3. Chapter 3: Identifying the Problems and Restoration Solutions in Each Focus Area

The Expert Panel and Action Team meetings were designed to provide the maximum opportunity for Collaborative members to evaluate the available data and local observations and determine the best course of restoration in each focus area. There was one Expert Panel meeting and one Action Team meeting for each of the seven focus sub-watersheds ultimately chosen (see Chapter 3). These fourteen, one-day meetings took place over approximately one year. To begin, the steering team identified community members known to have experience in a sub-watershed. These people, along with the steering team members, comprised the participants of the Expert Panel and Action Team meetings. The Expert Panel and Action Team often included all the same people; these names describe the major task those people completed during a particular meeting. During Expert Panel meetings, panelists discussed and ranked the limiting factors and threats in a focus area. Then, during the Action Team meeting, participants defined the actions to be taken to address the most severe limiting factors and threats identified in the first meeting. Specifically, they identified each restoration treatment needed and the reach-scale locations where it was needed. Each location of a prescribed restoration treatment was listed as a “project”. The steering team used the rankings and project information developed during these meetings to draft a comprehensive restoration plan for each.
focus area (Chapters 5 through 11 of this document).

**Expert Panel: Identifying the Problems**

Once HUC-12 sub-watersheds were identified for strategic restoration actions the steering team identified experts with specific salmonid habitat restoration experience or knowledge of the selected sub-watersheds. Experts consisted of agency biologists, Native American tribal members, researchers, restoration practitioners, private landowners, and watershed groups with specific expertise in salmon and their habitat needs. Experts were invited to attend an all-day meeting to present and discuss relevant data, observations, and studies related to the following: Native American land management, historic watershed conditions, European settlement, changing land management practices, contemporary land management, current research, habitat and salmonid monitoring data and trends, and current restoration practices. Experts were then tasked with identification of factors limiting salmon habitat productivity and threats to the persistence of these species. The Expert Panel then ranked the severity of various limiting factors and threats in that specific sub-watershed, as shown in Figure 3-3.

In preparation for each Expert Panel meeting, the steering team organized a set of maps presenting monitoring data and features of the watershed. Features were mapped at the smallest scale possible, generally at the scale of the Coastal Monitoring Program (CMP) salmon spawning ground survey reaches (1-3km). Where survey reach delineations had not been developed for the CMP, similarly sized and numbered reaches were added to create a simple, consistent location reference system. Geomorphic features included bedrock/soil type, landslides, stream gradient, and valley width. Biological conditions included the extent of known fish distribution for each species, features limiting distribution, and density of redds from spawning ground surveys. Physical stream habitat features comprised the following: ratings of pool depth, pool cover, substrate embeddedness, canopy cover, and density of large wood pieces as well as modeled and measured stream temperatures, expert opinion of stream potential to provide refugia, and the quantity of anchor sites. The final set of maps depicted land ownership, road networks and registered water diversions. In some cases, additional data (e.g. summertime streamflow) was contributed by watershed experts. Expert Panel members were provided all maps for peer review prior to the meeting to identify errors or additional data sources that could be valuable to identifying limiting factors and threats. Examples of these maps are located in Section 2 of this document within each sub-watershed chapter.

The Expert Panel meetings began with an introduction to the watershed and a general concept of the pre-colonial stream conditions followed by subsequent colonization, changes in land use, and alterations in watershed processes through the modern day. When available, local Native American tribal members presented their perspective of traditional land use and management. A history of the anthropomorphic impacts to the
watershed followed, describing the sequence of resource extraction and associated watershed degradation. This information set the stage for a review and discussion of contemporary data and watershed processes affecting instream habitat conditions, often informed by additional presentations from Collaborative members on specific restoration or research projects they had carried out in the focus area. Ecological processes such as stream shading, large wood recruitment, erosion and sediment transport are dynamic. These processes are best understood within the context of a watershed’s historical and contemporary conditions before setting goals for its future trajectory. A conceptualized life-history model of anadromous salmonids was then presented to explore how and when various portions of the steam network may be used by fish in different life-stages, how stream habitat features may be used, and what they may be lacking. This life-history model (displayed and explained on pages 3-4 and 3-5) helped guide important discussions and assisted participants in the subsequent ranking exercise.

**Life Cycle Model**

Pacific salmon and steelhead exhibit complex life histories that utilize nearly every portion of a river network, balancing risks with rewards; however, many of the habitats these fish have evolved to use have been drastically altered. Each life history faces its own 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 invasive species (Good et al. 2007). Given the wide range of habitats and ecological conditions that salmon and steelhead encounter, identifying the restoration actions that will most effectively aid in recovery can be extremely challenging. Understanding the life stages most susceptible to particular environmental conditions; from egg deposition in headwater stream gravels to rearing conditions through multiple seasons with various and complicated stressors, to migrations across contrasting environmental gradients has been the focus of salmonid ecology for decades. Collecting information to inform restoration planning at any given site, reach or sub-watershed, however, can be daunting given the data requirements, resources, time scales and uncertainty in human understanding of the true nature of the river systems.

Life Cycle Modeling is a paradigm used to help to organize and understand the pressures salmon are exposed to during their life cycle (Roni et al. 2018). While there are many different flavors of salmon Life Cycle Models, they all share a similar structure and goal. In general, they organize a life cycle into subcomponents of both space and time and attempt to understand the magnitude of transition rates (movements and survival) between time periods and areas in a watershed and productivity rates (growth) achieved during each time step. By organizing the life history components of salmon and steelhead in this way, restoration planners can begin to leverage the decades of scientific inquiry into the relationships between salmon habitat and population dynamics. While Life Cycle Modeling can take a quantitative form of using data driven
values of fish survival modeled as a function of habitat values and density dependence (i.e. stage based stock-recruitment), a much more generalized and conceptual model of Coho Salmon was used in the SHaRP process (Figure 3-2). We felt that Coho Salmon, a species that spends at least one year rearing in nearly every part of a watershed, adequately represent the habitat requirements of all salmonids of the SFER and that actions to support Coho Salmon life stages would also benefit the other species despite the apparent diversity among species.

A large body of scientific literature and studies were used to inform the creation of a generalized Life Cycle Model for Coho Salmon (Figure 3-2), and then habitat data was evaluated by the Expert Panelist and Action Teams in the context of the model. While much of the data was discussed in the light of the Coho Salmon conceptual model, all species and life stages were considered separately in a limiting factors analysis to develop hypotheses about which habitats and locations were hindering salmonid production. Using the available data and expert knowledge of each focus area in the context of the conceptual model, treatments to address the hypothesized limitation were recommended in the most appropriate locations.

Figure 3-2. Generalized conceptual Life Cycle Model of Coho Salmon used in the SHaRP process to organize hypotheses about limiting habitats and salmon life phases in the South Fork Eel Watershed. The y-axis describes the spatial use of habitat through a salmonids life history from headwater streams of a natal tributary through the mainstem, estuary and Pacific Ocean. The x-axis depicts time in seasonal steps. Salmonids grow and move through time and space with differential growth and survival experienced at every transition.
Expert Panel: Identifying the Problems

The final step of the Expert Panel meeting was to rank the various limiting factors and threats. Prior to the Expert Panel meeting, the steering team developed a list of the limiting factors and threats relevant to the subject area, which was informed by the recovery plans. The steering team also identified areas within each sub-watershed that tended to differ in the conditions and threats present (e.g. headwater tributaries, mainstem tributaries, and the mainstem) in relation to the life stages of Coho Salmon, Chinook Salmon, and steelhead. During the Expert Panel meeting, the team described large paper tables that reflected these limiting factors, threats, life stages, and areas. In many cases, these tables were modified during the meeting (prior to scoring) to reflect nuances identified by the panelists during discussion. Panelists independently ranked the impact of each limiting factor on each life stage in each area, and each threat on each life stage in the entire sub-watershed. Panelists used a five-step categorical ranking from least to greatest impact to score the impact of each limiting factor. The most severe impact received a score of 1 and the least severe impact a score of 5. Once the rankings were complete, the steering team immediately compiled the data and presented the results to the group. Panelists then discussed the group’s collective rankings (Figure 3-3). If the panel believed that a limiting factor or threat was incorrectly ranked, a discussion of how the ranking was incorrect followed until a consensus could be reached. The meeting concluded once a consensus on the most severe limiting factors and threats was reached. The steering team summarized the final rankings using the mean score for each limiting factor and life stage and coalesced the results into consolidated tables (Figure 3-3).

Action Team: Developing Restoration Solutions

Expert Panelists for a particular focus area were subsequently invited to a second meeting to prescribe restoration actions to address the limiting factors and threats with the most severe impacts on the three salmonids. The steering team identified a set of generalized restoration treatments used to address various physical/biological processes that the Action Team used as a common toolbox. When a unique or novel restoration action was identified, it was described and documented along with the other treatment recommendations. The Action Team broke into small groups to suggest restoration treatments that addressed the most severe limiting factors and threats for distinct reaches within each action group. Using the available data, treatments were recommended where they would be most likely to be effective at improving habitat or watershed processes. For example, the Expert Panel identified instream complexity as a very high-impact limiting factor for summer rearing parr in a portion of a sub-watershed.
**Figure 3-3.** From top to bottom: (1) Expert Panel members discuss and rank limiting factors for individual life stages in specific areas of a sub-watershed using. (2) The results of Expert Panel ranking for migrating adult salmonids in the Bull Creek sub-watershed. Each black spot represents a panelist's vote and the rows within each limiting factors are ordered according to severity (1-5). The top row (red) is most limiting and each vote receives a score of 1 and the bottom row (blue) is least limiting and each vote receives a score of 5. (3) The summarized results of Expert Panel ranking for all life stages of Coho Salmon and steelhead in the Bull Creek sub-watershed as presented in the watershed chapters (Chapters 5 – 11). The mean scores are presented in the center of each cell and cells are colored according to their respective score (1.0-1.9 = red, 2.0-2.9 = yellow, 3.0-3.9 = light green, 4.0-5.0 = dark green).
In response, the Action Team recommended adding large wood for summer rearing to a low-gradient headwater stream reach in this area. This reach may have adequate spawning gravel, is frequented by spawning adults, but lacks pools deep enough to persist over the summer. Existing pools may lack adequate complex cover and provide little refuge from predation. Large wood additions to this reach should scour pools and provide complex cover for rearing juvenile salmonids.

Similar to the mapping of spatial data, restoration actions were generally prescribed at the scale of spawning ground survey reaches. When site-specific information or expert knowledge was available specific actions were prescribed at precise locations (e.g. LiDAR data used to identify split channels for off-channel overwinter habitat improvements). These restoration actions were prioritized such that the actions could be implemented over a ten-year time-frame and yield the greatest benefit to salmonids. For many of these recommendations, specific project locations and the methods of implementation will require further investigation and site-specific designs. Bear in mind, a great deal of restoration planning is on-going in the SFER and SHaRP, where appropriate, encourages utilizing these already developed or nearly developed site plans.

Once every Action Team member had the opportunity to identify and review restoration treatments in each action group the steering team member who facilitated the action group presented the restoration treatments to the team. A discussion of the proposed restoration treatments followed and if there was concern regarding a particular treatment or lack of treatment, discussion ensued until a consensus could be reached. The meeting was concluded once the Action Team reached a consensus on which restoration treatments would address the high and very high-impact limiting factors and threats.

**Treatments to Address Limiting Factors and Threats**

The following describes the treatment types that the various Action Teams prescribed for their areas. The chapters for each of the focus sub-watersheds, which are the last seven chapters of this plan, refer to these treatments. The treatments are designed to improve a specific aspect of habitat conditions for one or more life stages of particular salmonids.

**Upslope Hazard Assessment/Treatment**

There are many ways in which sediments from upland slopes enter waterways, many of which are normal processes of a healthy, functioning watershed. The extent to which upslope soil particles become suspended sediment depends, in part, on properties of the landform (e.g. geology, slope, etc.), but also on disturbance activities such as timber harvest, road construction, and fire (Figure 3-4). Assessments would seek to understand the cause of acute sediment delivery locations and determine which actions to reduce excessive sediment delivery are appropriate. Potential treatments include the following: landslide stabilization, stream bank stabilization, upslope erosion control with mulching (Figure 3-5), revegetation in the riparian zone and upslope, check dam construction to control gully erosion,
waterbar construction to control erosion from unpaved roads, and exclusionary livestock fencing.

A complete road assessment would provide landowners with a prioritized list of actions to improve the road network and how to make those improvements.

### Sediment Reduction

Sediment reduction refers to treatments addressing sources of sediment which have been assessed and identified as priority actions to improve stream habitat. Site specific treatments are typically recommended in the associated assessments, such as a road network assessment or upslope hazard assessment.

Elevated turbidity resulting from fine sediment becoming entrained in the water column can directly harm salmonids by smothering redds, reducing fertilization rates, abrading gills, and causing stress (Lake and Hinch 1999, Greig et al. 2005, Zimmermann and Lapointe 2005, Galbraith et al. 2006). It can also influence salmonid behavior, ecological interactions, and ultimately reduce the growth and fitness of rearing juveniles (Bisson and Bilby 1982, Berg 1983, Berg and Northcote 1985, Newcombe and MacDonald 1991, Korstrom and Birtwell 2006, Shrimpton et al. 2007). Turbidity can be reduced by treating anthropogenic sources of sediment including roads, stream crossings, and land disturbances (Figure 3-5).
Figure 3-5. Decommissioning roads re-establishes natural hydrology and prevents erosion, reducing the amount of sediment delivered to waterways. The road bed above has been outsloped and mulch, grass seed, and woody slash material has been applied to rebuild and stabilize soils. CDFW

Riparian Treatment

Riparian treatment includes the application of silvicultural treatments and revegetation efforts. The long-term goal (decades to centuries) of riparian treatment is to restore properly functioning riparian zones that provide bank stability, streamside shading, and large coniferous trees that could be recruited to watercourses from senescence, channel avulsion, or land sliding. Many riparian zones in northern California have been clear-cut along with adjacent hillslopes and tall, large-volume coniferous trees are either exceptionally rare or non-existent. In addition to the clear-cut timber harvesting, many northern California watersheds were significantly degraded by two very large floods (1955 & 1964) that compounded the impacts of the unregulated timber harvesting often converting coniferous forest riparian zones to deciduous hardwood stands dominated by red alder.

Treatments in riparian zones generally fall into one of three categories.

1. In coniferous riparian zones with a high stem density, selective felling of trees with intermediate or co-dominant crown positions to favor trees with dominant crown positions will accelerate tree growth to heights and volumes that will function as sources of deep stream shading as well as key pieces and other large wood.

2. In some watersheds harvesting practices converted coniferous forest into hardwood dominated stands. In hardwood dominated stands treatments may include both silvicultural methods that favor established coniferous trees as well as thinning of hardwoods and planting of coniferous trees.

3. The final treatment is the planting of riparian zones to establish riparian vegetation and stabilize stream channels. In many cases establishment of early seral species such as red alder or willow is the first step in a succession of treatments (Figure 3-6).

Each of these riparian treatments may be viewed as a reflection of the continuum of degraded stream conditions with concomitant additional decades of recovery.
South Fork Eel River SHaRP Plan

Chapter 3: Identifying the Problems and Restoration Solutions

Flow Enhancement

Flow Enhancement refers to treatments which improve the quantity and/or quality of the summer surface flow of a stream as measured by flow volume and temperature. Although other chemical properties of stream flow may be considered to improve water quality, there are no common restoration treatments for non-point source chemical pollutants to tributaries of the SFER other than community outreach and education. Instream water quantity and quality are addressed with a diversity of strategies including treatments that restore natural hydrologic processes and engineered structures that directly enhance stream flow and temperature. The variety of treatments reflects the geomorphic, hydrologic, and anthropogenic diversity of the South Fork Eel River sub-basin, and the fact that the properties of surface water are the cumulative result of water's movement through the landscape.

Improve Temperature

Maintaining cool temperatures during hot, dry summer months is essential to juvenile salmonid survival. Riparian vegetation reduces solar exposure and ensures surface water remains cold (Beschta 1997, Roth et al. 2010, Garner et al. 2017). Improving riparian cover in key locations with appropriate plantings can drastically decrease stream temperatures (Garner et al. 2017) (Figure 3-6). Temperature can also be affected by heterogeneity in depth and stream structure that allows subsurface flow (e.g. hyporheic flow) (Poole and Berman 2001, Hester et al. 2009). Instream structures, such as log jams and beaver dams (or beaver dam analogs) that impound coarse sediments and form deep pools create thermal heterogeneity and can improve groundwater infiltration (Lowry 1993, Hester et al. 2009). This can help ensure cold water refugia and stream flows persist through the arid Mediterranean summer. Additionally, projects to improve groundwater infiltration through off-channel impoundments may be considered in suitable locations. Off-channel ponds and reservoirs can be used to store winter precipitation to supplement summer stream surface water. Diverting outflow from these storage areas through the ground can ensure that these sources remain cold year-round, cooling downstream habitats during critical months.

Observed and model temperature data were categorically summarized according to temperature requirements for Coho Salmon and steelhead, of which the latter tend to have higher temperature thresholds (Richter and
Kolmes 2005, Asarian et al. 2016). Summary statistics including Maximum Weekly Maximum Temperature (MWMT) and mean August temperatures were used to represent the maximum temperatures salmonids may experience for prolonged times (> 1 week). Generally, treatments to address temperature were recommended in reaches where temperature summary statistics exceeded suitability thresholds for Coho Salmon (>18°C; Richter and Kolmes 2005, Asarian et al. 2016). Although steelhead can tolerate higher temperatures and the availability of food may moderate temperature requirements for Coho Salmon, the steering team felt it was most appropriate to make recommendations to improve conditions for the most temperature-limited species to maximize the rearing capacity for all salmonids and provide a buffer against climate change environmental stochasticity.

**Improve Flow Volume and Duration**

Salmonids rely on persistent summer flows as a source of food and habitat. If streams become disconnected during flow recession, food supplies may become limited and juvenile salmonids may lose the ability to migrate, which leaves them more prone to predation, stranding, disease, and other stressors. Treatments to improve dry season flow are primarily based on reducing water diversion pressure through water use management, education, and outreach to ensure that the impacts of summer water withdrawal are minimized (see section below). However, instream structures such as beaver dams or beaver dam analogues can improve groundwater inundation and lengthen the dry season hydroperiod (Westbrook et al. 2006). Furthermore, off-channel pond and reservoir storage, as described above, can be used to capture winter precipitation and directly supplement instream flows during summer.

**Water Use Management, Education and Outreach**

Considering the importance of water quantity and quality to salmonids and other aquatic resources, human-related activities may cause significant impact to water availability for these resources. In populated watersheds, the ongoing challenge of low water flows requires proactive steps to keep more water in the rivers, tributaries, and streams so that people and fish have enough to survive. Water conservation treatments should be designed to engage rural landowners and stakeholders in a coordinated, community-led water conservation effort. Communicating with residents about the natural resources in their area and encouraging best management practices for water use, such as storage and forbearance, will enable voluntary community actions to improve dry season flow. Voluntary water conservation programs, such as those in the Mattole River watershed have demonstrated the effectiveness of community-based efforts to minimize water consumption and maintain
stream flows during summer/early fall dry periods. In addition to water conservation efforts, treatment types should also include examining equipment and infrastructure where water is wasted or needlessly lost. Many water users may have poorly designed and/or leaky water infrastructure which continuously diverts off-channel sources such as springs. Relatively simple updates and technical assistance could improve/update existing infrastructure to ensure water conservation.

**Addition of Large Wood: Where and Why?**

Clearing of large wood from stream channels (Bryant 1983) and the anthropogenic modification of riparian forests that have slowed the natural recruitment processes has resulted in a deficit of large wood in tributaries to the SFER (CDFW 2014). Restoring riparian and upslope processes impacted by past practices is necessary to ensure long-term recruitment of wood to the stream channel. The time scale of riparian forest maturation to the point where natural large wood recruitment is sufficient to offset transport and decay is on the order of decades to centuries (Boyer et al. 2003). As fish populations are facing local extirpation at much shorter time frames, many stream rehabilitation efforts now involve the supplemental addition of large wood to streams to restore habitat forming processes beneficial to stream biota over the shorter term (Davidson and Eaton 2013). The abundance of large wood, and the role that large wood plays in channel formation, varies across drainage networks (Abbe and Montgomery 2003, Wohl and Scott 2017) to create the diverse habitats necessary for salmonids at different life stages. Geomorphic processes and channel characteristics vary with spatial position in a river network, transitioning from constrained headwater colluvial reaches to confined then unconfined alluvial reaches (Frissell et al. 1986, Bisson et al. 2006). These characteristics govern water flow, sediment inputs, and the capacity of streams to store and transport sediment and organic matter (Hynes 1970, O’Neill et al. 1986, Pennak 1979, Vannote et al. 1980). Large wood interacts with the intrinsic characteristics of valley segment slope, channel width: depth ratio and sediment supply to force a stream morphology that differs from a free-form morphology that would result in its absence (Montgomery and Buffington 1997).

Because both large wood function in channel processes, and fish habitat needs differ across the drainage network and fish life history stages, SHaRP treatments utilizing large wood are separated into various types. The treatment types attempt to coalesce our understanding of watershed stream network morphology, current watershed process and stage of stream channel evolution in response to disturbance (e.g. Cluer and Thorne 2014) with habitat needs across salmonid life history stages. SHaRP treatment categories attempt to tailor the restoration action to the localized physical and biologic potential with consideration of the larger watershed processes (Beechie et al. 2010, Abbe and Montgomery 2003). Large wood within channels most often provides multiple and interactive benefits to channel process and habitat formation. Large wood treatment categorization described in this plan is a tool to communicate the intended process-based...
restoration outcome relative to inferred fish habitat limiting factors of the stream reach.

**Large Wood Addition for Sediment Retention**

Sediment budgets within stream channels are governed by rates of input, transport and channel storage (Swanson et al. 1982, Buffington et al. 2004). Large wood plays a critical role in the transport rate and storage of sediments within stream channels (May and Gresswell 2003, Faustini and Jones 2003). In smaller, higher-gradient alluvial channels, in-channel sediment deposition generally occurs upstream of channel spanning wood accumulations increasing bed elevations (Gurnell et al. 2002) (Figure 3-7).

Large wood additions in these reaches can aggrade incised channels and hydrologically reconnect the channel to the floodplain and create step pool longitudinal profiles that further dissipate stream energy (Figure 3-7).

One of the most important characteristics of in-channel sediment for spawning salmonids is gravel size, with optimal range from small gravel to cobbles (Kondolph and Wolman 1993). Large wood within streams create heterogeneous water velocities that sort sediments (Powell 1998) to provide salmonids with spawning habitat (Buffington et al 2002). In the SFER tributaries, most of the salmon spawning occurs in moderate 2-3% gradients in relatively small drainage area reaches (Starks and Renger et al. 2016). Presumably, these high use areas exhibit local basin physiography (channel width to depth, hydrologic regime) to support the formation of habitat amenable to spawning. In these channel segments where salmon spawning is currently occurring (or would be expected to occur given channel segment morphology if habitat was suitable), large wood augmentation should strive to increase hydraulic roughness, promote bar formation...
and sediment storing or sorting. Bankfull spanning large wood perpendicular to stream flow create steps that trap sediment upstream of the log, while also creating vertical plunges that dissipate stream energy and sort gravels in pool tail outs below. Flow-deflection jams are common natural wood jams in this size channel and function to create channel complexity with bank scour, and areas of both sorted sediment deposition and scour (Abbe and Montgomery 2003).

**Large Wood Addition for Summer Rearing**

Pool formation, depth, and size largely depend upon channel type, in-channel sediment storage and quantity of flow obstructions. The flow obstruction created by in-channel large wood affects the frequency of alternating patterns of scour and bar formation, increasing the number of pool-riffle sequences (Collins and Montgomery 2002, Buffington et al. 2002). Summer rearing juvenile Coho Salmon and steelhead prefer deep pool habitats associated with cover (e.g. Rosenfeld et al. 1999, Lonzarich and Quinn 1995). An increase in frequency of pool-riffle sequence can homogenize invertebrate drift across habitats (Leung et al. 2009) and large wood addition has been shown to increase invertebrate taxa richness and biomass (Miller et al. 2010) that increase forage opportunities for juvenile salmon (Nielsen 1992).

Large wood additions to enhance summer rearing conditions would influence channel morphology to increase the depth and complexity of cover in pools, increase the number of pool-riffle sequences and enhance secondary invertebrate productivity. A practical example of large wood placement intended to create summer habitat would be large wood with attached natural boles inserted into the active channel that create scour during high water, leaving a pool during summer that is associated with root wad cover (Figure 3-8). These benefits cannot be realized, however, in reaches that perennially de-water during summer or where steam temperatures surpass salmonid tolerances.

![Figure 3-8. Large wood additions which have scoured a deep perennial pool and created complex cover to shelter juvenile salmon. CDFW](image-url)
Winter habitat is a bottleneck for Coho Salmon (see opposing text box). Small headwater stream reaches are characterized as being more constrained by steeper valley walls, though notable exceptions to this paradigm do occur in SFER tributaries (e.g. upper Redwood Creek tributary to Hollow Tree Creek, upper Dutch Charlie Creek). In these more confined reaches, in-channel large wood supplementation is one of the few strategies available to augment habitat. In-channel large wood in bankfull-spanning configurations tend to collect smaller wood pieces, creating low-velocity pools upstream of the jam at a range of stream flows (Figure 3-9).

**Figure 3-9. Large wood improving in-channel winter habitat in a confined stream. CDFW**

**Winter habitat: A bottleneck for Coho Salmon**

Overwinter survival has been identified as a critical limiting factor influencing population abundance of Coho Salmon (Tschaplinski and Hartman 1983, Quinn and Peterson 1996, Huusko et al. 2007, Nickelson and Lawson 1998) in the Pacific Northwest. Density dependent mechanisms appear to set overwinter habitat capacity for Coho Salmon in California streams (Gallagher et al. 2012, Ricker and Anderson 2011). Coho Salmon overwinter habitat is characterized by complex, low-velocity habitats (Tschaplinski and Hartman 1983, McMahon and Hartman 1989, Quinn and Peterson 1996, Johnson et al. 2005). The target of large wood restoration projects introduced to increase overwinter habitat is to create larger and deeper pools and facilitate the interaction of winter flow with the floodplain. This ultimately provides low velocity refuge across a range of stream discharges (stages) where juvenile salmonids can shelter both in the stream channel during winter base flow and access adjacent, newly connected floodplains at elevated stages (Bustard and Narver 1975, McMahon and Hartman 1989, Bradford et al. 1995, Cunjak 1996, Bair et al. 2019). Because basin geomorphology and size impose a large control over the types of slow water winter habitats, SHaRP includes two treatment types: in-channel and off-channel that both target creation and enhancement of winter habitat through different channel and flow altering mechanisms.
In-channel winter habitat structures would tend to incorporate multiple pieces and may include ‘bole down’ placements to create complex cover areas in the eddies that form behind these structures during higher discharge. In-channel wood treatments are often indicated in areas where spawning, and rearing also occur, and therefore are important to the concept of ‘natal’ life-history pathways (see SHaRP Conceptual Salmonid Life-History Model).

**Large Wood for Off-Channel Winter Habitat**

As watershed size increases, valley widths tend to increase and channel gradients decrease. Wider valley morphology lends to more channel migration, meanders and split channels which, over time, can lead to backwaters that inundate during elevated stream discharge. Large wood supplementation in these areas seeks to take advantage of these features and enhance their benefit to salmonid habitat. Large wood can be used to inundate existing channel features and/or provide flow velocity refugia in channel features that become inundated during higher stream stages.

![Figure 3-10. A large wood jam on the mainstem of this stream (right side of photo) forces higher winter flows to inundate the surrounding floodplain (dry channel on the left side of the photo). CDFW](image)

**Barriers**

**Man-Made Barriers**

The most frequently encountered man-made barriers in the SFER are culverts and road crossings. Culverts often create temporary, partial, or complete barriers for adult and/or juvenile salmonids during their freshwater migration activities, and the cumulative effect of blocked habitat in Northern California streams is likely significant (Bates 1999, Ross Taylor and Associates 2005).

While numerous culverts and road crossings have been modified for suitable fish passage in the last decade or so, there are a remaining number of them that are impeding or hindering fish passage within the basin.

**Natural Barriers**

Natural barriers, including wood debris jams, boulder cascades and bedrock falls, exist throughout the SFER. Many of these barriers are associated with knick-zones which occur as the result of regional geologic uplift.
These barriers typically occur in smaller headwaters and tributaries where hydraulic power is insufficient to continue up-stream propagation of the post-uplift channel incision. For example, most of the bedrock falls in the Hollow Tree Creek sub-watershed occur within smaller tributaries just upstream from the mainstem of Hollow Tree Creek (Figure 3-11).

Figure 3-11. A natural bedrock barrier on a tributary in Hollow Tree Creek. CDFW

Wood debris jams also occur naturally and tend to form taller, more robust structures at constriction points bounded by steep valley walls or rock features. A particularly large and persistent wood jam is present in Moody Creek, a tributary of the Indian Creek sub-watershed. This jam formed at a natural constriction of the valley wall which is fortified by rock features on both banks. This jam has accumulated many pieces of large wood, cresting at a height of nearly 15 feet and accumulating hundreds of yards of sediment (Figure 3-12).

Figure 3-12. A large wood jam on Moody Creek. CDFW

Though some of these barriers are completely insurmountable by even the highest jumping adult steelhead, some may only be partial barriers, blocking some life stages of salmonids either seasonally or completely. These are also dynamic structures that change annually as pieces of wood are either lost or gained, potentially allowing fish passage some years and not others.

Alteration, removal, and management of debris jams became a particular focus for restoration in the late 1960s through the 1980s as excessive logging debris filled streams (Bryant 1983). As poorly regulated logging activities and large storms increased the instream wood supply, many of these jams grew unnaturally large and threatened fish passage, prompting their removal. However, this theme may have been too universally applied across the landscape and many jams which had not blocked fish passage were completely removed from the
system. Instream wood is now in scarce supply and hindering habitat forming processes. Current debris jam alterations or removal must carefully consider the severity of the barrier, the species and life stages blocked, the cause of the blockage, the proximity to other barriers, the amount of upstream habitat, and the potential effects to stream morphology. If careful consideration of these factors warrants alterations to the barrier, modification should be as minimal as possible to improve passage and maintain beneficial habitat characteristics (CDFG 2010).

Alterations to natural bedrock barriers and boulder “roughs” once included heavy-handed modifications including blasting with explosives or chaining boulders to rock faces to create step pools. These methods typically had poor results and modern approaches seek to modify the barrier indirectly by raising the stream bed or water surface elevation using large wood as described above (see Large Wood for In-Channel Winter Habitat). This type of treatment would improve passage over temporal or partial barriers by effectively reducing jump heights over barriers while maintaining the natural characteristics and processes associated with the barrier.

**Beaver Dam Analogs**

Beaver dams and associated ponds directly affect stream hydrology, geomorphology, and aquatic habitats for fish. Beaver ponds, wetlands and connected floodplains slow the movement of water through the watershed system, storing water to maintain flows later into the dry season (Pollock et al. 2003, Pollock et al. 2014). Beaver dams affect stream geomorphology by trapping sediments, elevating stream beds, reversing channel incision and reconnecting channels with their floodplains (Naiman et al. 1986, Butler and Malanson 1995, Pollock et al. 2014). Beaver ponds have also been shown to directly provide excellent habitat for salmonids, particularly Coho Salmon that prefer slow water velocities, ponds and stream pools (Pollock et al. 2003). The use of human-constructed beaver dams (beaver dam analogues or BDAs) is an emerging technique for restoring fluvial ecosystems based on biomimicry (Pollock et al. 2014). The goal of this technique is to assist recovery of habitat by mimicking the effects of natural beaver dams to create habitat or conditions similar to that which would be created by a natural beaver dam. Clearly defining desired outcomes in appropriate locations for BDA development in the watershed will be key to success in any future BDA project development. The Beaver Restoration Guidebook [http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp](http://www.fws.gov/oregonfwo/ToolsForLandowners/RiverScience/Beaver.asp) and the Beaver Restoration Assessment Tool [http://brat.riverscapes.xyz/](http://brat.riverscapes.xyz/) have been developed to assist restorationists interested in BDA development.

**Limiting Factors and Threats with no Restoration Solution**

For several sub-watersheds, panelists identified severe limiting factors for one or more species and life stages for which no suitable restoration treatment could be applied to directly alter the impact. These factors and threats included land conversion and development, water diversion, pollution, wet season flow, invasive predators and
competitors, and climate change. These factors were extensively discussed and, in some cases indirect treatments were recommended to address the impacts of the threat or limiting factor. However, many of these factors, especially those related to environmental stochasticity and climate, are beyond our ability to control and actions to manage invasive species need to be undertaken on a basin-scale to be effective. Furthermore, it is not within the scope of this process to enact or enforce environmental laws or regulations.

The strategies developed to indirectly relieve the impacts of these factors are based on improving habitat diversity and resilience across each sub-watershed as well as encouraging voluntary community action through outreach, education, and technical assistance. By improving overall habitat quality, restoring a diversity of complex habitat, and alleviating other stressors which are within our ability to manipulate, it is our hope that sub-watersheds will have increased capacity to buffer against climatic, ecologic, and anthropogenic impacts that cannot be predicted or controlled and will favor native species over non-native competitors. Additionally, encouraging restoration actions on a voluntary basis will improve landowner relations with the surrounding ecosystem as well as with the resource agencies charged with managing these resources.