes for each life stage in Mural. Each HUC 12 watershed had a separate attribute table (Figure 3). Participants voted on how limiting each attribute was to each life stage. Participants could select how limiting each attribute was for that life stage based on the below definitions.

- Least Limiting (green box): the attribute is not limiting survival at this life stage.
- Moderately Limiting (yellow box): the attribute somewhat limiting survival at this life stage.
- Most Limiting (red box): The attribute is a strong limiting factor at this life stage.

Participants also voted if they thought that the attribute would be more limiting under likely future climate change scenarios for that life stage. For example, more droughts are expected with climate change, so a participant would select the climate change box associated with the Water Quantity and Summer Juvenile. An attribute may be rated as poor for multiple life stages but for different reasons because of the sub-attributes. An example of this is Water Quantity. If low water flows are considered limiting to the summer juvenile life stage, it would be rated as poor. Water Quantity may also be rated as poor if high flow events are considered limiting for the winter juvenile life stage. Participants used

their knowledge of salmonids, the watershed, AGOL, and presentations to rate each attribute. If participants felt that they were unsure about an attribute/life stage relationship, they were asked to not vote on it. Voting at a HUC 12 watershed scale posed problems for some who saw these categories applying to certain parts of the watershed but maybe less so in others. This posed a challenge in how participants weighed the level of concern across the entire HUC 12. If factors ranked highly, even if they only applied to smaller sections of the HUC 12, the restoration actions could be as fine scale as the group decided.

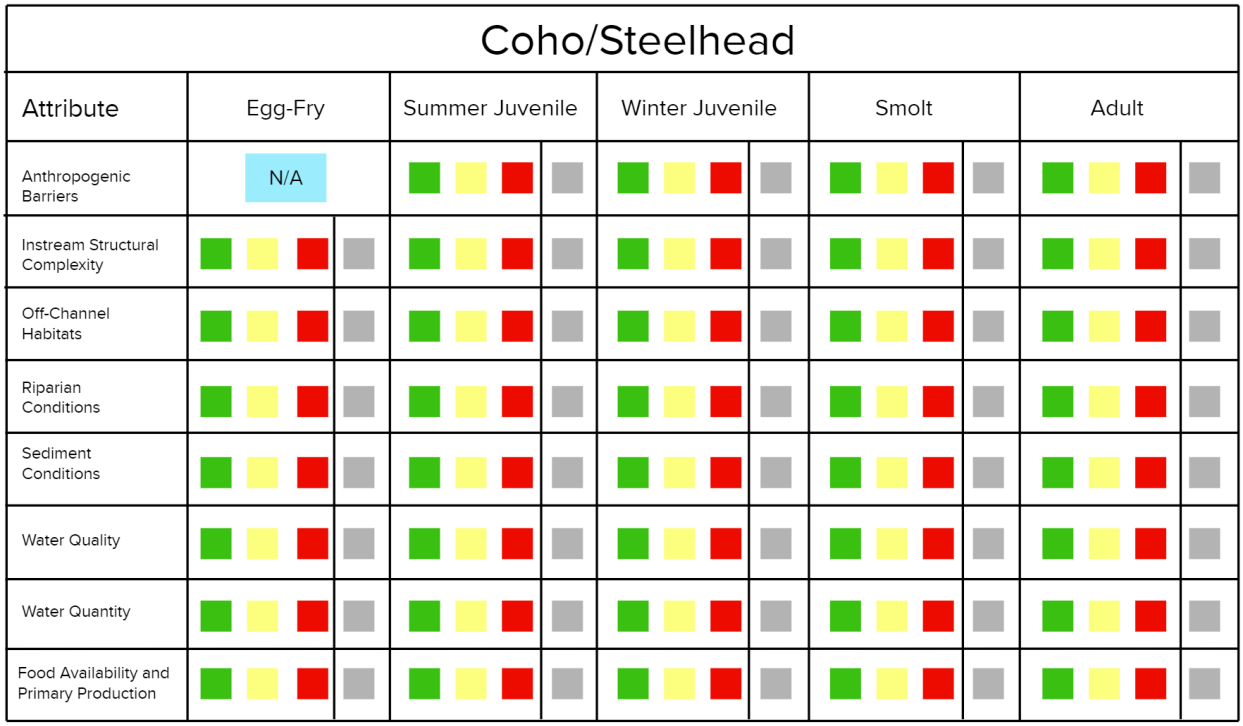

Figure 3. Lagunitas Creek SHaRP watershed attribute limiting factor voting table.

After the participants voted, the results were automatically tallied in Mural and available for everyone to view. The steering team averaged the tallies into numerical form. Then the numbers were binned into three categories, to be consistent with the voting. The scores of 0-3.3 were colored Green (least limiting). The scores from 3.4-6.6 were colored yellow (moderately limiting), and the scores from 6.7-10 were colored red (most limiting). If more than half of the votes thought that climate change was going to increase the severity of that attribute on the life stage's survival, then that was noted as well. The limiting factor results were discussed among the participants. If there was a disagreement on the voting results, it was discussed until a consensus was reached.

1.7.5 Developing Restoration Solutions

The last part of the SHaRP meeting focused on prescribing restoration actions to address the limiting factors identified through the attribute rating process. The participants worked together virtually over Web-EX and in AGOL. Reach or tributary areas were discussed, and a restoration treatment or two was proposed that would be most effective at remediating the limiting factor. If the participants had a consensus, the restoration action was added in AGOL. The restoration actions were prioritized such that the actions could be implemented over a 10-year time frame and yield the most significant benefit to

salmonids. Specific project locations and implementation methods will require further investigation and site-specific designs for many of these recommendations.

Lagunitas Creek Action Plan

1.8 Lagunitas Creek Overview

The Lagunitas Creek watershed is the largest watershed in Marin County (103 miles^2) (Figure 4). Lagunitas Creek has four major tributaries: San Geronimo, Devil's Gulch, Olema, and Nicasio creeks. Nicasio and Peters dams, as well as Bon Tempe and Alpine dams above Kent Lake, restrict Coho Salmon and steelhead access to half of the watershed, and their populations have fluctuated significantly since 1970 (Ettlinger 2019). Two of the four HUC 12 watersheds in Lagunitas Creek do not have Coho Salmon or steelhead because of dams. Roughly half of the watershed is privately owned. The remaining area is owned by the federal government (Golden Gate National Recreation Area), state government (Samuel P. Taylor State Park), Marin County, and other municipalities.

Like many watersheds supporting Coho Salmon and steelhead in California, historic and contemporary anthropogenic factors have negatively impacted salmonid habitat and populations. During the mid-1800s, European settlers began farming, ranching, and harvesting timber in the Lagunitas watershed. Dairy cattle were grazed across much of the watershed, and in 1856, Samuel P. Taylor built a paper mill on Lagunitas Creek near Devil's Gulch that was in production until 1893 (UCCE 1995). It was noted how the popular sport fishery suffered in Lagunitas Creek during the paper mill operation. Commercial logging in Olema Creek occurred as recently as the 1960s (Prunuske Chatham Inc. 2004).

In the 20th and 21st centuries, a shift from crop cultivation towards grazing and a growing human population increased the human water demand (Stillwater Sciences 2007). Increased demand for water for the growing population and agricultural needs, along with infrastructure like roads along stream corridors, has in certain areas of the watershed led to a simplification of stream habitat, channel incision, and an overall degradation of the habitat available to salmonids.

1.9 San Geronimo Creek - Lagunitas Creek Watershed

1.9.1 Watershed Background

The SG-LC HUC 12 watershed (Figure 4) is a mix of public and private land with several tributaries feeding Lagunitas Creek that creates a diversity of salmonid habitat. Much of the lower watershed is publicly owned, including large parts of the mainstem of Lagunitas Creek contained in Samuel P. Taylor State Park, as well as land managed by the NPS, particularly Devil's Gulch. The upper portion of the watershed including San Geronimo, Arroyo, and Woodacre creeks is privately owned and characterized by many small parcels.

While there have been considerable restoration efforts in the SG-LC sub-watershed, several factors prevent having enough quality salmonid habitat to increase survival and sustain populations at recovery target levels. In the San Geronimo Valley, the number of primary pools is relatively low compared to other sections of the stream, and a decreasing trend in pool frequency and wood in pools has been observed (Ettlinger 2017). While there is high intrinsic potential for Coho Salmon lower in mainstem Lagunitas Creek below the confluence of Devil's Gulch, redd densities are considerably lower, with most

of the spawning occurring higher in the system. Like many flashy coastal streams, water availability and storms seriously impact Coho Salmon and steelhead abundance. Too little water and spawning can be impaired, and multiple big storms during spawning or egg incubation can destroy redds and reduce juvenile abundance.

The SG-LC watershed is unique compared to the OC-LC watershed in that it is a hydrologically controlled system with dams providing drinking water for Marin residents. While these dams and their associated reservoirs greatly reduce the historic habitat available to salmonids and impair the natural geomorphology of the system, they do provide year-round base flows. The base flows ensure some water availability during summer and fall dry months.

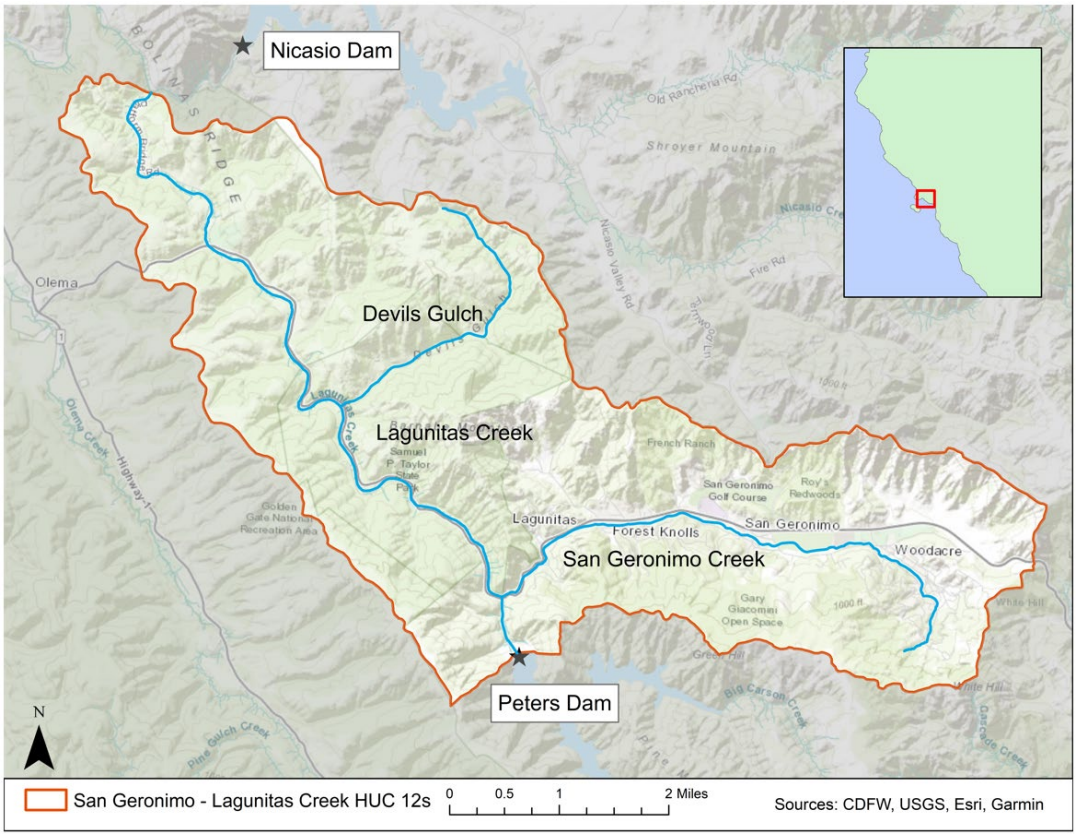

Figure 4. Map of the San Geronimo-Lagunitas Creek HUC 12 watershed with two major tributaries labeled: Devil's Gulch and San Geronimo Creek.

1.9.2 Historic and Current Restoration Efforts

The SG-LC watershed has experienced concentrated restoration efforts from several stakeholder groups that have utilized existing planning efforts. In recent years, many restoration projects have focused on increasing the availability of winter habitat, the limiting factor singled out by Stillwater Sciences in their 2008 Limiting Factors Analysis (LFA). Marin Water, Marin RCD, Salmon Protection and Watershed Network (SPAWN), and Trout Unlimited have all increased large wood and stream complexity in the watershed, providing refuge for salmonids during high winter flows. Several of these projects create floodplain habitat that spreads water to slow down flows and provides important foraging opportunity for juvenile salmonids.

Along with winter habitat, addressing passage barriers in the watershed has been a focus for restoration practitioners. Roy's Pools, the highest priority fish passage barrier in Marin County, was recently remediated by SPAWN. This project improved passage to the 157-acre parcel that the Trust for Public Land and Trout Unlimited are restoring in San Geronimo. Marin Water has also addressed several passage barriers on Woodacre Creek, Arroyo Creek, and other tributaries to San Geronimo Creek (Marin Water 2014). Marin County has also been influential in addressing passage issues through planning and funding projects to improve access throughout the watershed.

1.9.3 Attributes Limiting Coho Salmon and Steelhead Survival Results

Like other coastal watersheds in northern California, many factors limit the success of salmonids in Lagunitas Creek, and restoration has sought to address these various constraints. After the 2008 LFA that labeled winter habitat as the greatest limiting factor for Coho Salmon and steelhead, restoration efforts focused on this threat. Winter habitat was considered the greatest threat to Coho Salmon when looking at juvenile-to-smolt survival (Stillwater Sciences 2008). Subsequent smolt monitoring in the watershed has shown that winter survival has fluctuated often independent of abundance and has highlighted the importance of large storm events and the potential relationship between late-season storms, sediment transport, and food availability that may negatively impact winter survival (Ettlinger 2019).

These previous planning efforts and monitoring data, along with the data compiled by the steering team, were the foundation for the discussion and voting around attributes limiting the success of Coho Salmon and steelhead in the SG-LC HUC 12 watershed.

SHaRP participants rated the SG-LC HUC 12 using the methods described in the 2.2.4 Attribute Rating.

For the SG-LC watershed, the bulleted list below of attributes were found to be most limiting. The results are shown in Figure 5.

- Instream Structural Complexity (Egg-Fry, Summer Juvenile, and Winter Juvenile)
- Off-Channel Habitats (Winter Juvenile and Smolt)
- Riparian Conditions (Summer Juvenile)
- Sediment Conditions (Egg-Fry)
- Water Quality (Summer Juvenile)
- Water Quantity
    - Low Flow: Summer Juvenile, Smolt, Adult
    - High Winter Flows: Winter Juvenile

Instream structural complexity, off-channel habitat, and water quantity (during stages where too much water can wash fish out of the system prematurely) ranked as the most limiting and can have significant interplay. For example, increasing off-channel habitat could shift instream structural complexity and spread water out during high flow events. As any of these factors is changed, the other two will also likely shift. The interactive nature of these factors is important when designing restoration actions to address them.

San Geronimo-Lagunitas	Egg-Fry		Summer Juvenile		Winter Juvenile		Smolt		Adult	
Attributes	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?
Anthropogenic Barriers	N/A									
Instream Structural Complexity										
Off-Channel Habitats										
Riparian Conditions				Y						
Sediment Conditions										
Water Quality				Y		Y				
Water Quantity		Y		Y		Y		Y		Y
Food Availability & Primary Production		Y		Y		Y		Y		Y

Figure 5. Results from voting on attributes limiting the success of Coho Salmon and steelhead in the San Geronimo Lagunitas Creek HUC 12 by different life stages. Least Limiting (green): the attribute is not limiting survival at this life stage. Moderately Limiting (yellow): the attribute somewhat limiting survival at this life stage. Most Limiting (red box): The attribute is a strong limiting factor at this life stage. "Y" = yes (i.e. more than half of the votes thought that climate change was going to increase the severity of that attribute on the life stage's survival). Eighteen participants voted on limiting attributes for SG-LA sub-watershed.

1.9.4 Recovery Strategy

The recovery strategy for SG-LA watershed mostly focuses on installing large wood and creating off-channel and floodplain habitat to address the lack of stream complexity. The significant spatial coverage suggested for this recommendation highlights expert opinion that while certain areas in the watershed have more complexity than others, overall, most of the watershed would benefit from returning to a more natural and complex system. Table 2 provides a detailed list of the priority restoration actions that are displayed in the SG-LC map (Figure 6.)

Table 2: Priority SHaRP Restoration Actions for San Geronimo Creek-Lagunitas Creek HUC 12. Figure 6 provides more detailed locations.

Restoration Action	Targeted Attribute(s)	Targeted Life stage(s)	Location(s)*	Comments
Riparian Fencing and Road Treatment/ Decommission	Sediment Conditions, Riparian Conditions	Egg-Fry, Summer Juvenile	Devil's Gulch Cheda Creek	Riparian fencing to keep cattle out of streams and road treatment/decommission to prevent sediment input into streams.
Gravel Augmentation	Sediment Conditions	Egg-Fry	Lagunitas Creek Mainstem from below Peters Dam to above confluence with Cheda Creek	Augment gravel to develop more spawning areas and address the deficit of gravel supply because of dams in the watershed.
Large wood/Instream Habitat Enhancement	Instream Structural Complexity, Sediment Conditions	Egg-Fry, Summer Juvenile, Winter Juvenile	San Geronimo Creek near San Geronimo Commons Arroyo Creek Devil's Gulch	The wood augmentation project in Devil's Gulch could be done in conjunction with creating alcoves. Devil's Gulch is likely too steep to have off-channel habitat. Instream habitat complexity aids in the sorting of spawning gravels. Adding large wood slows water flow which can help recharge groundwater and increase stream flows. Incised sections would benefit from projects that aggrade the stream.
Off-channel/Floodplain and Engineered Large Wood	Off-Channel Habitat, Instream Structural Complexity, Water Quantity (too much flow)	Summer Juvenile, Winter Juvenile, Smolt	San Geronimo Creek Woodacre Creek Lagunitas Creek Mainstem starting below Peters Dam	Creating off-channel and floodplain habitats has an additional benefit of raising the groundwater table and contributing to increased stream flows. Creating more off-channel habitat will also address the limiting factor for winter juvenile of too much stream flow by giving them a refuge from the flows.

Restoration Action	Targeted Attribute(s)	Targeted Life stage(s)	Location(s)*	Comments
Water Infiltration	Water Quantity, Water Quality	Summer Juvenile, Smolt	San Geronimo Creek	Water infiltration projects at Roy's Redwoods to recharge groundwater is a direct way to increase water availability
Investigate Culvert for Impact on Gravel	Sediment Conditions	Egg-Fry	Cheda Creek	Culvert was identified as a structure to investigate as it may prevent gravel migration and distribution downstream.
Reroute Pipe	Water Quantity, Water Quality	Summer Juvenile, Smolt	San Geronimo Tributary	Reroute a Marin Water pipe to provide some additional flow to San Geronimo.
Treat Barrier	Anthropogenic Barriers	Summer Juvenile, Winter Juvenile, Smolt, Adult	Arroyo Creek (Upper, Lower) Larsen Creek Upper San Geronimo Creek (Dixon Weir)	Habitat improvement upstream of these barriers is recommended to ensure access for all life stages across various environmental flow conditions.

* See Figure 6 for exact reach scale locations

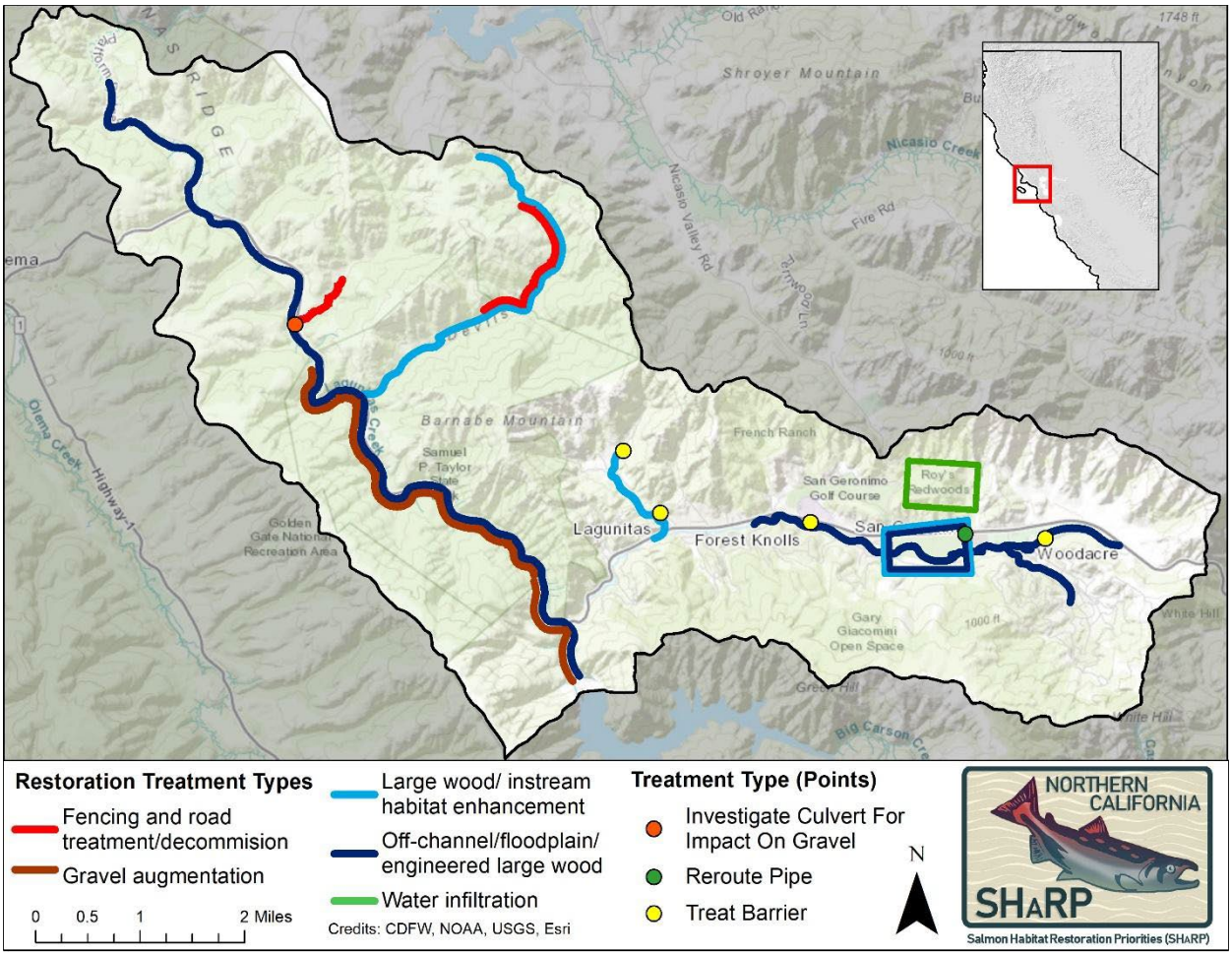

Figure 6. Action map of priority restoration actions for San Geronimo-Lagunitas Creek HUC 12.Many on-the-ground implementation projects will first require feasibility study and incremental design plans to fit specific reaches. Projects specially called out to “investigate” are done so to highlight that further study is needed to know whether it will address the intended attribute.

Water quantity is likely becoming more limiting for every life stage due to climate change. If climate predictions of increased frequency and drought severity play out in the SG-LC watershed, summer base flows that sustain this population may be threatened. Food availability and primary production, often associated with water availability and water temperatures, was also voted to worsen with the impacts of climate change. Participants stressed that resilience should be a focus in restoration design and that instream habitat restoration should be built in ways that functions during wet and dry years as this inter-year variability continues. Restoration that builds refugia for temperature, features like deeper pools, and shade cover, should also be a focus.

In reviewing restoration actions with stakeholders, it became evident that certain future threats were not captured in the SHaRP process (where data is not available to ascertain the exact within the 10-year planning timeframe of SHaRP). Issues like predation of juvenile salmonids by birds and the tire chemical

6PPD-quinone may be future threats in Lagunitas Creek. Some of the already recommended restoration actions, such as increasing stream complexity, can build resilience into emerging issues like predation. It will be essential to continue collaborating on these issues as they develop to incorporate them into restoration designs.

1.10 Olema Creek - Lagunitas Creek

1.10.1 Watershed Background

The OC-LC HUC 12 comprises all of Olema Creek and the lower part of the mainstem of Lagunitas Creek (Figure 7). Olema Creek flows for 15.9 kilometers northwest through the Olema Valley, until the confluence with Lagunitas Creek and then into Tomales Bay. Olema Creek flows in nearly a straight line through a rift valley along the San Andreas Fault zone and is the largest undammed watershed in coastal Marin County.

In the early 1920s, Olema Creek between the town of Olema and its confluence with Lagunitas Creek was straightened into the 3-km long “Olema Canal” that drained the surrounding land for agricultural production. Dairy farming, beef and sheep production, and potato growing dominated the more open landscapes of the lower watershed and Nicasio and Olema valleys. Gravel and sand were mined from the streambed at the confluence of Lagunitas and Nicasio creeks until a short time after Nicasio Dam was constructed. Ranchers regularly harvested small amounts of streambed gravel to maintain ranch roads through the 1980s. Logging continued in the Olema Creek watershed until 1962 (Prunuske Chatham Inc. 2004). The last reservoir built in the Lagunitas watershed was Nicasio Reservoir, formed by Seeger Dam in 1960, on Nicasio Creek. In addition to blocking anadromous fish passage to miles of spawning and rearing habitat, the impoundments have altered stream flows and reduced bedload transport from the watershed's upper reaches to lower Lagunitas Creek, which is this HUC 12.

The OC-LC watershed is mostly protected from development because it is primarily within NPS boundaries. There is a need for more large wood, instream habitat complexity, and cattle exclusion fencing in the OC-LC HUC 12 watershed.

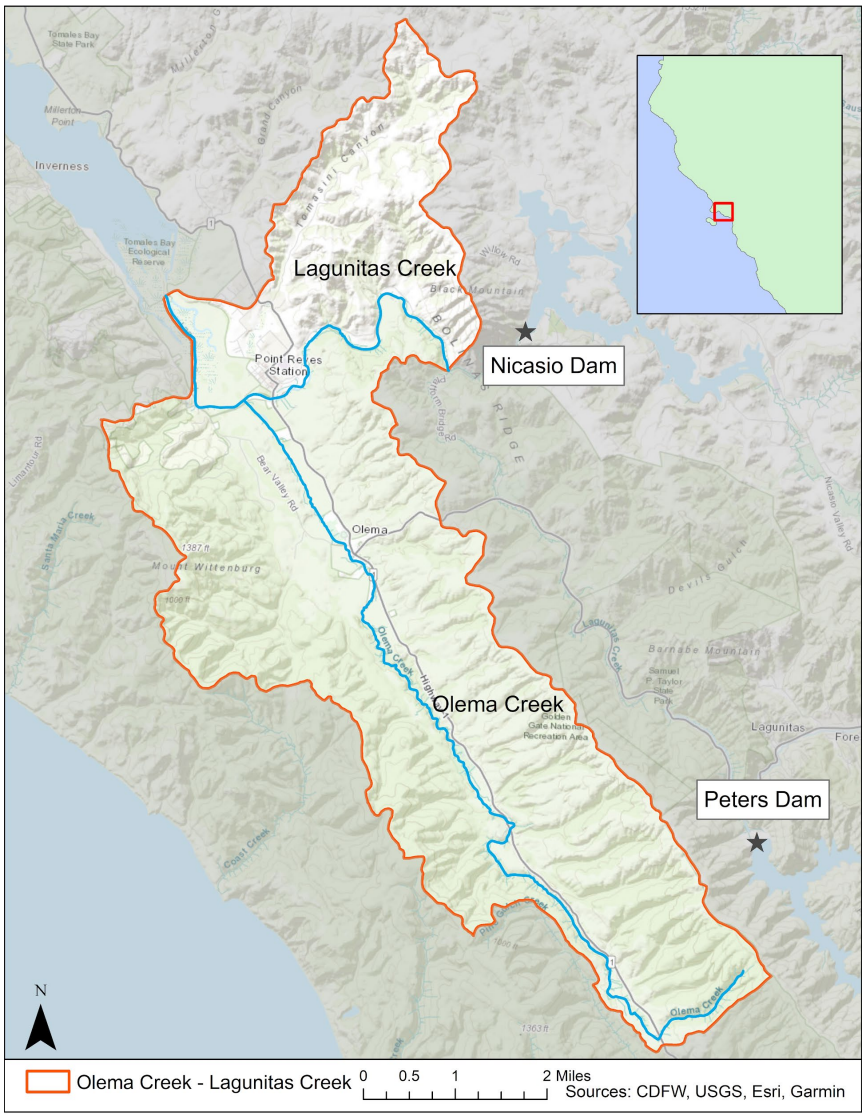

Figure 7. Map of Olema Creek - Lagunitas Creek HUC 12 with Olema Creek and the lower section of Lagunitas Creek labeled.

1.10.2 Historic and Current Restoration Effort

Unlike SG-LC, few restoration projects have been completed in the OC-LC HUC 12, especially in Olema Creek. The work that has occurred has largely focused on protecting the stream from livestock and allowing Olema Creek to recover naturally. The land around Olema Creek is almost entirely owned by the NPS and they have implemented many best management practices (BMPs) aimed at protecting stream corridors from cattle. Between 1999 and 2017 the NPS implemented 40 BMPs including stream fencing, hardened stream crossings for cattle, and off-stream drinking systems, spending around $870,000 (Lewis et al. 2019). Livestock exclusion fencing and road upgrades and decommissioning has been implemented in parts of this HUC 12 by Marin RCD.

One of the largest restoration efforts in OC-LC was the Giacomini wetland restoration project. The NPS purchased the Giacomini Ranch in 2000 and implemented the restoration project in 2008. The project restored the natural hydrologic and ecological processes of the wetland and increased the resilience of the Olema marsh ecosystem. NPS removed buildings, agricultural infrastructure, non-native plants, and levees.

Marin RCD and SPAWN have partially implemented a riparian restoration at the abandoned Redi-Mix Cement Plant on Black Mountain Ranch in Point Reyes Station in lower Lagunitas Creek. This project will remove an abandoned concrete parking lot adjacent to the stream and will restore the area to a natural riparian forest. The project will also re-contour streambanks to enhance salmonid access to the floodplain. Phase 1 of this project was completed in 2016, and phase 2 will occur in 2023.

Marin RCD in 2015-2016 upgraded 2.25 miles of unpaved ranch roads and decommissioned an additional 1.0 miles of roads on the Black Mountain Ranch. This project minimizes road-related sediment from entering Black Mountain Creek, a tributary to lower Lagunitas Creek. In addition, two stream crossings were upgraded to pass fish, and one crossing was decommissioned. Marin RCD installed 1,000 feet of riparian fencing to exclude cattle from the stream.

1.10.3 Attributes Limiting Coho Salmon and Steelhead Survival Results

The OC-LC watershed in recent years, experienced relatively low numbers of adult Coho Salmon and steelhead returns compared to the SG-LC watershed. Two of the Coho Salmon cohorts have had several years where there are fewer than 20 redds in the watershed (McNeil et al. 2020). Early life stages in the watershed have been susceptible to large spring storms where rain events have contributed to high egg-to-fry mortality (McNeil et al. 2020). The flashiness of the system is exacerbated downstream in lower Olema Creek and mainstem Lagunitas Creek part of this watershed, near the towns of Olema and Point Reyes Station.

SHaRP participants rated the OC-LC HUC 12 using the methods described in the 2.2.4 Attribute Rating

For the OC-LC watershed the bulleted list below of attributes were found to be most limiting. The results are shown in Figure 8.

- Instream Structural Complexity (All life stages)
- Off-Channel Habitats (Summer Juvenile and Winter Juvenile)
- Sediment Conditions (Egg-Fry)
- Water Quality (Summer Juvenile)
- Water Quantity (Egg-Fry and Summer Juvenile)

Olema-Lagunitas	Egg-Fry		Summer Juvenile		Winter Juvenile		Smolt		Adult	
Attributes	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?	Rating	Climate Change?
Anthropogenic Barriers	N/A									
Instream Structural Complexity		Y								
Off-Channel Habitats				Y						Y
Riparian Conditions		Y		Y		Y		Y		Y
Sediment Conditions		Y								
Water Quality				Y		Y		Y		
Water Quantity		Y		Y		Y		Y		Y
Food Availability & Primary Production				Y		Y		Y		

Figure 8. Voting results of the attributes limiting the viability of Coho Salmon and steelhead in the Olema Creek Lagunitas Creek HUC 12 by different life stages. Least Limiting (green): the attribute is not limiting survival at this life stage. Moderately Limiting (yellow): the attribute somewhat limiting survival at this life stage. Most Limiting (red box): The attribute is a strong limiting factor at this life stage. "Y" = yes (i.e. more than half of the votes thought that climate change was going to increase the severity of that attribute on the life stage's survival). Sixteen participants voted on limiting attributes for OC-LC sub-watershed.

1.10.4 Recovery Strategy

The participants took the results from the limiting attribute voting and discussed what restoration actions by stream reach. The SHaRP recovery actions that the participants agreed were needed to address the limiting factors are in Table 3 and mapped in Figure 9.

Table 3: Priority SHaRP Restoration Actions for Olema Creek-Lagunitas Creek HUC 12. See map below for more detailed locations.

Restoration Action	Targeted Attribute(s)	Targeted Life stage(s)	Location(s)*	Comments
Treat downstream knickpoint and Incision	Sediment Conditions, Instream Structural Complexity	Egg-Fry, Summer Juvenile, Winter Juvenile	Downstream of the Town of Olema	Investigate ways to treat the knickpoint and stop it from further incising the stream. This task may require significant stream restructuring and engineered logjams. This task may be a considerable effort, particularly with current flooding concerns around the town of Olema and near the campground.
Fencing and other sediment treatments	Sediment Conditions	Egg-Fry	Unnamed tributary upstream of Sir Francis Drake Blvd. and Shoreline Hwy intersection	Add fencing along the stream with active grazing and where sediment has been observed entering the creek
Investigate beaver reintroduction	Off-channel habitat, Water Quantity	Summer Juvenile, Winter Juvenile	Lower mainstem Lagunitas Creek below Nicasio Creek	Beaver restoration can slow down and spread out water, recharge groundwater, and provide sustained flow during dryer months. Beaver-assisted habitat change could address the incision in Olema Creek and restore floodplain connection
Large wood/ instream habitat enhancement	Instream Structural Complexity, Sediment Conditions	Egg-Fry, Summer Juvenile, Winter Juvenile, Smolts, Adults	Lower Olema Creek, Upper Olema Creek,	Olema Creek is lacking in large wood and primary pools. Action will also help sort sediments. Incised sections would benefit from projects that aggrade the stream.
Off-channel/ floodplain habitat	Off-channel Habitat	Summer Juvenile, Winter Juvenile	Lower mainstem Lagunitas Creek near Point Reyes Station	Assess feasibility of project by taking into account the proximity to Point Reyes Station. With much of the restoration focused in the upper SG-LC watershed, this lower area is important for expanding and connecting restoration efforts across the landscape.

Restoration Action	Targeted Attribute(s)	Targeted Life stage(s)	Location(s)*	Comments
Riparian Restoration	Riparian Conditions, Sediment Conditions	Summer Juvenile, Winter Juvenile	Lower Olema Creek	Restoring the riparian corridor to improve stream water quality conditions and increase primary production input to the streams. Target areas where grazing may be slowing down, or halting altogether.
Address flooding risk	Water Quantity, Instream Structural Complexity, Off-Channel Habitat	Winter Juvenile	Town of Olema	With increased risk of flooding to the Town of Olema from atmospheric rivers. Improvements to habitat complexity and off-channel habitat to reduce the risk of flooding should be explored
Implement water conservation strategies	Water Quantity	Egg-Fry, Summer Juvenile	Upper Olema Creek	Explore opportunities to implement water conservation restoration projects that could supplement flows especially during the summer months.
Treat Culvert	Anthropogenic Barrier	Summer Juvenile, Winter Juvenile, Adult	Quarry Gulch, John West Fork	There is good spawning habitat above both culverts with passage still being an issue. Treating these culverts could open additional spawning habitat and allow better juvenile migration.

* See map for exact reach scale locations

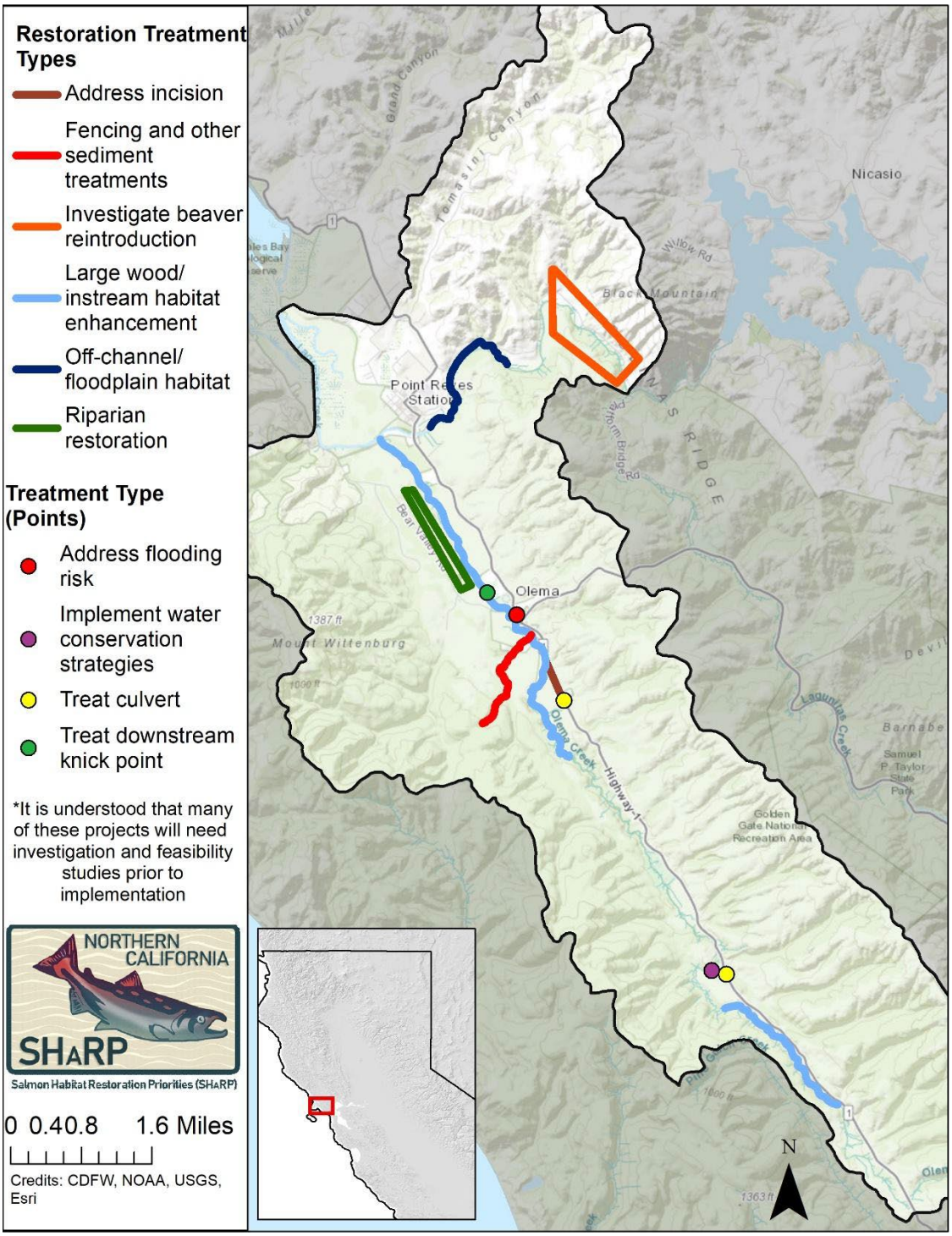

Figure 9. Action map of priority restoration actions for Olema Creek-Lagunitas Creek HUC 12. Many on-the-ground implementation projects will first require feasibility study and incremental design plans to fit specific reaches. Projects specially called out to “investigate” are done so to highlight that further study is needed to know whether it will address the intended attribute.

Climate change will exacerbate how limiting some of the attributes are the individual life stages. For every life stage in OC-LC, climate change would likely make water quantity a more significant issue moving forward. The increased frequency and severity of drought conditions could significantly impact the relatively small Olema Creek system. Because water quantity is already limiting the egg, alevin, and summer juvenile life stages. Water conservation strategies in the upper parts of Olema Creek to increase water availability will be crucial (Table 3, Figure 9). In addition, Riparian restoration will be especially important moving forward, as it will assist in the cooling of stream temperatures. Food availability and primary production was an attribute that was added before voting while discussing the OC-LA watershed with participants. This attribute did not rank as a strong limiting factor for any of the life stages (Table 5). However, it was agreed that climate change would likely worsen this attribute for summer and winter juvenile. Linked to water quantity, food availability and primary production may suffer as the frequency and intensity of droughts increase, as streams warm and flows decrease (particularly in the Olema Creek part of the watershed where summer base flows are not controlled through reservoir releases).

The capacity of restoration professionals to take on new projects in this watershed is another factor limiting salmonids in Lagunitas Creek. While the SG-LC watershed has a robust restoration community, the OC-LC watershed has experienced considerably less planning and restoration implementation. The lower section of Olema Creek was artificially straightened and has incised considerably into the floodplain. While the challenges of working near development shares similarities with the highly parcellated San Geronimo Valley, there have been fewer projects seeking to tackle the degraded habitat in Olema Creek. The majority of the watershed is held by the NPS, which conducts robust monitoring, but has not had a capacity for restoration for some time.

1.11 Next Steps

The SHaRP steering team will track the implementation of restoration action within Lagunitas Creek and will revisit if the SHaRP plan needs to be updated every 5 to 10 years. If you have any questions or would like to collaborate on implementing the actions in this chapter, please contact Erin Seghesio, NOAA Fisheries Recovery Coordinator (707-578-8515 or Erin.Seghesio@noaa.gov) or Chester Lindley, CDFW Fisheries Branch (Chester.Lindley@wildlife.ca.gov).

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Appendix A: Web Layer Glossary

Glossary of Data in Webmap

Introduction

The California Department of Fish and Wildlife (CDFW) and the National Oceanic and Atmospheric Administration (NOAA) Fisheries are jointly leading the Salmonid Habitat Restoration Priorities (SHaRP) effort. SHaRP brings together watershed experts and agency staff to develop reach scale restoration priorities for listed salmonids. Critical to this effort is collecting and distributing as much biological, habitat, water, and other relevant data to best inform discussions about the specific factors limiting salmonids at each life stage. As this process has transitioned to an online setting, so too has the data-sharing component. ArcGIS Online (AGOL) enables agency staff and stakeholders to share interactive webmaps with anyone and allows SHaRP participants to customize the datasets they want to explore at different spatial scales and at their own leisure. The Lagunitas Creek SHaRP effort has developed such a webmap with the help of staff from CDFW and NOAA and with data and feedback from watershed experts; the webmap can be accessed here.

Biological Layers

Coho Salmon Distribution

Distribution of Coho Salmon through the Lagunitas Creek watershed as defined by CDFW and NOAA.

Steelhead Distribution

Distribution of steelhead through the Lagunitas Creek watershed as defined by CDFW and NOAA.

Redds

The redds group contains several layers broken into species and Hydrologic Unit Code 12 (HUC12) subwatersheds. Individual redds were separated by species and assigned to a California Monitoring Plan (CMP) reach. Occasionally a species was not assigned to a redd, and those were labeled as "Unknown." Redds were summed at the reach scale and divided by the length of that reach to give a redds per kilometer density.

> *Lagunitas Redds*: data collected by Marin Water (formerly Marin Municipal Water District) span 17 years. These data are for Coho Salmon, steelhead, and redds that were marked as "Unknown" species.
>
> *Olema Redds*: data for Olema Creek were collected by the National Park Service (NPS) and span a 10-years. These data were broken out into Coho Salmon and steelhead.

Important notes when using these data for the SHaRP effort:

1) These data are summed across all years for both HUC12 watersheds- effort in terms of the number of years and samples per year are not the same. Therefore, redd data should not be used to compare relative spawning between watersheds, but instead should denote hot spots within each HUC12 watershed.

2) Along similar lines, specific areas within each watershed received less sampling, whether because flows were so low that spawning is improbable or flows and turbidity were high enough in areas to prevent sampling. While relatively long datasets of 10 and 17 years can account for some variation in environmental conditions between years, this issue of effort is an important caveat to note when discussing spawning potential and restoration actions.

Steelhead Intrinsic Potential

NOAA Fisheries created this layer and for our purposes, it was clipped to Lagunitas Creek. NOAA Fisheries describes the layer as:

> "Intrinsic potential measures the potential for development of favorable habitat characteristics as a function of the underlying geomorphic and hydrological attributes, as determined through a Digital Elevation Model (DEM) and mean annual precipitation grid. The model does not predict the actual distribution of "good'' habitat, but rather the potential for that habitat to occur, nor does the model predict abundance or productivity. Additionally, the model does not predict current conditions, but rather those patterns expected under pristine conditions as related through the input data. Thus, IP provides a tool for examining the historical distribution of habitat among and within watersheds, a proxy for population size and structure, and a useful template for examining the consequences of recent anthropogenic activity at landscape scales."

Coho Salmon Intrinsic Potential

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Trap Locations

Approximate locations of juvenile and smolt traps in Lagunitas Creek HUC12. These two trap locations are operated by Marin Water and the NPS. These are approximate locations, and traps sometimes move slightly between and within a trapping season depending on environmental conditions.

Habitat Layers

Olema Primary Pools

This layer includes primary pool data collected by the NPS as part of its habitat monitoring from 2010 to 2020. Primary pools are deeper than 3 feet. Primary pool counts were assigned to the nearest CMP reach by creating a "near table" with coordinates that intersected reach line data (referred to as

“snapped” throughout document), summed by a three-year monitoring interval, and divided by the length (kilometer) of the assigned reach. A three-year time step was chosen in discussion with NPS staff to account for variation in water years. As this is a ten-year dataset, the first step is only two years (2010-2011).

Olema Large Wood Density

This layer was created with data collected by the NPS during habitat surveys. LWD jams identified by the NPS were snapped to CMP reach scale, summed by reach, and divided by the length of each reach to get a LWD jam per kilometer metric. In an attempt to account for seasonal environmental variation in observers and flow that could affect jams in or out of the wetted channel; these data were binned into three-year periods from 2009 to 2020.

Lagunitas Riffle Frequency

Marin Water collected riffle data as part of its 5-year habitat surveys in 2016. Individual riffles that were identified throughout the watershed were snapped to CMP sample frame, summed, and divided by length of the sample transect to give a number of riffles per kilometer measurement.

Lagunitas Primary Pools

Marin Water collected primary pool data as part of its 5-year habitat surveys in 2016. Primary pools have a depth greater than three feet. Individual primary pools that were identified throughout the watershed were snapped to CMP sample frame, summed, and divided by length of the sample transect to give a number of primary pools per kilometer measurement.

Lagunitas Large Wood Projects

This layer contains large wood projects implemented in the last ten years. Compiling these projects was a joint effort between CDFW and NOAA Fisheries staff and relied on grant data administered by the two agencies and input from restoration stakeholders. Some projects depicted in this layer were characterized as a single unit with multiple features. Other projects with multiple features within a given reach are represented with their up and downstream points. While this does not capture all of the LWD, and some of the wood that has been installed may have since moved, it represents some of the efforts to add wood to the Lagunitas Creek watershed over the last ten years.

Sediment Treatment Sites

GIS data from a 2013 Stetson Engineers Inc. report prepared for Marin Water. An inventory of road-related sediment was performed and inventoried around 110 miles of unpaved roads, with 21% or 23 miles being hydrologically connected to the stream system (Stetson Engineers 2013). The treatment sites included in this layer are ranked as "High" or "High Moderate" priorities are a subset of all the sites accounted for in this study. They represent approximately 5.5 miles of roads and 64 sites. These 64 sites account for 24,055 cubic yards of estimated future sediment delivery, accounting for 43% of the total sediment delivered identified in this study.

Unpaved Roads Sediment Source Survey

GIS data from a 2013 Stetson Engineers Inc. report prepared for Marin Water. An inventory of road-related sediment was performed and inventoried around 110 miles of unpaved roads, with 21% or 23 miles being hydrologically connected to the stream system (Stetson Engineers 2013).

Height Above River (Integer)

Adam Fleenor processed the Lidar data as part of his master's thesis at CSU Stanislaus (Fleenor 2015). Lidar data were taken and processed to produce a height above river raster; these heights were calculated to integer values with the river height subtracted, so what is left is the relative height of habitat off the stream channel. These data can be used as a basic tool, without hydraulic modeling, to look at potential areas of floodplain habitat across the watershed.

Passage Assessment Database (PAD)

The Passage Assessment Database (PAD) is an ongoing map-based inventory of known and potential barriers to anadromous fish in California. The PAD compiles currently available fish passage information from many different sources, allows past and future barrier assessments to be standardized and stored in one place, and enables the analysis of cumulative effects of passage barriers in the context of overall watershed health. The database is set up to capture basic information about each potential barrier. It is designed to be flexible. As the database grows, other modules may be added to increase data detail and complexity.

For the PAD to be useful as a restoration tool, the data within the PAD need to accurately depict the on-the ground reality of fish passage constraints. This requires the PAD to retrieve new barrier data and updates to existing sites and to have verified and vetted the information it receives. In 2013, new PAD data standards were designed to standardize this process, and refine the data in PAD making the data more robust. The new standards have been implemented for all new records since 2013. In 2014 and 2021, the standards were further refined. In the future, the standards will be implemented for all existing records. The data standards including a description of the database, data collection procedures and data quality and limitations can be found in the combined PAD methodology and data standards document (PAD 2021).

Passage Priorities

The Passage Priorities layer is based on input from CDFW, NOAA Fisheries, and CalTrans staff. Staff from these agencies looked at the broader set of barriers in PAD and deemed these barriers to be the highest priority to remove within the two HUC12s focused on for this SHaRP effort.

Sea Level Rise Inundation

NOAA's description of the web layer:

> "This dataset was created as part of the National Oceanic and Atmospheric Administration Office for Coastal Management's efforts to create an online mapping viewer depicting potential sea level rise and its associated impacts on the nation's coastal areas. The purpose of the mapping viewer is to provide coastal managers and scientists with a preliminary look at sea level rise and coastal flooding impacts. The viewer is a screening-level tool that uses nationally

consistent datasets and analyses. Data and maps provided can be used at several scales to help gauge trends and prioritize actions for different scenarios. The purpose of this dataset is to show potential sea level rise inundation of 1 ft above current Mean Higher High Water (MHHW) for the area."

For more information, visit the Sea Level Rise Impacts Viewer (https://coast.noaa.gov/slr). For metadata and source map service, see https://coast.noaa.gov/arcgis/rest/services/dc_slr/slr_1ft/MapServer.

For SHaRP we are using the 1-6' sea level rise inundation tile layers.

Water Layers

California Streams

This California streams layer is a dataset from the National Hydrography Dataset with streams as lines. These line data are clipped to the Lagunitas Creek HUC10 boundary.

California Stream Gages

This layer is hosted by the State Water Resource Control Board (SWRCB), and it describes the layer as:

> "... a snapshot of stream gages from the fall of 2020. It is the product of an attempt to compile a comprehensive, geospatial list of long-term stream gages whose data is publicly available. Initially, the layer will consist of USGS and CDEC gages. Over time, local (county, municipal, etc.) gages will be added. This layer is not claimed to be authoritative. In cases where this layer and the data maintained by the source entity differ, this layer always defers to the source entity. For analysis purposes, the gage point locations have been altered by SWRCB to coincide with the corresponding line features in the National Hydrography Dataset (NHD) Medium Resolution. The original point locations can be found "x" and "y" fields of the layer's attribute table."

The stream gage layer was clipped to Lagunitas Creek HUC10 watershed.

Diversions (Acre Feet)

Diversions identified by the SWRCB, Division of Water Rights. The State Water Resources Control Board describes the layer as:

> "Under the California Water Code, water is a public resource that is protected for the use and benefit of all Californians. California's waters cannot be owned by individuals, groups, businesses, or governmental agencies. But permits, licenses, and registrations give individuals and others the right to beneficially use reasonable amounts of water. Points of Diversion (PODs) are locations where water is being drawn from a surface water source such as a stream or river. Each water right registered with the California State Water Resources Control Board's Division of Water Rights includes an identified point of diversion. Ground water extraction points (such as water supply wells) are not included in this dataset. The spatial and attribute information are maintained by the Division of Water Rights in the electronic Water Rights Information Management System (eWRIMS). Water Rights staff plot points of diversion based on the coordinates provided as part of the water right statement or application. The water source is identified visually in the GIS edit process. Additional spatial attributes (such as Regional Board,

> county, and public land survey system coordinates) are calculated automatically by the eWRIMS GIS system."

Diversions from the SWRCB were clipped to the Lagunitas Creek watershed and displayed as a factor of their face value in acre-feet.

NorWest Predicted Mean August Temps (1993-2011)

Modeled mean august temperatures for Lagunitas Creek watershed based on data from 1993 to 2011. The United States Forest Service describes the layer:

> "The NorWeST webpage hosts stream temperature data and climate scenarios in a variety of user-friendly digital formats for streams and rivers across the western U.S. The temperature database was compiled from hundreds of biologists and hydrologists working for >100 resource agencies and contains >200,000,000 hourly temperature recordings at >20,000 unique stream sites. Those temperature data were used with spatial statistical network models to develop 36 historical and future climate scenarios at 1-kilometer resolution for >1,000,000 kilometers of stream.

Temperature data and model outputs, registered to NHDPlus stream lines, are posted to the website after QA/QC procedures and development of the final temperature model within a river basin (example interactive temperature map). It is hoped that open access to the data and the availability of accurate stream temperature scenarios will foster new research and collaborative relationships that enhance management and conservation of aquatic resources."

Other Layers

Areas of Private Landowner Access or Restoration Willingness

These data were collected in collaboration with partners within the watershed. Parcels are not meant to identify specific landowners or people to contact. Rather it gives a general idea of areas where stakeholders in the watershed may be willing to allow access either for monitoring or future restoration work. These data are some of the more sensitive we have collected and appreciate everyone's commitment to not distribute or take this layer as an affirmative from individual land owners that they want to be contacted by the SHaRP team or are committed to any specific restoration action.

Public Land (State and Federal)

Marin County parcel data was clipped to Lagunitas Creek HUC10 watershed and then narrowed down by listed property owners. Public land included here is state (state parks or other State of California demarcation in "Owner" field) and the Federal government, largely the NPS.

Marin Vegmap

This layer was produced by the California Native Plant Society in partnership with Golden Gate National Parks Conservancy, National Park Service, Tukman Geospatial LLC, and other partners of the Marin Countywide Vegetation Map and Landscape Database Project. This layer relies on a number of different methods including processing Lidar data with computer based learning, field work and aerial photo interpretation. Many more details can be found on their layer description here, as well as the report put together here.

Samuel P Taylor State Park

This layer consists of a polygon representing the boundary of Samuel P Taylor State Park. This layer is a subset of all park boundaries layer created and hosted by California Department of Parks and Recreation, and more information can be found at: https://www.parks.ca.gov/?page_id=29682.

Salmonid HUC12s

United States Geological Survey (USGS) HUC12 watershed boundaries in the Lagunitas Creek HUC10 watershed that currently support salmonid populations. These two HUC12s represent anadromous waters in the Lagunitas Creek HUC10 and are: San Geronimo-Lagunitas Creek (180500050103) and Olema Creek-Lagunitas Creek (180500050104).

Lagunitas Creek HUC12s

USGS HUC12 watershed boundaries within the Lagunitas Creek HUC10 watershed. There are four HUC12 watersheds in the larger HUC10 watershed.

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